

THE ROTARY KILN

HANDBOOK



FROM THE FEECO
PROCESS EQUIPMENT SERIES

FEECO
INTERNATIONAL

TOMORROW'S PROCESSES, TODAY.

FEECO.com

CONTENTS

INTRO

About FEECO	1
Intro to Rotary Kilns.....	3

ROTARY KILN OPERATION & PROCESSING

How Rotary Kilns Work.....	5
Direct vs. Indirect.....	7
Options in Air Flow.....	11
Rotary Kiln Systems: Supporting Equipment	13
Rotary Kiln Processes.....	16

SIZING & DESIGN

Rotary Kiln Sizing & Design.....	19
Increasing Efficiency Through Customization	22

CONSIDERATIONS

Thermal Testing	30
Profile: Kiln Testing in the FEECO Innovation Center	33
Moisture Reduction: Dryer or Kiln	37

INSTALL & MAINTENANCE

Ensuring A Smooth Kiln Installation	39
Damage Prevention	41
A Look at Modern Rotary Kiln Alignment Methods.....	44

CONCLUSION

What to Look for When Choosing a Rotary Kiln Manufacturer	50
Additional Resources.....	52
The FEECO Commitment to Quality.....	53

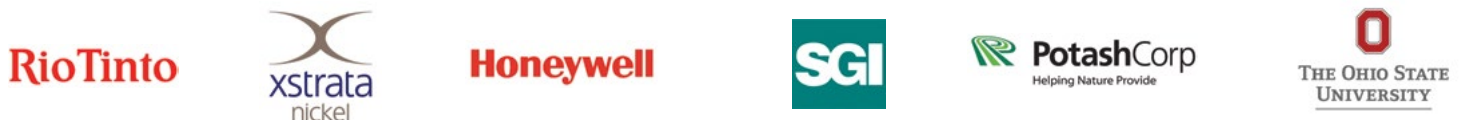
Introduction

FEECO International was founded in 1951 as an engineering and equipment manufacturer. We quickly became known as the material experts, able to solve all sorts of material processing and handling problems, and now serve nearly every industry, from energy and agriculture, to mining and minerals.

As experts in the field of thermal processing, FEECO has been solving problems through feasibility testing and custom thermal processing equipment since the 1950s. We've helped our customers process hundreds of materials into value-added products, eliminating handling and transportation problems, improving product characteristics, and creating marketable products.

Our Rotary Kiln Handbook is a comprehensive resource on advanced thermal processing techniques in which methods, processing considerations, and equipment are examined.

Many of the world's top companies have come to rely on FEECO for the best in custom process equipment and solutions. Some of these companies include:



For further information on thermal processing with rotary kilns, [contact a FEECO expert](#) today.

FEECO US Headquarters

3913 Algoma Rd. Green Bay, WI 54311, USA

Phone: (920)468.1000

Toll Free: 1.800.373.9347

FEECO.com/contact

Find us on:

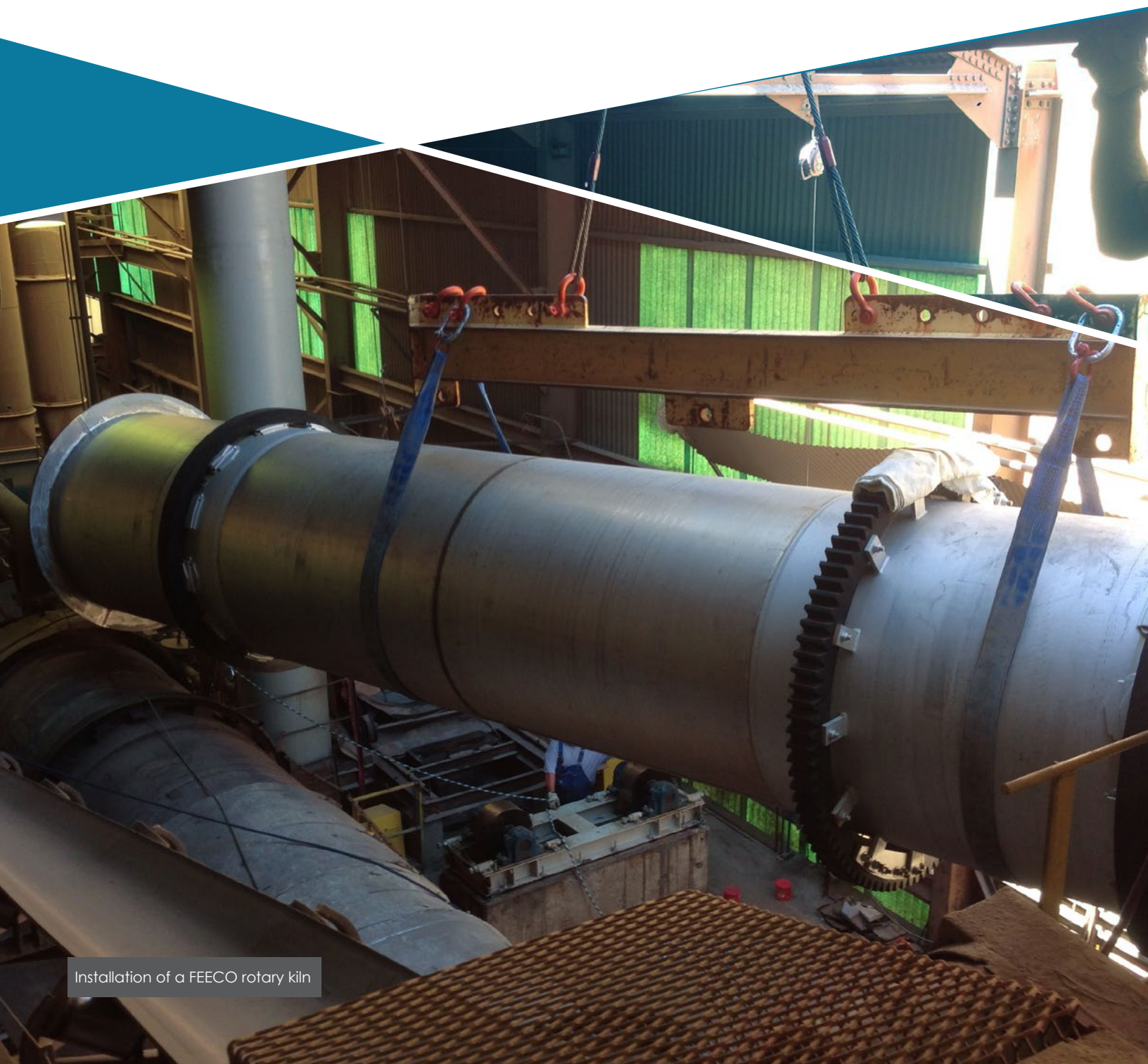


DISCLAIMER

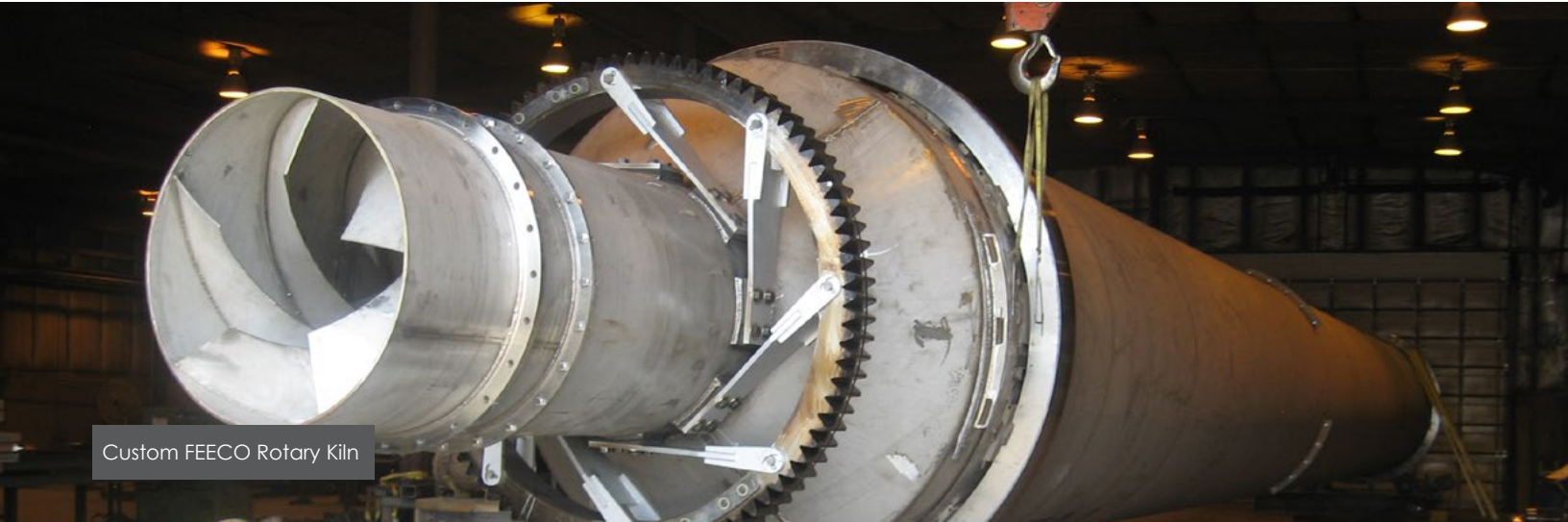
FEECO is committed to publishing and maintaining this Handbook. As we continue to grow and evolve, information in this document is subject to change without notice. FEECO does not make any representations or warranties (implied or otherwise) regarding the accuracy and completeness of this document and shall in no event be liable for any loss of profit or any commercial damage, including but not limited to special, incidental, consequential, or other damage.

Please note that some images may display equipment without the proper safety guards and precautions. This is for photographic purposes only and does not represent how equipment should be properly and safely installed or operated. FEECO shall not be held liable for personal injuries.

Intro to
ROTARY KILNS



Installation of a FEECO rotary kiln



Custom FEECO Rotary Kiln

AN INTRO TO ROTARY KILNS

[Rotary kilns](#) are an advanced thermal processing tool used for processing solid materials at extremely high temperatures in order to cause a chemical reaction or physical change. Capable of carrying out both exothermic and endothermic reactions, they are commonly used to carry out processes such as:

- Calcination
- Thermal Desorption
- Organic Combustion
- Sintering/Induration
- Heat Setting
- And more...

While rotary kilns were originally developed for use in the cement industry, due to their flexibility, they can now be found throughout a variety of industries, aiding in both processing commodities, as well as in highly specialized applications. Some of the most common kiln applications in use today include:

- Mineral Roasting
- Proppant Sintering

- Gypsum and Bauxite Calcining
- Waste Incineration
- Desorption of Soil Contaminants
- Upgrading of Phosphate Ores
- Waste Lime Recovery
- Catalyst Activation
- Activated Carbon Production & Reactivation
- Plastics Processing
- Ceramics Processing

Rotary kilns have become the backbone of many new industrial processes that make the world a more efficient and sustainable place. As new applications for rotary kilns continue to be developed, much experimental work is being done, prompting many questions and the need for further research and development.

This handbook serves to give an overview of rotary kilns and answer some of the commonly asked questions about these versatile thermal processing machines.

OPERATION & PROCESSING

HOW ROTARY KILNS WORK | DIRECT VS. INDIRECT | AIR FLOW | SUPPORTING EQUIPMENT | PROCESSES



Custom indirect rotary kiln internals

HOW ROTARY KILNS WORK

Rotary kilns are used to heat solids to the point where a chemical reaction or physical change takes place. They work by holding the material to be processed at a specified temperature for a precise amount of time. Temperatures and retention times are determined through creating temperature profiles, based on thorough chemical and thermal analyses of the material.

A rotary kiln is comprised of a rotating cylinder (called the drum), sized specifically to meet the temperature and retention time requirements of the material to be processed. The kiln is set at a slight angle, in order to allow gravity to assist in moving material through the rotating cylinder.

Rotary kilns can be either of the direct-fired type, or the indirect-fired type (sometimes referred to as a calciner). In a direct-fired kiln, a process gas is fed through the drum, processing the material via direct contact. In an indirect-fired kiln, material is processed in an inert environment, and is heated through contact with the shell of the kiln, which is heated from the outside to maintain an inert environment.

ROTARY KILN CONSTRUCTION

While FEECO rotary kilns are custom designed around the material to be processed, in general, there are some standard components that serve as the basic design of a rotary kiln. The diagram shown on page 8 illustrates some of the common standard components found on a basic direct-fired kiln. A diagram of an indirect-fired kiln can be seen on page 9.

DRIVE ASSEMBLY

The drive assembly is the component that causes the kiln to rotate. A variety of drive assembly arrangements are available: chain and sprocket, gear drive, friction drive, and direct drive. Unlike most other rotary kiln components, there is not a need for further customization in terms of the mechanical components of the drum; the need for one drive type over another is primarily dependent on how much horsepower is required.



Chain & Sprocket Drive Assembly

Chain & Sprocket: A chain and sprocket arrangement works much like a bicycle; there is a large sprocket wrapping around the rotary drum with a chain on it that goes to the reducer and motor. The spinning motor turns a gear box, which spins a small sprocket that is attached by the chain to the large sprocket wrapping around the rotary drum. Chain and sprocket drive setups are reserved for small rotary kilns, running up to 75 horsepower (55kW). This type of arrangement is typically not suitable for larger kilns running above 75 horsepower, but is ideal for smaller jobs, as it is cost-effective and easy to run.

Gear Drive: The gear drive is best for heavy-duty applications running above 75 horsepower. Similar to the chain and sprocket drive, instead of a sprocket

wrapped around the girth of the drum, this drive has an actual gear around the drum. This gear meshes with a small gear drive, which rotates it. This type of drive is more costly, but operates better in heavy-duty applications and requires less maintenance.

Friction Drive: Friction drive assemblies are reserved for small applications requiring low horsepower. This is commonly seen with drums around 6' (1.8m) and under. With a friction drive, two of the four trunnion wheels are connected by one shaft and driven by a shaft-mounted reducer and motor arrangement.

Direct Drive: Direct drive assemblies are used in small- to medium-size drums, with motors up to 75 horsepower. In this design, a shaft is mounted to a solid discharge end plate at the outlet of the kiln. The motor and reducer are either directly connected to this shaft with a coupling, or a shaft mount arrangement.

RIDING RINGS

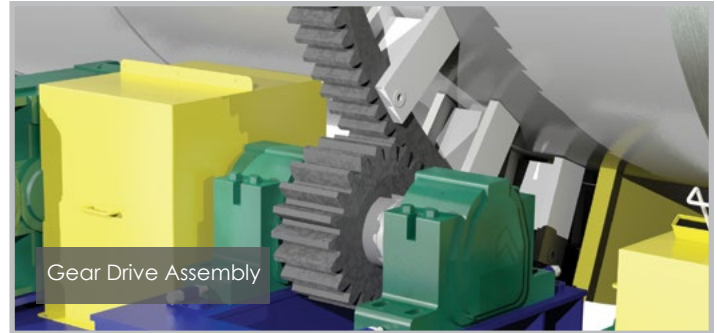
The riding rings provide a surface for the kiln load to be distributed. They also provide strength for shell ovality and integrity.

THRUST ROLLERS

Thrust rollers prevent the drum from drifting or moving horizontally by pushing against the riding rings.

TRUNNION WHEELS

The trunnion wheels act as the cradle for the rotating drum shell. They ensure smooth and concentric rotation during operation. The wheels are mounted to steel support bases with sealed roller bearings. Support rollers bear the weight of the drum.



DISCHARGE BREECHING

The discharge breeching serves two purposes: to provide a place for product to exit the kiln, and to mount the kiln burner in a counter current system.

PRODUCT DISCHARGE

The product discharge area is where product exits the kiln. Typically, the product will then move on to cooling or subsequent processing if needed.

EXHAUST GAS SYSTEM

The exhaust gas system is typically much larger when working with a direct-fired kiln. Here, exhaust gases (both products of combustion and any loss on ignition from the material) and small particulates exit the system and typically go through exhaust gas treatment to remove contaminants before being discharged into the environment. The exhaust gas system on a kiln often requires an afterburner and heat exchanger/quench tower to cool the gases before they enter either a scrubber and/or bag filter (baghouse), or electrostatic precipitator. More information about this can be found on page 13.

REFRACTORY

Refractory serves the purpose of insulating and

protecting the shell of the drum from the high temperatures within. It also serves to minimize heat loss. Many types of refractory are available, and refractory layers can be customized to suit the unique application. Refractory is discussed further on page 25.

BURNER

The burner of a rotary kiln supplies the energy required by the process. Instead of utilizing a combustion chamber, the burner on a kiln is typically mounted on the discharge/inlet end housing.

Burners can be designed to accommodate a variety of fuel sources, from natural gas, to propane, diesel, and other common fuels. They can also allow for flame shaping, which sets the temperature profile within the length of the kiln for higher temperature operations. Optionally, a combustion chamber can be used to house the reaction, avoiding direct contact between the material and flame. More information on burners and combustion chambers can be found on page 15.

RAW MATERIAL FEED

The raw material feed is where feedstock enters the drum. This is typically carried out using a feed screw or chute and is often made from a more heat-resistant alloy. This area must be designed to be robust and to lessen the opportunity for buildup to occur.

AIR SEAL

The seal connects the stationary breeching to the rotating drum, and helps to prevent the escape of process gas from the system, as well as preventing air from leaking in. Holding the appropriate temperature within a rotary kiln is what allows the desired chemical reaction to occur. Sustaining that temperature,

however, can be difficult if the right seal is not chosen. Various seal options exist, including the labyrinth seal, single and double leaf seals, and the bellows seal.

SHELL

Direct-fired kilns are typically made out of carbon steel (with refractory lining). Indirect-fired kilns, however, must be more resistant to high temperatures and are therefore made out of a more heat-resistant alloy.

DIRECT VS. INDIRECT

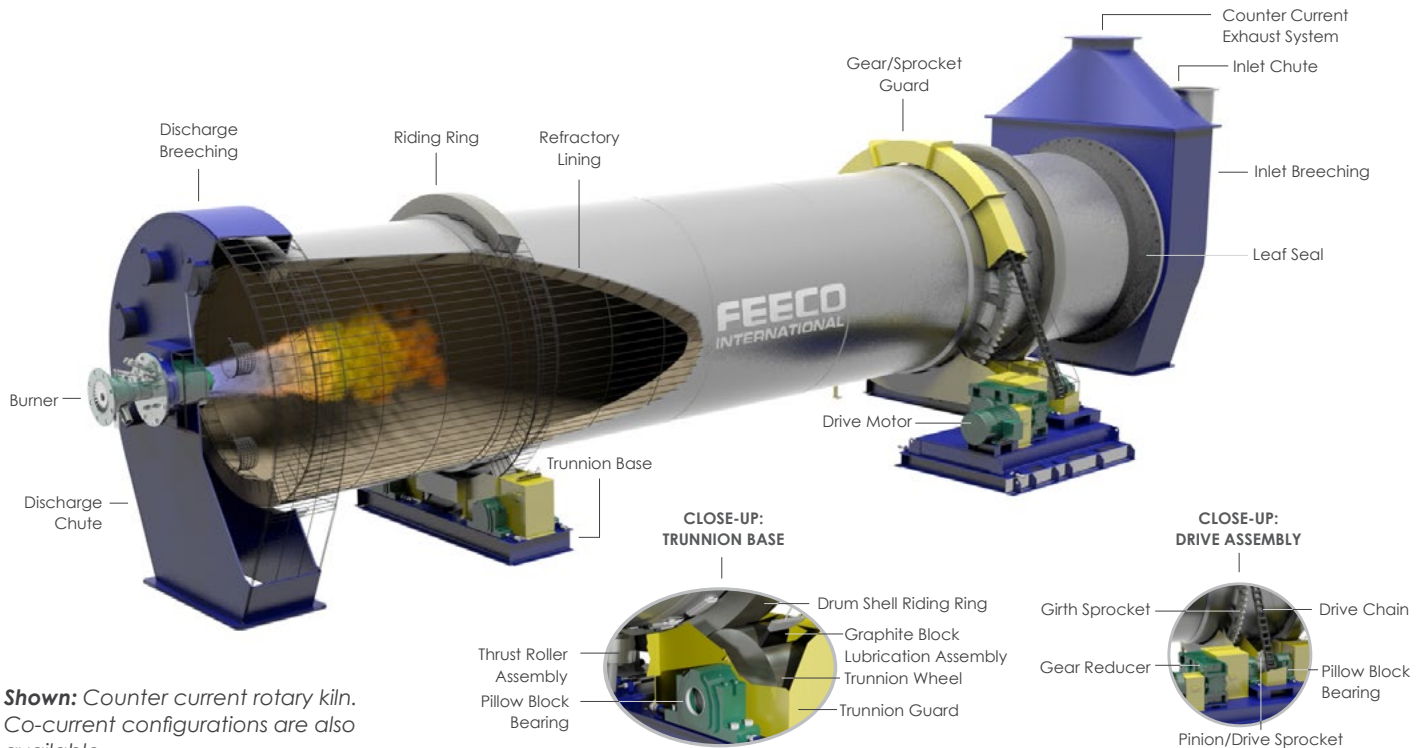
When designing a thermal processing operation, confusion often results on whether a direct-fired or indirect-fired kiln is the better option. And while there can be some overlap in applications, in general, each type of kiln is better suited for different processes. Below is a brief overview on these two types of kilns.

DIRECT-FIRED KILNS

As mentioned, direct-fired rotary kilns rely on direct contact between the process gas and the material in order to heat the material to the specified temperature. Direct-fired kilns can be either of the co-current design, or counter current design, referring to the direction that the process gas flows through the drum in relation to the material (more information on air flow can be found on page 11).

Direct-fired rotary kilns are most often the equipment of choice in thermal processing, because they are more efficient than their indirect counterparts. There can be disadvantages to a direct-fired kiln, however. For example, because a process gas is used to treat the material, direct-fired kilns subsequently produce more off-gases that will require treatment.

DIRECT-FIRED ROTARY KILN



Shown: Counter current rotary kiln. Co-current configurations are also available.

Additionally, some materials must be processed in an inert environment, so as not to be exposed to oxygen or nitrogen. In applications such as this, a direct-fired kiln would not be an option. Materials that are commonly processed in a direct-fired kiln include:

- Proppants
- Minerals
- Specialty Ceramics and Clays
- Limestone
- Cement
- Iron Ore

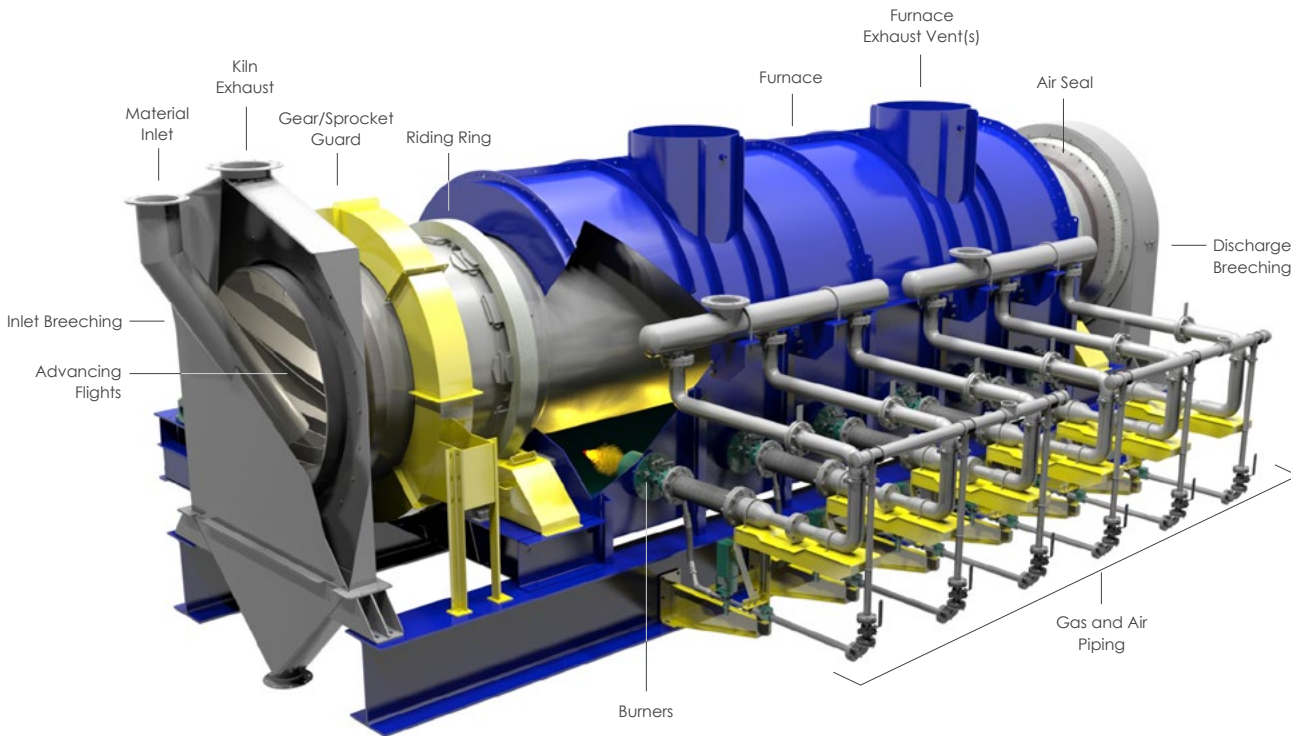
INDIRECT-FIRED KILNS

Conversely, indirect-fired kilns can process material in an inert environment, where the material never comes into contact with the process gas. Here, the kiln is

heated from the outside, using a heat shroud, and the material is heated via contact with the hot kiln shell. While this method is significantly less efficient than a direct-fired kiln, it is necessary in some processes that require a more tightly controlled environment. This might include instances where an undesirable oxide compound will form in the presence of oxygen at high temperatures. Similarly, some materials may form an undesirable compound with nitrogen at high temperatures. In situations such as these, the use of an indirect-fired kiln provides the necessary inert environment for effective processing.

Indirect kilns also allow for precise temperature control along the length of the kiln. This is advantageous in settings where a material will need to be

INDIRECT-FIRED ROTARY KILN



brought up to temperature, and then held there for a specific amount of time as it moves through the kiln. Indirect-fired rotary kilns can also be beneficial when the material to be processed consists of finely divided solids. In a direct-fired rotary kiln, the heat source is hot gas (products of combustion and air), which flows with an inherent velocity. These gases can carry particles through form drag. The degree of entrainment depends on a variety of factors, such as gas velocity, gas density, particle density, and shape. Due to entrainment potential, direct-fired rotary kilns processing fine materials require the design to be centered on permissible gas velocities as opposed to heat transfer requirements. Examples of materials commonly processed in an indirect-fired kiln include filter cakes, carbon black, chemical precipitates, and other finely ground solids.

Because the heat is being transferred through the shell, an indirect rotary kiln is not lined, in order to maximize the heat transfer through the shell. Therefore, an indirect rotary kiln is usually made out of a more temperature-resistant alloy, instead of carbon steel.

While direct-fired kilns offer maximum efficiency, they are not always appropriate for the intended process. In settings such as these, an indirect-fired kiln would offer the best processing solution. In some process situations, a combination of a direct and indirect rotary kiln is required; the direct-fired rotary kiln is used to burn off the organic fraction of the material being processed, and further polishing of the resultant ash material is conducted in a specialty indirect kiln.

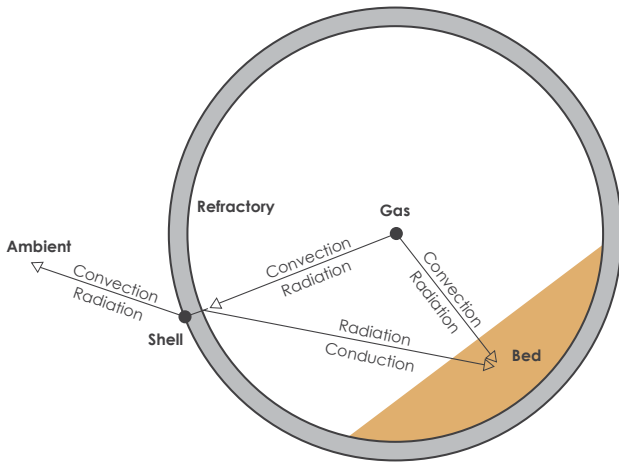


Diagram: Direct-Fired Kiln Heat Transfer Paths

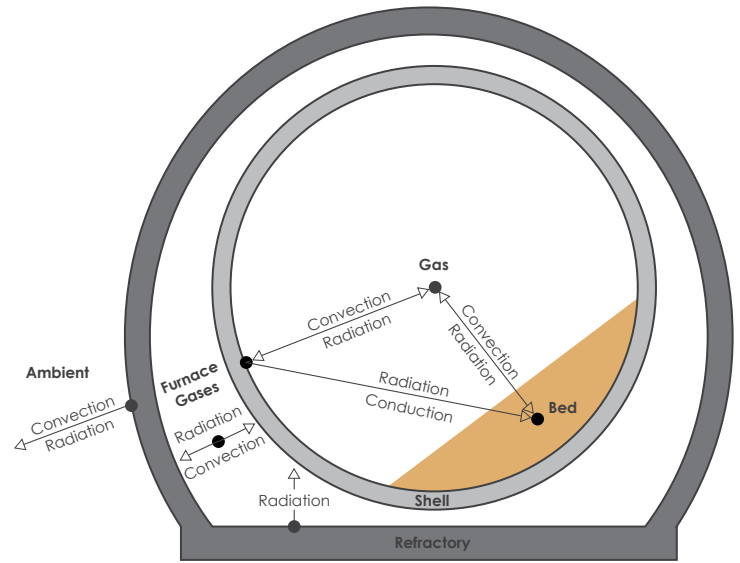


Diagram: Indirect-Fired Kiln Heat Transfer Paths

TABLE: FEECO DIRECT-FIRED KILNS AT A GLANCE

SIZE	Up to 15' dia. x 100'+ long (Up to 4.6m dia. x 30.5m+ long)
CAPACITY	1 TPH - 50 TPH (1 MTPH - 45 MTPH) <i>Maximum capacity is dependent on process variables unique to each application</i>
CUSTOMIZABLE?	Yes
OPERATING TEMPERATURE RANGE	800-3000° F (430-1650° C)
AIR FLOW OPTIONS	Co-current or Counter Current
FEATURES	- Optimized refractory lining - Engineered shell for mitigating distortion and misalignment due to high operating temperatures.
OPTIONAL COMPONENTS	- Various seal options - Machined bases - Screw conveyor feeder - Automatic gear lubrication system - Exhaust gas handling equipment - Ductwork - Various burner configurations - Components for increasing efficiency (flights, dams, bed disturbers, etc.)
FUEL TYPES	- Fuel oil - Natural gas/Propane - Waste heat - Biogas

TABLE: FEECO INDIRECT-FIRED KILNS AT A GLANCE

SIZE	Up to 15' dia. x 75'+ heated length (up to 4.6m dia. x 23m+ heated length)
CAPACITY	1 TPH - 20 TPH (1 MTPH - 18 MTPH)
CUSTOMIZABLE?	Yes
OPERATING TEMPERATURE RANGE	800 - 1800° F (430-980° C)
AIR FLOW OPTIONS	Not applicable (Cross flow)
FEATURES	- Heat-resistant alloy shell - Separate zones for temperature control - Integrated cooling zone can be added - Engineered shell for mitigating distortion and misalignment due to high operating temperatures.
OPTIONAL COMPONENTS	- Various Seal Options - Machined Bases - Screw Conveyor Feeder - Automatic Gear Lubrication System - Ductwork - Internal Bed Temperature Measurement - Components for increasing efficiency (flights, dams, bed disturbers, etc.)
FUEL TYPES	- Fuel oil - Natural gas/Propane - Electricity - Waste heat - Biogas

OPTIONS IN AIR FLOW

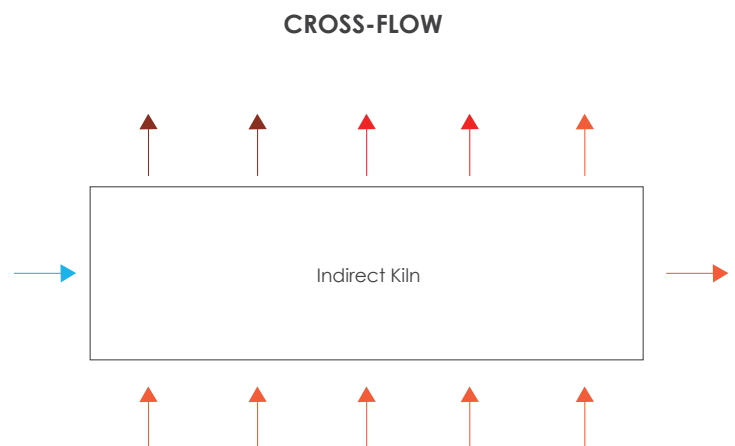
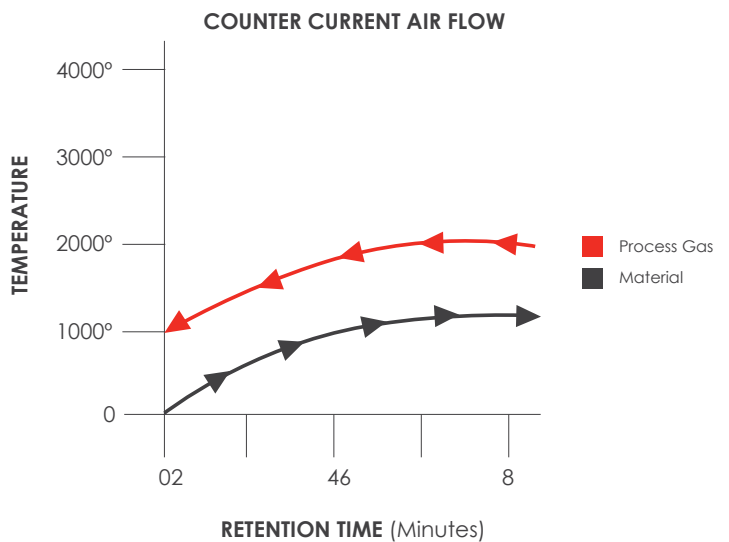
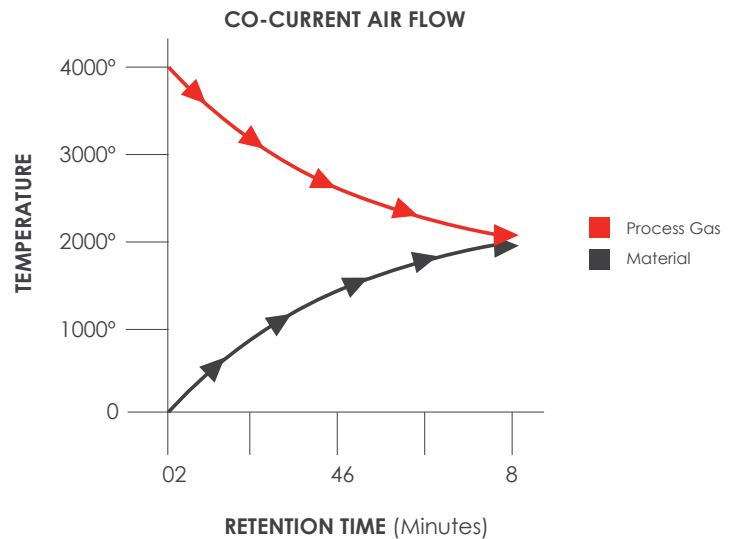
As mentioned, direct rotary kilns are available in two types of air flow configurations: co-current and counter current. Both options have been developed through extensive research and development in order to maximize the thermal efficiency of the process. Most rotary kilns are of the counter current configuration, because this option is much more energy efficient. However, in some instances, the co-current configuration is more appropriate. Additionally, indirect kilns use a different air flow altogether: cross-flow. This is because combustion gases are not flowing through the kiln, but rather, are perpendicular to the material.

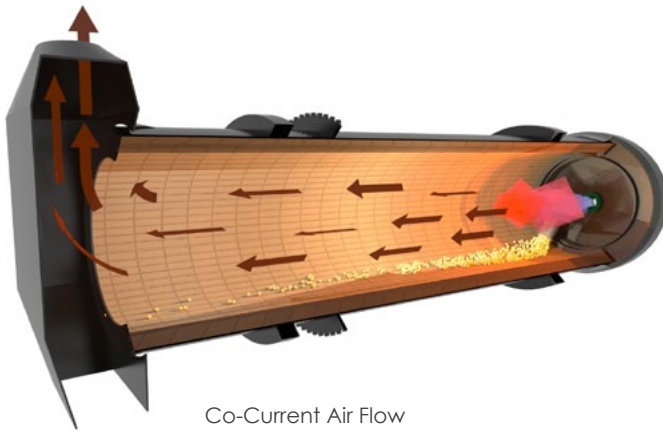
During the design process of a direct-fired kiln, the selection of which air flow configuration (co-current or counter current) will best suit the application is based on the material's properties, as well as overall process requirements. Because of this, it is important to understand how each air flow option functions to fully recognize the benefits each has to offer.

CO-CURRENT

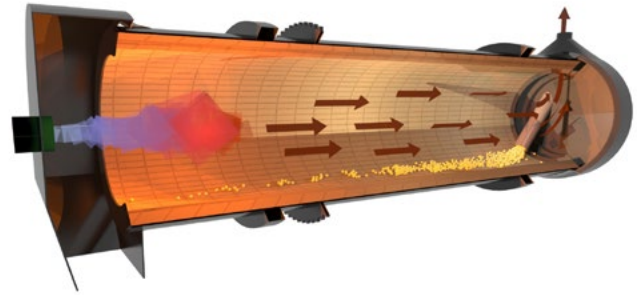
Co-current air flow, which is also referred to as parallel flow, is when the products of combustion flow in the same direction as the material. This immediately puts the coldest material in contact with the hottest gas in the kiln, resulting in a rapid initial temperature change.

Co-current kilns work best with materials that don't need a gradual temperature increase for a controlled transformation. An organic combustion process commonly uses this air flow configuration, because it does not require a very specific end product. In this





Co-Current Air Flow



Counter Current Air Flow

example, a waste material (e.g. spent catalyst) containing both organic and inorganic material is introduced into the kiln. These materials can come into immediate contact with the high heat and the volatile components will be vaporized soon after feeding. The organic material is burned off with the high heat and what is left is a dry ash.

COUNTER CURRENT

Counter current air flow is when the air flows in the opposite direction of the material flow. In this design, the material is heated gradually while traveling through the kiln. Here, material comes in contact with the hottest products of combustion just before discharge. The main benefit to this air flow configuration is the thermal efficiency; with the burner being mounted at the end of the thermal processing cycle, less heat is required, resulting in decreased fuel consumption. This is illustrated in the tables on the previous page.

The co-current configuration needs a much higher initial temperature in order to heat the process material from its initial temperature and get the desired phase or chemical change. In contrast, in a counter current configuration, the material and the process gas temperature are directly correlated. For

the example in the chart, the air flow (process gas) temperature only needs to be slightly higher than the required temperature for the material transformation. The result is a lower exhaust gas temperature and lower operating costs.

Additionally, the counter current design is commonly used for a more controlled physical or chemical change, where the material temperature needs to be gradually increased to achieve the desired end result. Sintering is a common process that utilizes the counter current air flow to maintain a controlled phase change. The gradual, yet extreme heating process allows for a material such as a proppant, to transform into a much harder material.

CROSS-FLOW

As mentioned, the cross-flow configuration is specific to indirect kilns. In co-current or counter current flow, the gas and solid streams flow parallel to each other. In a cross-flow configuration, however, the gas and solid streams are perpendicular to one another.

One advantage of cross-flow heat transfer is that the solids can be held at a constant temperature for an extended time. This is very difficult to achieve in a co-current or counter current kiln.

Understanding how each air flow system works is one of the many considerations in designing the most efficient and effective rotary kiln for the job. Each air flow configuration has its unique and varying benefits for material transformation.

ROTARY KILN SYSTEMS: SUPPORTING EQUIPMENT

Rotary kilns do not function as a standalone unit; they are accompanied by several pieces of equipment that form a complete thermal processing system.

The typical support equipment that makes up a complete kiln system is outlined here. In addition to our custom rotary kilns, FEECO can provide the listed equipment as part of a complete system.

EXHAUST GAS HANDLING SYSTEMS & EQUIPMENT

All rotary kilns must be equipped with exhaust or flue gas handling equipment, sometimes referred to as a gas conditioning system. This system collects and treats (or “conditions”) any products of combustion, loss on ignition, gaseous emissions, and small particulates leaving the kiln in order to prevent air pollution and control emissions. The level of exhaust gas treatment required in a system is based on the unique emissions produced by the process, combined with local, state, and federal regulations.

Exhaust gas treatment systems can differ considerably based on the level of treatment needed, with indirect rotary kilns (calciners) requiring the most minimal treatment as a result of the process gases and material being kept separate.

Listed here are some of the most common types of exhaust gas handling equipment used for controlling emissions from rotary kilns.

THERMAL OXIDIZER/SECONDARY COMBUSTION CHAMBER

Thermal oxidizers are the first step in any gas treatment process, serving to oxidize or break down volatile organic compounds (VOCs) into carbon dioxide (CO₂) and water vapor (H₂O).

Various types of thermal oxidizers exist, with a common configuration being the direct-fired type—also called a secondary combustion chamber or afterburner.

QUENCH TOWER

The thermal oxidizer is typically followed by a quench tower. Quench towers are used to reduce the temperature of the hot gases exiting the oxidizer and take the gas stream to adiabatic saturation conditions.

After the quench tower, process gas typically moves on to a venturi scrubber (wet approach) for control of particulate emissions. The venturi scrubber can also be followed by a packed tower system for control of gaseous emissions.

VENTURI SCRUBBER (WET METHOD)

The venturi scrubber is a wet scrubber. This device uses primarily water to clean contaminants and particulates from exhaust gas.

PACKED TOWER (WET METHOD)

Packed towers often follow venturi scrubbers for removal of gaseous emissions. Also a form of wet

scrubber, packed towers use a scrubbing liquid to absorb or react with the contaminants in the gas.

The decision to utilize the wet scrubbing approach is dependent on the availability of water. The wet approach requires a significant water source and must be tied in to a sewer system, so it is often not an option in remote or water-constrained areas. If water and scrubber blowdown processing is an issue, then the dry scrubbing approach can be a more attractive alternative to control emissions.

In the dry scrubbing approach, the quench tower is typically followed by an evaporative cooler and baghouse.

EVAPORATIVE COOLER (DRY METHOD)

Evaporative coolers convert liquid water to water vapor via evaporation, immediately reducing the temperature of the gas.

BAGHOUSE (DRY METHOD)

The baghouse is a dry scrubber that can be used to control both particulate and gaseous emissions. By incorporating a sorbent injection system into the baghouse configuration, the system can also control gaseous emissions such as SO₂ and HCl. Activated carbon can also be introduced into the baghouse to control both heavy metals and Dioxin/Furan emissions as well.

The baghouse or bag filter collects any particulates that may have become entrained in the process gas and carried out through the exhaust air, which can especially be an issue when a high airflow velocity is

combined with a fine material.

Not only do baghouses aid in air pollution control, but they can also be used to reduce wasted product; the dust and fines collected by the baghouse can often be recovered and reintroduced to the process, mitigating any waste lost as dust.

In some operations, operators may choose to implement an agglomeration circuit to process baghouse fines or send them back to the process as recycle.

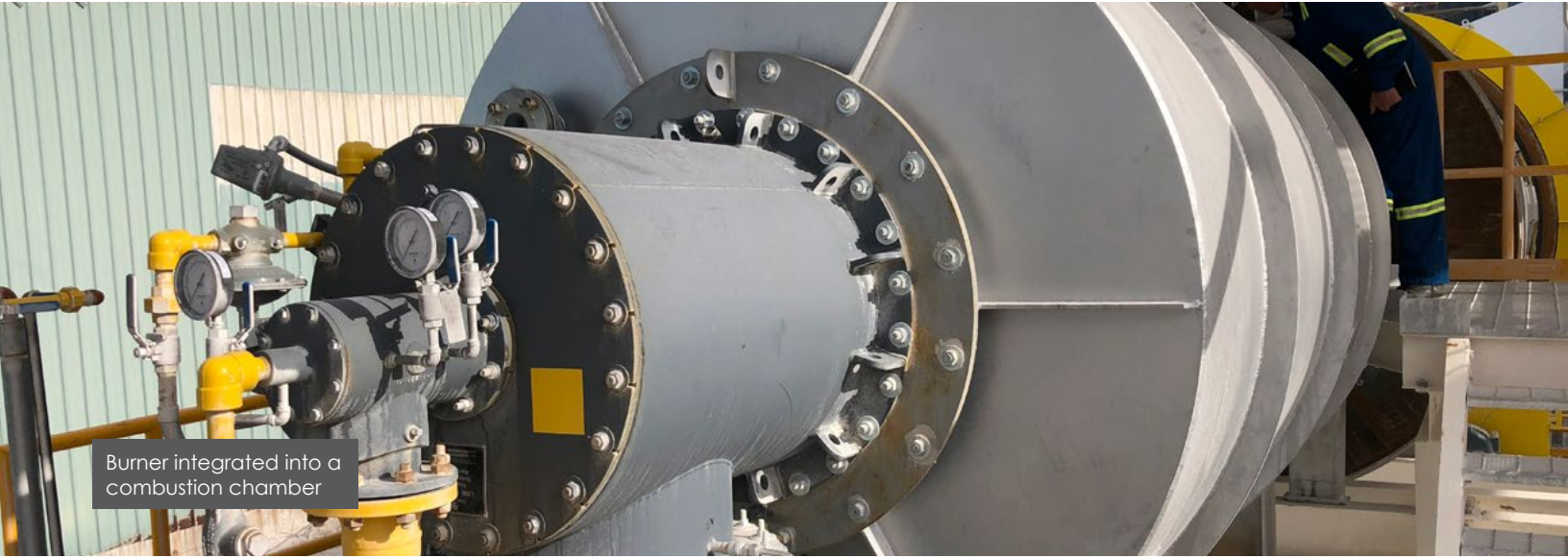
WET ELECTROSTATIC PRECIPITATORS

Wet electrostatic precipitators (WESP) offer an alternative to wet scrubbers and baghouses for fine or sub-micron particulate removal. This type of device uses positive and negative electric charges to attract and hold particles so they are not released into the atmosphere. The system also requires some other type of scrubbing system (typically a cyclone or a venturi) to remove large particulates before entering the precipitator system. The WESP will also require a water source and blowdown.

WASTE HEAT RECOVERY BOILER

A common alternative to a quench tower is a waste heat recovery boiler (sometimes referred to as a heat recovery steam generator, or HRSG). This can be used with a venturi scrubber and optionally, a baghouse. In addition to reducing the temperature of the gas exiting the kiln or thermal oxidizer, it also allows for energy recovery and the production of steam for use in other areas of the facility.

While there are common approaches to gas



Burner integrated into a combustion chamber

handling, each system is unique. Depending on the application at hand and the necessary emissions requirements, a system may utilize any combination of the technologies mentioned here to best address the unique needs of a project.

As these systems can be complex and must meet stringent criteria, the ideal configuration is best determined by an experienced expert.

Furthermore, it's important to note that an induced draft (ID) fan is required in all systems. The use of an ID fan creates a negative pressure environment, drawing exhaust gas, air, and particulates, or "flue gas" through the system to facilitate their removal. For this reason, the ID fan is always the last piece of equipment in the system, so it can be used to draw the exhaust through and create a negative pressure.

COMBUSTION REQUIREMENTS

In a direct rotary kiln, a controlled combustion reaction is used to produce the products of combustion. As

mentioned, this requires a burner and in some cases, a combustion chamber.

BURNER

The burner provides the source of combustion, using the fuel source, along with combustion and dilution air to create a combustion reaction that produces the required energy.

Burners can be designed to accept several fuel sources, including natural gas, propane, diesel, and more. In some settings, waste heat from various sources can be used to preheat the combustion air and improve burner efficiency and lower fuel costs. The combustion air required comes from a blower forcing air into the burner. An air-to-air heat exchanger can be used to raise the temperature of the burner combustion air, increasing the overall efficiency of the combustion system. Utilization of preheated combustion air will result in increased costs to the burner system and an evaluation needs to be undertaken to determine if the resulting increase in

efficiency of the system actually provides a realistic advantage from a cost savings standpoint.

COMBUSTION CHAMBER (OPTIONAL)

[Combustion chambers](#) are not required in all settings, but can be a valuable add-on. Combustion chambers serve to house the combustion reaction and direct the airflow into the kiln (either co-currently or counter currently).

Implementing a combustion chamber can offer a number of benefits. Perhaps most importantly, the addition of a combustion chamber can promote a quality product by preventing contact between the burner flame and the material being processed.

Combustion chambers are highly customizable. The base design of a FEECO combustion chamber offers the following benefits:

- Lower fuel cost through a more complete combustion of fuel
- More uniform results
- Avoidance of product breakdown

NO_x REDUCTION

Nitrous oxides, or NO_x gases, present in nearly every thermal processing operation, are becoming increasingly regulated. Not addressed in the aforementioned emissions control systems, NO_x must be treated during combustion, or in post-combustion treatment. This might include the use of low-NO_x combustion systems when available, or post-combustion treatment methods such as SCR (selective catalytic reduction) and SNCR (selective non-catalytic

reduction) to address these harmful pollutants.

PRODUCT COOLING REQUIREMENTS

Though not part of the rotary kiln system itself, rotary kilns are often accompanied by a [rotary cooler](#) for product cooling requirements.

Rotary coolers can be either direct or indirect water deluge, with the indirect configuration being favored for processing ultra-fine materials that would otherwise risk entrainment.

MATERIAL HANDLING EQUIPMENT

In addition to the immediate support equipment, various types of [bulk material handling equipment](#) will be required to transport material to and from the kiln. This might include screw conveyors, belt conveyors, bucket elevators, feeders, etc.

ROTARY KILN PROCESSES

Because rotary kilns simply serve as a vessel to cause a chemical reaction or phase change, there are many types of processes that they can be used for. The following is an overview of some of the processes that are commonly carried out in a rotary kiln. It's important to recognize that some of these terms may be used interchangeably, despite not fitting the technical definition.

CALCINATION

The calcination process requires heating a material to a high temperature with the intent of chemical dissociation (chemical separation). Calcination is commonly used in the creation of inorganic materials. One of the most common examples of this process

is the dissociation of calcium carbonate to create calcium oxide and carbon dioxide.

The calcination process can also be used in the removal of bound moisture, such as that which is chemically attached in Borax.

THERMAL DESORPTION

Thermal desorption uses heat to drive off a volatile component, such as a pesticide, that has mixed with an inorganic mineral like sand. It is important to remember that this is not incineration, which may produce harmful pollutants and would require a more extreme exhaust treatment system; instead, it is a separation process that uses the different reaction temperatures of absorbent minerals and chemicals. The organic chemical (e.g. pesticide) is vaporized at the increased temperature, causing a separation without combustion. An indirect rotary kiln is best for this application, because the volatile chemicals may be combustible. The indirect kiln would supply the heat for desorption, without the material coming into direct contact with the flame.

ORGANIC COMBUSTION

Organic combustion is the thermal treatment of organic waste with the intent of reducing mass and volume. This is commonly seen in waste treatment plants to reduce the volume of waste for depositing in landfills. Direct-fired rotary kilns are most common here, because air is required to combust the organics.

REDUCTION ROASTING

Reduction roasting is the removal of oxygen from a component of an ore usually by using carbon monoxide (CO). An example of this is the reduction

roasting of a hematite-containing material to produce magnetite that can be magnetically separated.

SIZING & DESIGN

SIZING & DESIGN | CUSTOMIZATION



Batch kiln testing in the
FECCO Innovation Center

ROTARY KILN SIZING & DESIGN

Every material is different in terms of how it will behave in the kiln and at what temperatures different reactions will occur. When designing a process around a rotary kiln, as well as in the design of the kiln itself, the material must undergo thorough chemical and thermal analyses. Various material characteristics will play a part in how the material will perform in the kiln, and subsequently, how the kiln will need to be designed around the material to accomplish the process goal. For example, will the material melt, vaporize, or combust at certain temperatures?

Much of this data can be gathered through testing (discussed on page 30). The following provides an overview of some of the common material characteristics that can influence kiln design.

CHARACTERISTICS THAT AFFECT ROTARY KILN DESIGN

PARTICLE SIZE DISTRIBUTION & BULK DENSITY

The particle size distribution and bulk density of a material will influence the sizing of some kiln components. For example, a material with a high bulk density will likely require more horsepower, and therefore a more robust drive system. Additionally, a material that has been agglomerated into pellets (or has a larger particle size distribution) will not require as large of a kiln diameter as fines would. This is because when processing fines, a lower air velocity must be used to minimize entrainment. When processing pellets, however, a higher air velocity can be utilized, and therefore, the kiln does not need to be as large.

ABRASIVENESS & CORROSIVENESS

While the abrasiveness or corrosiveness of a material may not have a direct effect on the sizing aspects of the kiln, it does influence the materials of construction. Working with abrasive or corrosive materials may require parts, or all, of the kiln to be lined or constructed with a corrosion- or abrasion-resistant refractory.

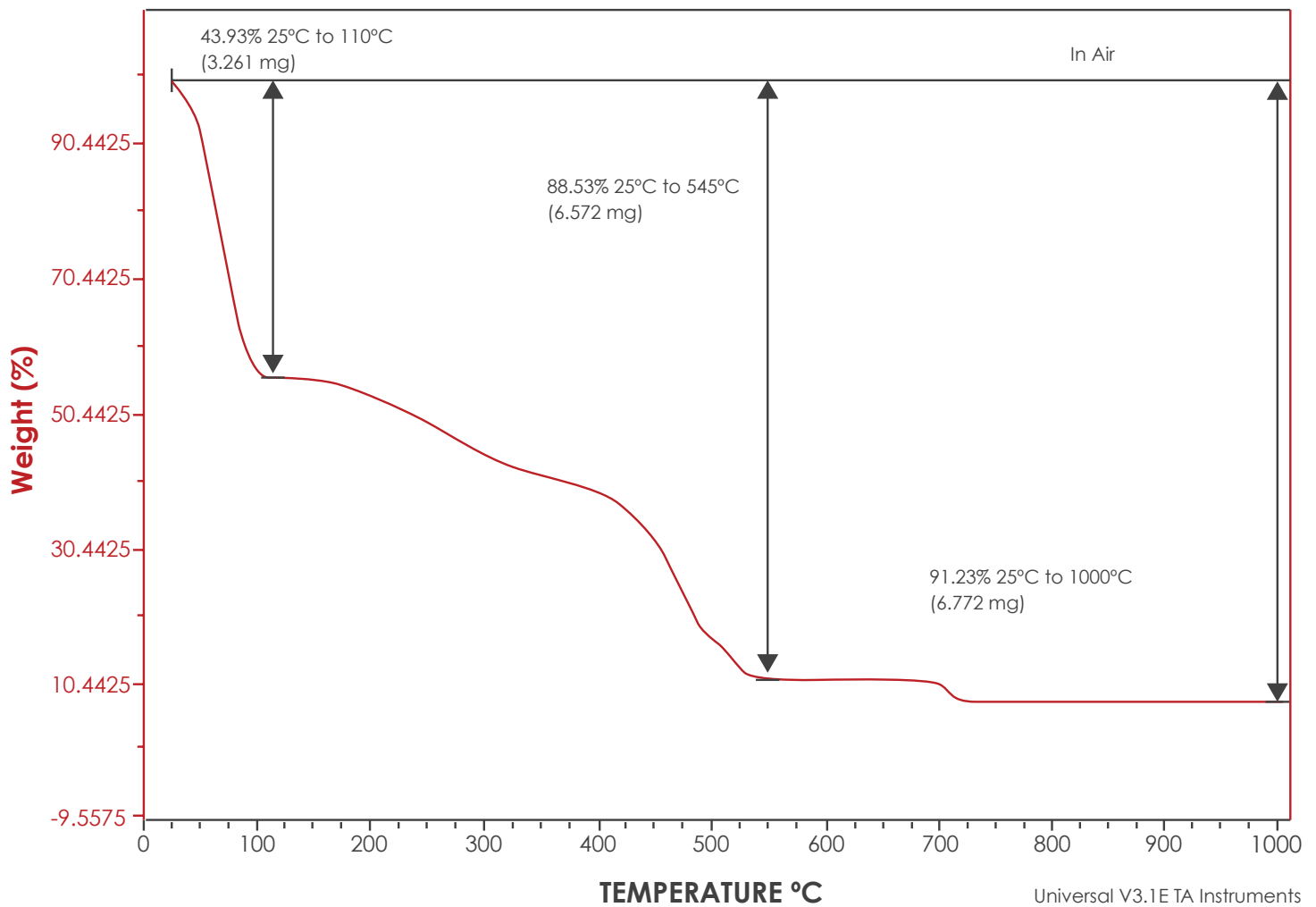
SPECIFIC HEAT

The specific heat of a material is another central factor in the design of a rotary kiln. Specific heat is how resistant a material is to heating. By definition, it is how much energy (i.e. calories) it takes to raise 1 gram of material by 1 degree Celsius. Some materials, such as water, have a very high specific heat, meaning it takes a significant amount of energy to raise the temperature. Other materials, such as metals, have a much lower specific heat, meaning it takes much less energy to cause a change in temperature.

HEAT OF REACTION

In many kiln applications, heat is required in order for a reaction to occur. For example, in the calcination of limestone to lime, energy is required to dissociate CaCO_3 into CaO and CO_2 . In addition to energy, an elevated temperature is required for most reactions to occur; the dissociation of limestone will not happen at a temperature below 900°C .

The temperature and energy required for a reaction can be found in published data or by running a DTA test (described on page 21).



Universal V3.1E TA Instruments

Diagram: TGA Analysis for a Sample

THERMAL CONDUCTIVITY

Similar to specific heat, the thermal conductivity of a material also plays a part in the design of a rotary kiln. How a material transfers heat will have a direct effect on how the material behaves in the rotary kiln; will it transfer its heat easily, causing even heat distribution and low retention time, or will it hold onto its heat, causing cold pockets of material, a longer retention time, and possibly the need for additional accessories like dams or bed disturbers?

TEMPERATURE PROFILES

A Thermal Gravimetric Analysis, or TGA, can be performed on a material to determine changes in mass as a function of temperature. A TGA describes the temperature ranges at which mass loss occurs. This is critical in determining the required temperature profile in a kiln. As an example, free water will show primary removal at around 212° F, where tightly bound chemical water may show a mass loss upwards of 500° F.

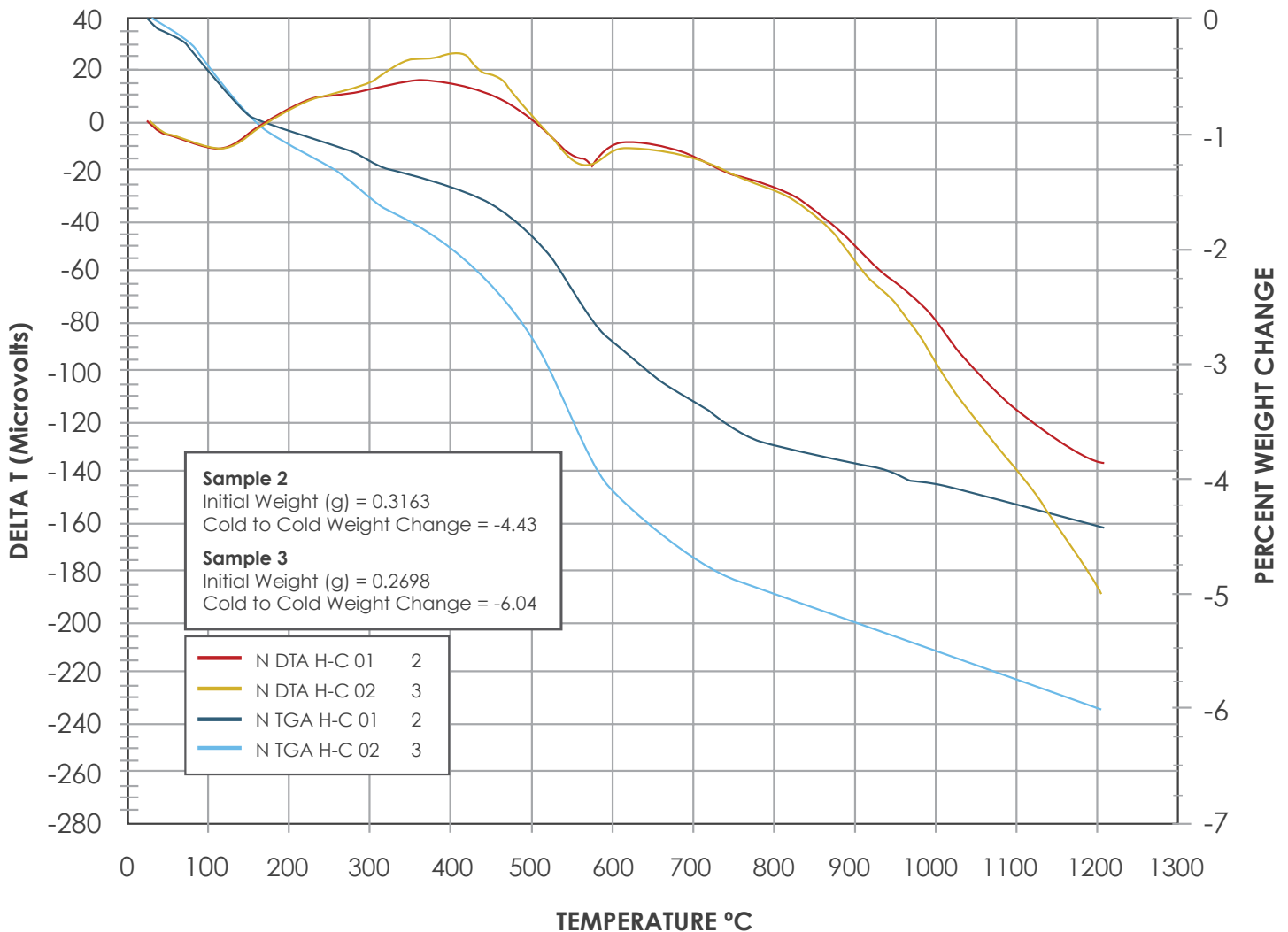


Diagram: TGA and DTA Analyses for Two Samples

A TGA also helps show where a reaction begins, and ends, as often, the curve on a TGA starts at a specific temperature, but does not complete until a much higher temperature. Overall, a TGA helps determine the temperature profiles that will be required in a rotary kiln by showing at what temperature reactions are occurring. Additionally, while the intent of a process may be to convert a material in a specific way, a TGA will reveal reactions that might occur between the start and end point, helping to indicate

where unpredicted reactions may occur.

A **Differential Thermal Analysis (DTA)** or Differential Scanning Calorimeter (DSC), is also useful at this stage, as it shows the amount of heat required to perform the reactions and to heat the material to the final temperature.

CHEMICAL COMPOSITION

Knowing the chemical composition of a material is a

valuable asset in rotary kiln design for several reasons. One important reason is that many materials will combust inside the rotary kiln at high temperatures, creating more heat than was put into the rotary kiln. In cases such as these, the rotary kiln will need to be designed to withstand those excess amounts of heat. In other cases, materials may need a particular chemical atmosphere for a reaction to occur—for example, an atmosphere devoid of oxygen, or rich in carbon dioxide. Still another reason to understand the chemical makeup of a material, and how those chemicals react together at certain temperatures, is to predict what exhaust gases will be generated and subsequently, what type of exhaust gas treatment will be necessary.

SIZING

After the material has been thermally and chemically analyzed, sizing can begin. Sizing is a complex process not easily explained in brief; the process of sizing a rotary kiln is one that combines engineering principles with the thermal and chemical analyses, along with experience, to design a kiln that meets its intended processing goal.

The size of a rotary kiln is not only a function of capacity, but also of the amount of heat that can be generated inside the rotary kiln from the volatilizing and/or combustion of the material. The diameter and length of the rotary kiln are calculated based on the maximum feed rate, the required retention time, and what the bed profile (how full of material the rotary kiln is) will need to look like. In the FEECO design process, once we have engineered a rough design of the rotary kiln, we use several computer programs to

help predict and model how the material will behave in the rotary kiln we have designed. We review the combined analyses, and if our design does not meet the appropriate criteria, we adjust accordingly.

Once we have our preliminary rotary kiln size, we can start to think about the details of the rotary kiln internals, such as if there will be a need for a dam, or what type of refractory will best suit the process.

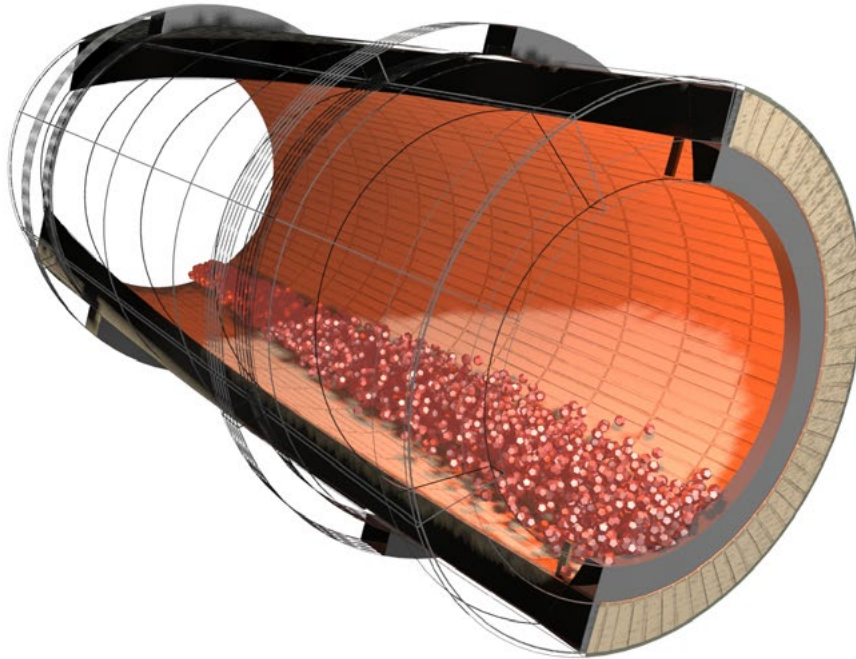
FEECO encourages that each material go through a research and development process at our on-site, concept testing facility. The information gained through our proven testing procedures allows us to design the most efficient and beneficial thermal processing system for our customer's material requirements. Testing is discussed in-depth on page 30.

INCREASING EFFICIENCY THROUGH CUSTOMIZATION

Rotary kilns are extremely customizable, and can be configured to fit nearly any process needs. There are various ways to customize a kiln in order to attain the most efficient processing possible. Below are some of the common customizations used to maximize the performance of a rotary kiln.

DAMS

For various reasons, it is often desirable to increase retention time or bed depth in a rotary kiln. This is done by adding what is called a "dam." A dam in a rotary kiln works much like a dam in a river; material builds up behind the dam, forcing retention time and bed depth to increase. Material then spills over the dam, and discharges from the rotary kiln. Since most kilns uti-



Dams are put in place when retention time needs to be increased using the same size rotary kiln. Dams allow the loading to be increased, which increases retention time and bed depth by forcing the material to build up in the rotary kiln.

lize a counter current air flow, end dams are the most commonly used.

End dams efficiently hold the material where the air is warmest (at the discharge end in a counter current kiln). Internal dams can also be used if a discharge end dam is not sufficient.

FLIGHTS

Flights are most commonly seen in rotary dryers. They are, however, sometimes utilized in low-temperature kilns in order to shower the material and increase heat transfer efficiency.

BED DISTURBERS

Indirect rotary kilns create heat transfer by conduction through the shell of the rotary kiln, rather than by means of contact with a process gas. Because all of this heat transfer is occurring through the shell, it is

essential that the bed rolls rather than slides in order to expose fresh material and promote even heat distribution throughout the bed. This will assure that the transfer of heat is as efficient as possible. For this reason, when processing material in an indirect-fired kiln, it is often desirable to employ a bed disturber. Bed disturbers are also commonly used in a direct-fired kiln for the same reason; the bed disturber helps to prevent the bed from sliding, as well as promotes more uniform heating.

A bed disturber, often custom designed to create maximum, material-specific efficiency, is essentially anything affixed to the inside of the rotary kiln that helps to mix the bed of material. Ideally, the bed should tumble, turning over and minimizing dead spots, or temperature variations within the bed.

Unfortunately, not all materials tumble well, which results in a slipping bed with poor mixing and large temperature variation. Bed disturbers can be attached to the interior of the rotary kiln in order to disturb the bed and turn it over. However, what seems like a simple task can get complicated quickly, as thermal stresses come into play.

A common bed disturber used in an indirectly heated kiln is a bar that runs the length of the interior of the rotary kiln. Material pushes up against the bar, building up and rolling over it, so material that was on the top of the bed now gets redistributed to the bottom of the bed. The disadvantage to using a bar bed disturber is that they can sometimes bend and break with the thermal stresses of the rotary kiln. A rotary kiln naturally has gradients of temperature—usually cooler on the ends of the rotary kiln, and hotter in the middle. This gradation in temperature causes differential thermal expansion on the rotary kiln shell. As a result, the bar, welded to the shell, is pulled in different directions, which can cause the weld to break. When this kind of thermal expansion is at work, it is usually best to look at alternative bed disturbers.

Flights, or lifters can also be used as a bed disturber. In this case, flights are welded with one weld point each to the inside of the rotary kiln. This method of disturbing the bed is designed to accept the different thermal expansion stressors, making it ideal for drums with temperature gradations.

SEALS

Almost all rotary kilns run at a negative pressure, meaning gas doesn't leak out, but rather, air leaks in.

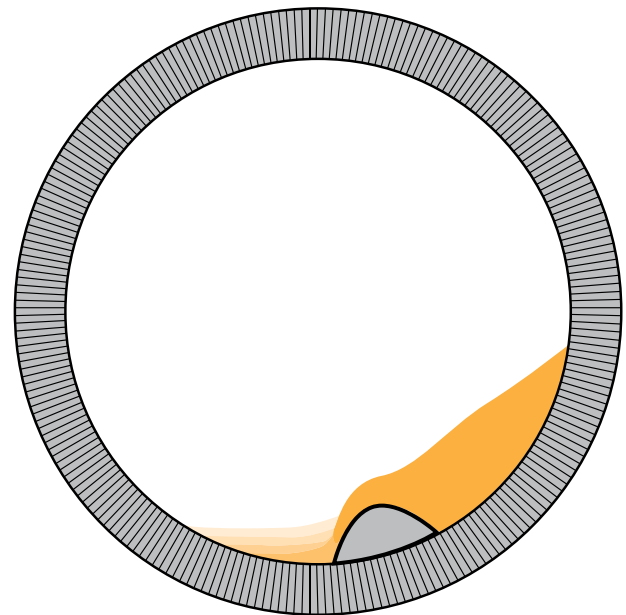
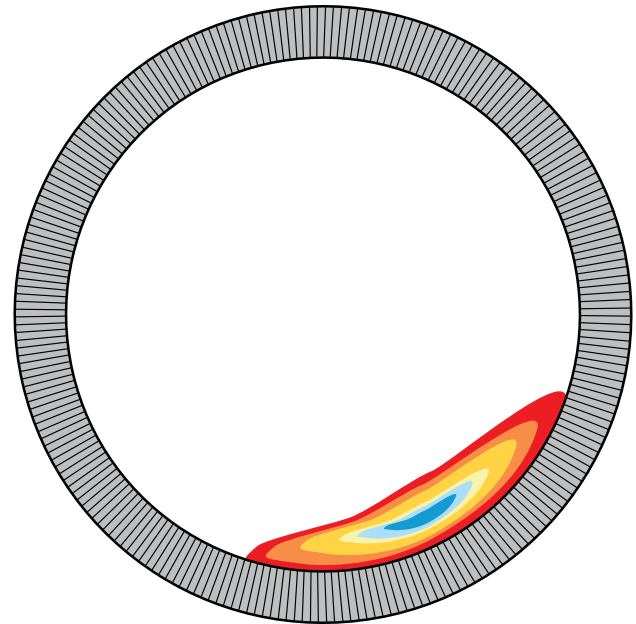


Diagram: The illustration above shows the gradations that can occur in a bed of material that is poorly rotated (top). The addition of a bed disturber helps to rotate the bed, ensuring even distribution of heat throughout the bed (bottom).

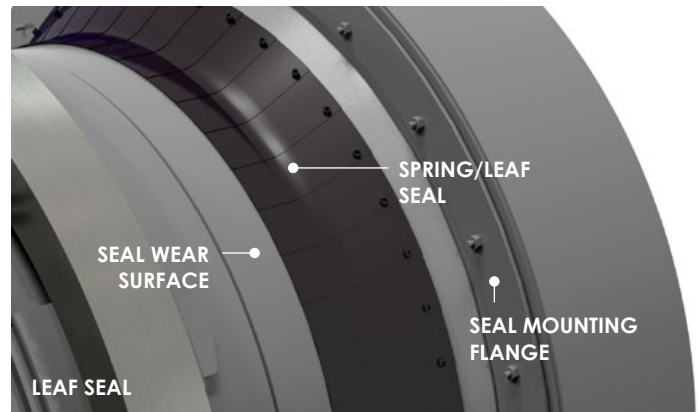
Because rotary kilns are always running at a higher temperature than ambient, any ambient air leaking into the rotary kiln will cause the temperature inside of the rotary kiln to drop. Not only will this result in an unnecessary amount of energy being used and wasted, but if the leak is severe enough, it could also potentially disrupt the process. This is why it is crucial to have a quality [seal](#).

Sealing the ends of a rotary kiln can be a difficult task. The stationary part, referred to as the breeching, is typically where leakage will occur. One option is a leaf seal—leaf seals are the standard seal used on both rotary kilns and rotary dryers.

How Leaf Seals Work: Leaf seals are similar to a fanned out deck of cards. The “cards,” or leaves, are made out of spring steel. These fanned out leaves are bolted to the breeching, and the springy leaves are forced to push against the seal/wear plate of the rotating kiln, naturally keeping pressure on the rotary kiln to create a good seal. Double leaf seals are also available when minimizing leakage is more critical. The double leaf seal is similar to the single leaf seal, but instead offers two layers of leaves with a ceramic fiber blanket sandwiched between to increase sealing efficiency. As mentioned, additional seal options are also available.

REFRACTORY

Arguably one of the most critical components of a direct-fired rotary kiln, the refractory is what protects the shell from the high temperatures within, and maintains heat retention. A quality refractory is of the utmost importance. Many options are available,



depending on the needs of the rotary kiln. Refractory is specific to direct-fired kiln shells; the addition of refractory to an indirect-fired kiln shell would further decrease efficiency, because it would add another layer for heat to pass through before it could reach the material.

Further necessitating the need for refractory, direct-fired kilns typically do not utilize combustion chambers, so the flame is in constant direct contact with the internals. Flame temperature can typically range anywhere between 1600 – 3200° (depending on excess air)—a harsh processing environment that carbon steel is not capable of withstanding.

While the main objective of refractory is to protect the kiln shell, refractory also serves to minimize heat loss. A kiln with sub-par refractory may protect the kiln shell, but allow significant heat loss, reducing overall process efficiency and increasing operational costs.

Typically, there are two kinds of refractories for lining a rotary kiln: castable and brick. Each kind of refractory has its advantages and disadvantages. The choice of refractory is dependent on the rotary kiln temperature,

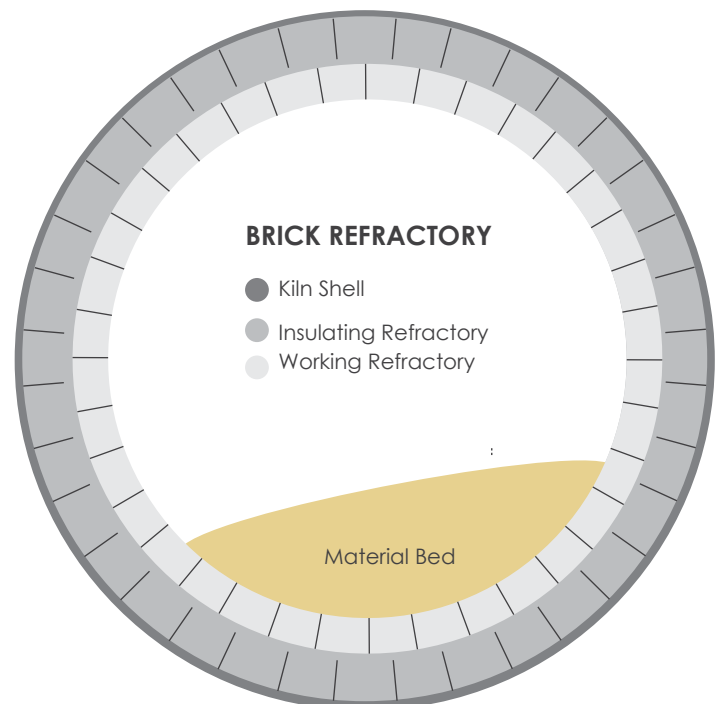
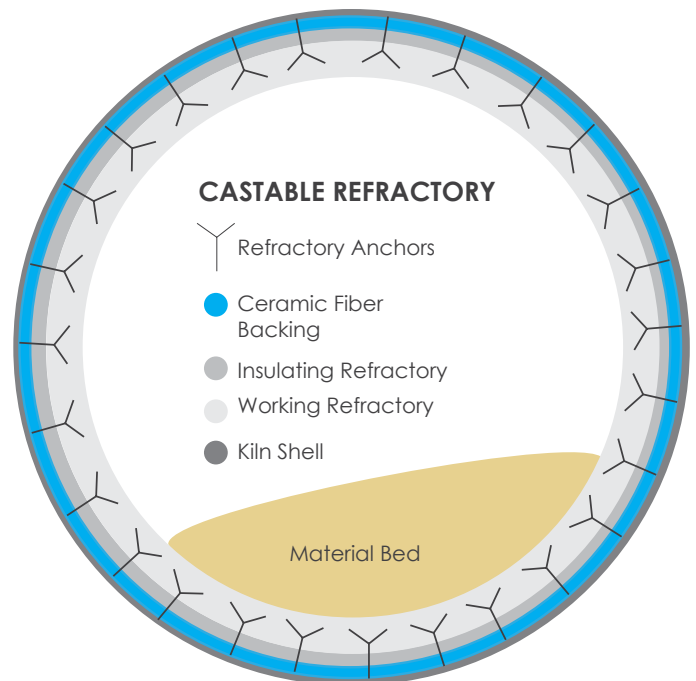
material chemistry, and how abrasive the material is. Castable and brick refractory are comparably priced for similar refractory compositions. However, the installation cost for brick is higher, since it is more labor intensive. Brick is usually used for abrasive materials, because it is more wear resistant.

Castable:

Castable refractory comes in a powder form and is mixed with water on-site. Before the mixture can be put in place, anchors are installed. These y-shaped anchors are similar to rebar in cement; they help give the castable lining its strength. Once these anchors are in place, the cement-like mixture is pumped into the lining of the rotary kiln, and allowed to cure for several days.

Besides lower overall cost, the advantage to using castable refractory in a rotary kiln is that it is usually easily patched when a problem is encountered. Down time is typically minimal, because the problem area can be cut out and new refractory poured into the cavity.

The disadvantage to using castable refractory in a rotary kiln is that it is very susceptible to installation problems. When castable refractory is expertly installed, it can nearly match the quality of brick. But if installed incorrectly, there can be a considerable difference in quality, and the life of the refractory can be severely compromised. Castable refractory can exhibit hairline cracks over time. If anchors are not properly installed, these cracks can get bigger and allow portions of refractory to fall out. Similarly, these hairline cracks can become bigger, trapping material and creating hot spots.





Castable refractory being poured into a kiln door

Brick:

Brick is fired in a furnace under tightly controlled conditions that allow it to achieve better properties than a similar composition castable refractory.

Although slightly more expensive than castable, brick does not require anchors, and its quality is superior, but as mentioned, it incurs greater install costs. When processing a highly abrasive material, brick refractory is advisable most of the time, as castable does not have the durability to stand up against abrasive materials as well as brick.

The disadvantage to brick refractory is that it is kept in place much like a roman arch; bricks are held in place by the pressure of the other bricks pushing against each other. When a problem is encountered, typically the failed brick needs to be replaced, but when one brick is relying on the bricks around it to hold it in place, whole sections of the refractory must be replaced. Unlike castable refractory, the repair of a fail in brick refractory is much more involved.

Working vs. Insulating Layer

The way in which refractory is layered is also customizable. When higher efficiency is desired, or very high temperatures are involved, often it is desirable to use multiple layers of refractory: a “working” layer, and an insulating layer.

The working layer is what is in direct contact with the material being processed. Because of this, this working layer is a dense lining that can withstand the high temperatures within the rotary kiln and the constant abrasion from the material. However, when it comes to refractory, the more dense it is, the less insulating capabilities it has. This means that even though there may be a tough, durable, thick working layer in place, the heat can easily pass through to the shell of the rotary kiln. For this reason, an insulating layer is needed beneath the working layer, as shown in the diagrams on the previous page.

The insulating layer does just that; it insulates the shell of the rotary kiln so the high temperatures cannot reach the shell and damage it.



Proppants created during batch testing in the FEECO Innovation Center

Typically the working layer and the insulating layer are made of the same form of material (i.e., brick or castable), with varying chemistries. The working layer tends to be a higher density, stronger material that is more conductive. The insulating layer does not need these qualities, and tends to be softer, lighter, and less conductive, therefore more insulating. These two layers often vary in thicknesses, and these are determined from the needs of the rotary kiln and what material is being processed. In some unique cases, where processing temperatures are low, or efficiency is less of a concern, it is only necessary to use one working layer. For these reasons, refractory in a rotary kiln is often a very custom part of the design.

When insulation is extremely critical, an optional third layer of ceramic fiber backing can be used (as seen in the castable illustration on page 26).

Though there are various kinds of this backing, this thin, but very efficient layer is similar to fiberglass insulation found in a house, but much more compressed.

The decision to employ this layer comes with some responsibility. Should a crack in the refractory occur and go unnoticed, it is possible for the high heat inside the rotary kiln to reach this backing and burn it up. This would create a gap between the refractory and the shell of the rotary kiln, which would cause disastrous problems. Due to this potential of increased risk, this third layer is not always appropriate.

CONSIDERATIONS

TESTING | MOISTURE REDUCTION



Indirect batch kiln testing in
the FECCO Innovation Center



Batch kiln testing in the Innovation Center

THERMAL TESTING

Testing plays an integral part in the development of many industrial processes, and is especially critical in the thermal processing industry when working with kilns. Testing gathers important process data and lays the groundwork for developing a safe, efficient, and effective process that meets the desired processing capacity and product quality.

WHY USE TESTING?

Testing is useful in a multitude of processes. Commonly tested processes include:

- Thermal Desorption of Organic/Hazardous Wastes
- Sintering/Induration
- Heat Setting
- Organic Combustion
- Metal Recovery
- Calcination
- Mineral Processing
- Reduction Roasting

There are many reasons why it may be desirable to conduct [testing with a rotary kiln](#). Some of the most common reasons are summarized here.

TO SIZE AND DESIGN A COMMERCIAL-SIZE KILN

Perhaps the most common reason for thermal testing with a kiln is to gather the data necessary to size and design a commercial-scale kiln for an intended application. In this setting, the desired product specifications have typically been determined, but the customer needs to know what the kiln and surrounding process will need to look like to reach those parameters.

TO AID IN PRODUCT DEVELOPMENT

Oftentimes, a customer is looking to develop a new or enhanced product. This is commonly seen in the proppant industry, where ceramic proppants are processed in a rotary kiln to develop the ideal characteristics needed for the hydraulic fracturing process.

Testing can be carried out on small samples of

material and used for field trials to evaluate the product properties.

TO CONFIRM VIABILITY OF AN INTENDED PROCESS

Testing is also useful in determining if a particular process holds potential for a commercial-scale operation. Customers come to FEECO with an idea and a sample of material, and trials are run to determine if the process is technically and economically feasible.

While this is seen throughout a variety of industries, one common example is in the reclamation of valuable materials, such as the recovery of metals from wastes. Many waste materials have previously been landfilled even though they contained a valuable component, because the component was not economically accessible or recoverable in its existing form. Advanced thermal processing techniques have opened the door to the recovery of these valuable components. In cases such as these, a company may test a material to see if the valuable component could be economically recovered from the waste material.

TO TEST VARIABLE PROCESS CONDITIONS

Another common reason for thermal testing is to research and develop different processing conditions. Many customers may have an existing thermal system, but are looking to adjust the process, or feel that their current process could be improved upon. Testing allows them to try out various process conditions in a test setting, without disrupting production in their existing commercial kiln.

HOW TESTING WORKS

Testing is commonly conducted first at batch scale, and then at pilot scale.

BATCH/FEASIBILITY TESTING

Batch testing, also referred to as feasibility testing, is a cost-effective way to test small sample sizes and gather initial process data, such as time and temperature profiles. Batch test work also helps to define the process parameters needed for continuous pilot-scale testing.

PILOT TESTING

Pilot test work is done on a much larger scale than batch testing, allowing for a continuous process—including exhaust gas treatment—to be tested, and commercial process conditions to be simulated.

During both batch and pilot testing, solid samples can be regularly withdrawn in order to determine the material chemistry and physical properties of the material at various intervals. Qualities such as those listed here are commonly analyzed to ensure a product is meeting desired specifications:

- Temperature
- Flowability
- Compression Strength
- Bulk Density
- Crush Strength
- Gas Sampling & Monitoring

Gathered process data can then be used to produce the desired product specifications and aid in process scale-up. These data points may include:

- Residence time

- Kiln slope
- Temperature requirements
- Kiln speed
- Emissions
- Feed Rate

- Fuel Usage
- Gas Sampling & Analysis
- Horsepower
- Speed
- System Pressure
- Temperature
- Torque

AVAILABLE TESTING EQUIPMENT

Direct-fired and indirect-fired kilns can be tested in the FEECO Innovation Center, at both batch and pilot scale. Co-current and counter current air flow configurations can also be tested, with a variety of optional equipment available to accommodate the process.

Optional testing equipment in the FEECO Innovation Center includes:

- Kiln combustion chamber
- Thermal oxidizer
- Baghouse
- Wet scrubber
- Removable flights, dams, and bed disturbers

AUTOMATION

[The FEECO Innovation Center](#) offers an extensive programmable logic control system. We have partnered with Rockwell Automation to bring our customers the best in process automation, both as part of testing in our Innovation Center, and as part of a system purchase.

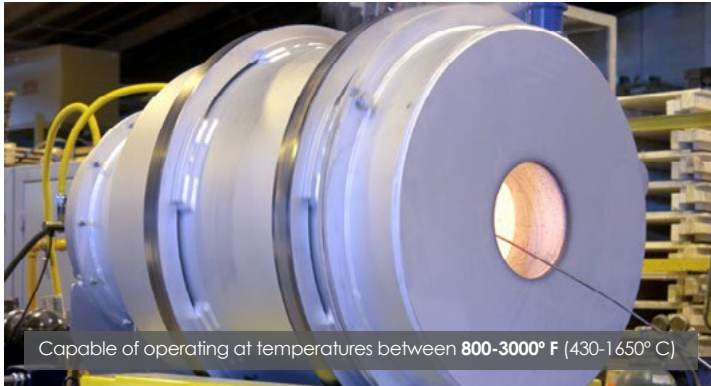
Our system allows for a variety of data points to be tracked and adjusted from a single interface, in real time. This includes:

- Current (Amps)
- Feed rate
- Flow Rates

In addition, data points can be selected, trended, and reported on, allowing users to select only the data they need, from the exact time frame they need.

More information on testing is available in the following profile, which details the capabilities and testing process in the FEECO Innovation Center.

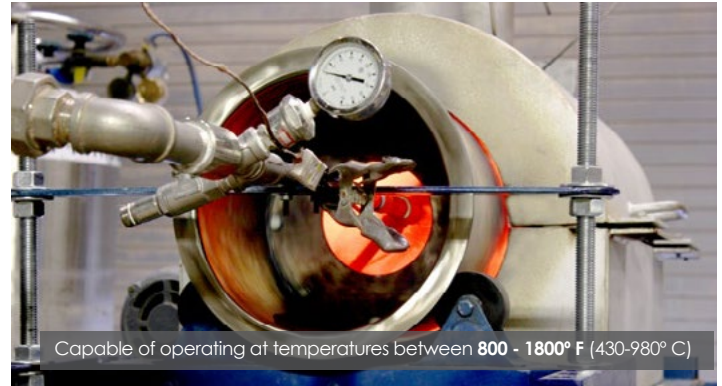
The [FEECO Innovation Center](#) offers a variety of test kilns that can simulate the conditions of continuous, commercial-size [rotary kilns](#). Our available test kilns are described below.



Capable of operating at temperatures between **800-3000° F** (430-1650° C)

18" X 24" DIRECT-FIRED BATCH KILN (0.46 x 0.61m)

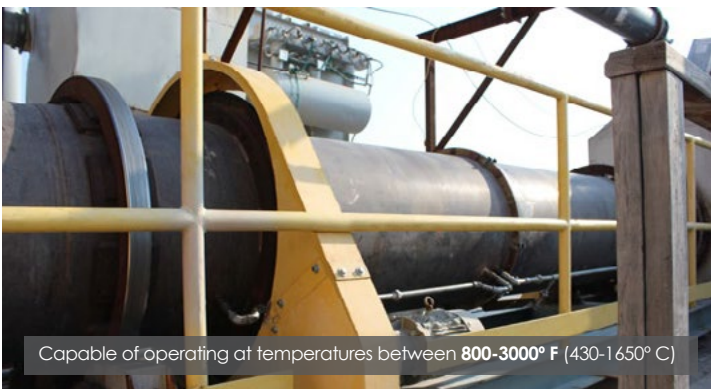
Our direct-fired batch kiln is equipped with a propane burner with oxygen enrichment, variable speed drive, and both bed and gas thermocouples. A reducing atmosphere can also be used. The batch kiln is lined with 99% alumina castable refractory and can be operated to simulate either co-current or counter current flow.



Capable of operating at temperatures between **800 - 1800° F** (430-980° C)

10.5" X 24" INDIRECT-FIRED BATCH KILN (0.27 x 0.61m)

Our indirect-fired batch kiln is heated with a propane burner beneath the shell. Dams inside the kiln hold material within the heated zone. Two thermocouples, located near the shell in the furnace, are used to measure its temperature. Two additional thermocouples are used to measure the bed and exhaust gas temperatures. Kiln ends can be sealed and have an inlet for a purge gas and an outlet for purge gas exhaust.

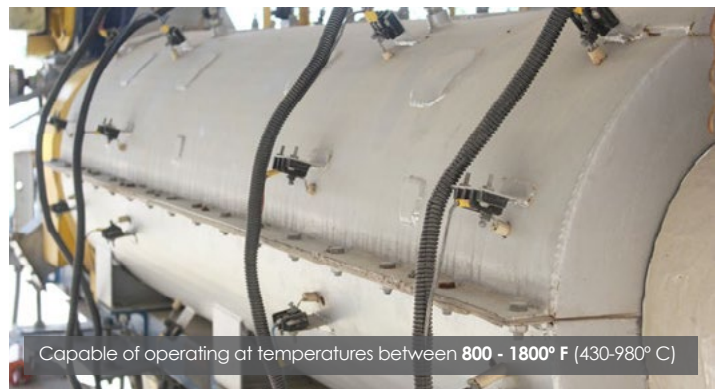


Capable of operating at temperatures between **800-3000° F** (430-1650° C)

30" X 20' CONTINUOUS DIRECT-FIRED PILOT KILN

(0.77 X 6.1m)

Our continuous direct-fired pilot kiln is equipped with a refractory brick lining, feed system, natural gas burner, and cooled screw. Adjustable dams allow for a deeper bed depth and longer residence times. The kiln can be operated in either a co-current or counter current configuration. Kiln exhaust is ducted through a thermal oxidizer (TO), quench chamber, bag filter, or wet scrubber and ID fan.



Capable of operating at temperatures between **800 - 1800° F** (430-980° C)

6.5" X 84" CONTINUOUS INDIRECT-FIRED PILOT KILN

(0.17 X 2.1m)

Our continuous indirect pilot kiln is divided into two electrically heated zones. Thermocouples in each zone near the shell measure temperature and control outputs from the heating elements. Both kiln speed and slope can be adjusted to alter the bed profile and residence time. Kiln exhaust is ducted through a thermal oxidizer (TO), quench chamber, bag filter, or wet scrubber and ID fan.

THE ROTARY KILN TESTING PROCESS

Testing in the Innovation Center offers a host of invaluable information, allowing you to gain critical data on your material, work out process variables, and develop a recipe for process scale-up. Our flexible setup, combined with the expertise of our process engineers and our experience with hundreds of materials allows a variety of thermal tests to be expertly conducted. We also have the capabilities to incorporate additional processing, including drying and agglomeration.

COMMONLY CONDUCTED ROTARY KILN TESTS:

- Carbon Activation
- Catalyst Activation
- Calcination
- Desorption & Combustion
- Heat Setting
- Metal Recovery
- Organic Combustion
- Reduction
- Sintering
- Upgrading of Ores

We offer comprehensive testing options in four categories:

1. Feasibility/Proof of Concept

Muffle furnace testing along with Thermal Gravimetric Analysis (TGA), Differential Scanning Calorimeter (DSC), and chemical analysis to determine your specific material's chemistry and reaction to heat.

2. Proof of Product

Batch testing where it is determined whether a product can be made to the required specifications.

3. Proof of Process

A continuous testing phase that aims to establish the equipment setup and parameters required for commercial production of your specific material.

4. Process/Product Optimization

An in-depth study to optimize your specific material's characteristics and/or production parameters for an operating industrial kiln.

OPTIONAL TESTING CONDITIONS & EQUIPMENT:

- Baghouse
- Data Collection & Trending System
- Direct or Indirect
- Parallel or Counter Current Flow
- Removable Flights, Dams, and Bed Disturbers
- Thermal Oxidizer
- Water Quench Tower
- Wet Scrubber

COMMONLY TARGETED TEST INFORMATION:

- Baghouse Efficiency
- Bulk Density
- Crush Strength
- Dust Generation
- Exhaust Gas Composition
- Extent of Reaction (e.g. Calcination, Reduction)
- Particle Size Distribution
- Reactivity of Product
- Temperatures
- Thermal Oxidizer Efficiency



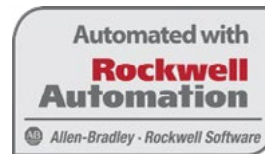
REPORTING & DATA IN REAL TIME

Our state-of-the-art system allows you to monitor various data points, trending them, and even adjusting process variables in real time, all from a single interface, or even from a remote device. This allows for a user to view process data and respond accordingly during production.

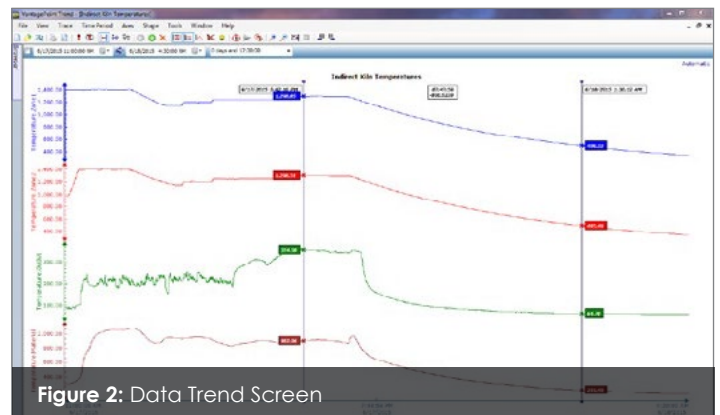
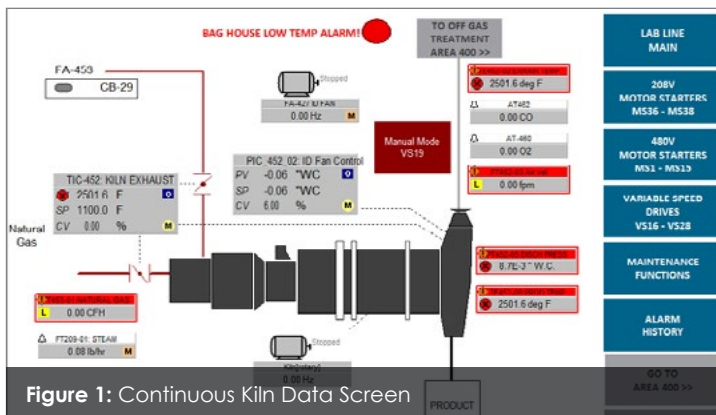
FEECO is a Rockwell Automation partner, providing integrated process control solutions, both as a service in the Innovation Center, and as part of a system purchase. FEECO and Rockwell Automation process control solutions are provided with current technology, motor control centers, programmable logic controllers, and data collection systems with advanced technologies for reporting. The Innovation Center features a Rockwell Automation MCC system, which utilizes current technologies for optimizing testing operations.

Data gathered includes:

- Burner Fuel Usage
- Drum Slope
- Emissions
- Fan Speed ^{RT}
- Feed & Product Rates ^{RT}
- Temperature (Feed end, Internal, TO, product, & exhaust gas) ^{RT}
- Heater Amps ^{RT}
- Natural Gas Flow Rates ^{RT}
- Outlet Gas Parameters
- Quench Tower Water Flow ^{RT}
- Residence Time
- Rotational Speed
- Samples: Feed, Product, & Internal Kiln
- Screen Analysis of Feed & Product
- Steam Flow ^{RT}
- System Pressures ^{RT}
- Gas Sampling & Analysis (Oxygen, Carbon Monoxide, Nitric Oxide, Nitrogen Dioxide, Sulfur Dioxide, and combustibles discharged from various thermal processes) ^{RT}



^(RT) indicates that the data can be tracked in real-time.



FEECO can integrate third party equipment into your control system, giving you complete process tracking and visualization. Secure remote access to the system by a Rockwell Automation expert provides unparalleled troubleshooting capabilities.

MATERIAL TRANSFORMATIONS

Completed through testing in the Innovation Center

BEGINNING MATERIAL

FINAL END PRODUCT

		Agglomeration	Drying	Blending	Thermal	Compaction
Ammonium Sulfate	Granular Fertilizer					●
Ash (Wood, Fly)	Granular Fertilizer	●	●			
Bentonite Clay	Cat Litter Granules	●	●			●
Biomass	Biochar, Activated Carbon		●		●	
Bone Meal	Granular Fertilizer	●	●			
Calcium Carbonate	Granular Fertilizer	●	●			
Calcium Chloride	Ice Melt Pellets	●	●			
Calcium Sulfate	Granular Fertilizer	●	●		●	
Carbon Black Dust	De-dusted Pellets	●	●			
Cell Phone Batteries	Lithium, Zinc Metal Recovery				●	
Cement Kiln Dust	Granular Calcium Fertilizer	●	●			
Ceramic/Aluminum Clay	Refractory	●	●			
Clay	Proppants				●	
Clay	Cat Litter, Oil Dry Granules, Encapsulate Seeds	●	●	●		
Coal Dust	De-dusted Coal Pellets	●	●			●
Composts(Yard Waste)	Granular Fertilizer	●	●	●		
Copper Dust	Metal Recovery Pellets	●	●	●		
Corn Cobs	Cat Litter, Oil Dry Pellets	●	●	●		
Diatomaceous Earth	Filter Agent	●	●			
Dredge Sludges	Non-leaching Granules	●	●	●		
Electric Arc Furnace(EAF) Dusts	Metal Recovery	●	●	●		
Ethanol Plant Waste(DDG)	Animal Feed	●	●	●		
Foundry Dust	Metal Recovery	●	●	●		
Glass Batch	Glass Blend	●	●	●		
Gold Ore Dust	Precious Metal Recovery	●	●	●		
Grain Dust	Non-explosive Pellets	●	●	●		
Gypsum	Granular Fertilizer	●	●			
Gypsum Wallboard Waste	Granular Fertilizer, Cat Litter Pellets	●	●	●		
Humate	Granular Fertilizer	●	●	●		
Iron Ore	Metal Recovery Pellets	●	●			
Iron Oxide	Metal Recovery Pellets	●	●	●		
Kaolin Clay	Paper Coating	●	●			
Lime (Wastewater Treatment Sludge)	Granular Calcium Fertilizer	●	●	●		
Limestone	Granular Calcium Fertilizer	●	●	●		
Manure – Cattle/Chicken/Hog	Granular Fertilizer	●	●	●		
MAP Fertilizers	Granular Fertilizer	●	●	●		
Mined Frac Sand	Dried Frac Sand		●			
Municipal Wastes	Granular Fertilizer, Fuel Pellets	●	●	●		
Nickel Ore	Metal Recovery Pellets	●	●			
Nitrogen Fertilizers	Granular Fertilizer	●	●	●		
NPK Blends	Granular Fertilizer	●	●	●		●
Paper Sludge	Granular Fertilizer, Cat Litter	●	●	●		
Paper Sludge	Bright White Clay				●	
Petroleum Coke Dust	Fuel Pellets	●	●	●		●
Phosphates Powder	Granular Fertilizer	●	●	●		
Potassium Chloride	Granular Fertilizer	●	●	●		●
Raw Coal	Purified Coal				●	
Saw Dust	Cat Litter, Fuel Pellets	●	●	●		●
Soda Bottles	Recycled Plastic				●	
Soy Flour	Animal Feed	●	●	●		
Steel Dusts and Sludges	Metal Recovery Pellets	●	●	●		●
Sugar	Sugar Pellets	●	●	●		
Sulfur Dust	Non-explosive Pellets	●	●	●		
Sulfur Stack Emissions	Granular Fertilizer	●	●			●
Talc Ore	Sterilized Baby Powder				●	
Tar Sands Waste Sludge	Substitute Fuel Pellets	●	●	●		
Titanium Dioxide	Pigment Pellets	●	●			●
Titanium Metal Shavings	Metal Recovery	●	●	●		
Tungsten Oxide	Metal Recovery Pellets	●	●			●
Zinc Oxide	Metal Recovery Pellets	●	●			●

Agglomeration: Drum, Pan Pelletizer, Pin Mixer

Drying: Rotary Drum Dryer, Fluid Bed Dryer

Blending: Pug Mill

Thermal Process: Rotary Kiln

Roll Compaction: Roll Compactor

SCHEDULE A TEST

To discuss your testing needs with one of our process engineers and schedule a test, contact us today at:

FEECO.com/contact



MOISTURE REDUCTION: DRYER OR KILN?

Although rotary kilns are designed to be used for driving a chemical reaction, an issue that often comes up in the processing of a material is when to remove the excess moisture from the feedstock.

Many times, there is surface moisture that needs to be removed from the material before it is processed in a rotary kiln, and one is faced with a decision: buy another piece of equipment, or use the rotary kiln to do the work. There are costs and benefits to each approach.

While rotary kilns have the ability to remove moisture from a material, this tends to be a less efficient process. In a rotary kiln, material is typically not showered like in a rotary dryer, but rather, slides along the interior of the rotary kiln. This results in lower heat transfer between the material and the gas. Because of this, drying material in a rotary kiln takes much longer than in a rotary dryer.

The alternative to drying material in a rotary kiln is to add a rotary dryer into the process prior to the material going into the rotary kiln. Taking this approach would efficiently dry the material before it enters the rotary kiln, leaving the rotary kiln the sole job of converting the material. With a rotary dryer, flights lift the material and drop it through the stream of hot gas, creating a showering effect called a curtain. This showering effect allows for maximum heat transfer between the material and the gas, drying the material in an efficient manner.

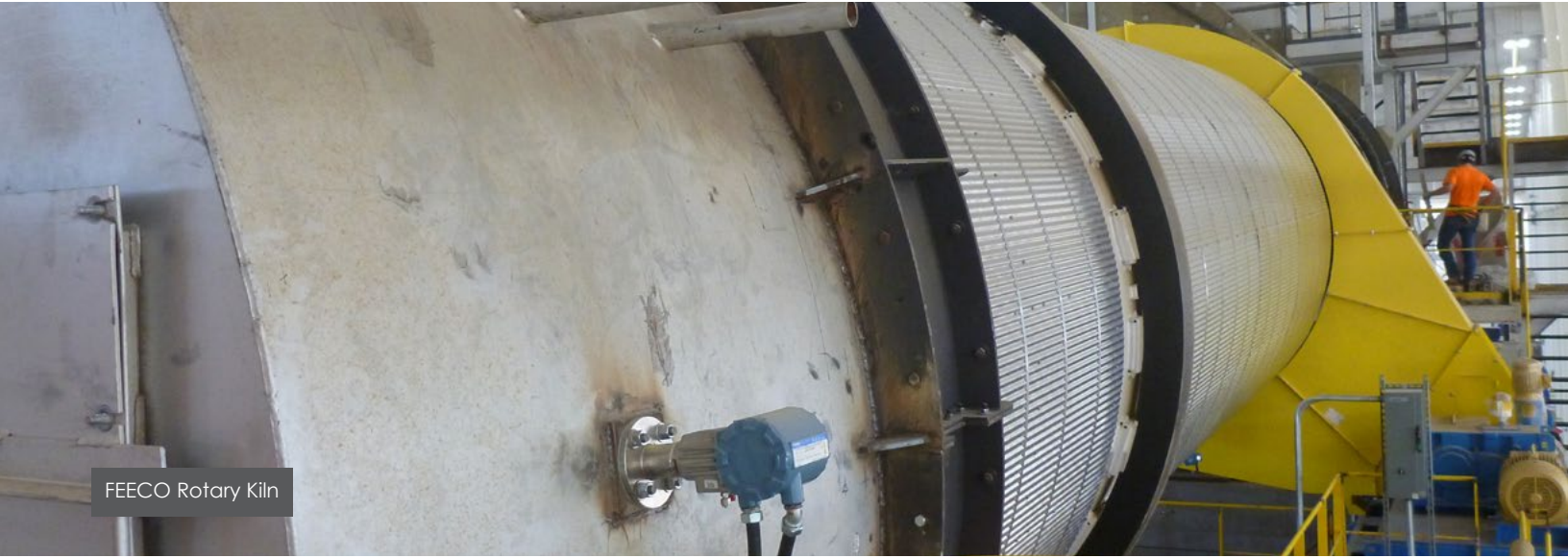
In this situation, the rotary kiln would be shorter. The down side to this method would be that an additional piece of equipment would be required. Another option is to use the kiln exhaust in a rotary dryer.

INSTALL & MAINTENANCE

INSTALLATION | DAMAGE PREVENTION | MODERN ROTARY KILN ALIGNMENT



A FEECO Customer Service Engineer inspects the refractory in a rotary kiln



FEECO Rotary Kiln

ENSURING A SMOOTH KILN INSTALLATION

A rotary kiln is a major investment and integral part of many industrial processing systems. And while a significant amount of time and research is put into finding the right rotary kiln manufacturer and engineering a solution that blends seamlessly into the process, the work continues after the purchase.

The install of a new rotary kiln requires just as much planning and attention to ensure proper installation, optimal performance, and equipment longevity.

WHY PROPER ROTARY KILN INSTALLATION IS IMPORTANT

A properly installed rotary kiln is the first step in prolonging equipment life and reducing potential downtime and maintenance. Problems that begin at install can quickly result in serious damage and downtime. A poorly installed rotary kiln can result in a variety of problems, including:

- Damage to wheels/tires from poor alignment
- Damage to drum shell because it was handled improperly
- Re-work needed and/or voided warranties because critical hold points/inspections were not done

However, there are a few simple steps you can take that will help to achieve a smooth and successful install, avoiding the problems mentioned above.

KEY STEPS FOR A SMOOTH INSTALLATION HAVE A CUSTOMER SERVICE ENGINEER ON-SITE

Having an customer service engineer or service technician from the manufacturer on-site for installation offers many benefits. The customer service engineer is well trained in the exact specifications needed for efficient installment and operation of your equipment. They know what to look for, any potential places where error could occur, and can oversee installation, assuring that things are done right, and no warranties are voided in the process.

In addition, customer service engineers are a valuable source of knowledge for answering installation and operation questions on the spot. Furthermore, they can train maintenance personnel on the ins and outs associated with the equipment during their time on-site.

PLAN AHEAD

Contacting the equipment manufacturer well ahead of the installation date to begin planning is vital to carrying out a seamless rotary kiln installation.

Ideally, the equipment purchaser, manufacturer, and installation contractor should be in contact with one another prior to installation so that everyone knows what needs to happen before install day arrives. This will help to ensure that on-site service technicians and supporting manpower will have everything they need on-site, and won't waste valuable time waiting on things that could have been prepared for. The items listed below are all things that should be considered during the planning stages of installation:

Appropriate equipment staging: In cases where the kiln is a replacement and will need to be fit into place, ensuring all ancillary equipment, such as feed chutes and/or discharge chutes are in place and pre-positioned will prevent wasted time during install. This is less of a concern when putting together a new process where equipment will be fit around the kiln, but can still be prepared for.

Materials & Equipment: Having the right materials and equipment on hand can mean the difference between a smooth install and days wasted.

Materials such as grout needed for pouring under bases, or shimming materials used in the alignment process should all be purchased and prepped for install. It's worth mentioning also, that the proper tools and equipment should be on-site as well. While most install contractors will have the right tools and equipment at their disposal, the importance of having them on-site and ready for use cannot be emphasized enough. An inadequate crane, for example, could mean that technicians have to wait for a new crane to arrive and be mobilized before work can begin.

Pre-Alignment: The installing contractor should install and pre-align the drum bases prior to kiln installation. Having the drum bases installed and pre-aligned will allow technicians to begin their work right away on installation day, instead of waiting a day or two for the pre-alignment to be completed.

All of the items above can be planned for by a simple conference between the equipment purchaser, installing contractor, and original manufacturer.

Planning for these items will help to ensure that no time is wasted on installation day and progress moves according to plan.

ALIGNMENT

Properly aligning the kiln bases and shell is an important part of installation, and can set the tone for operational efficiency and equipment longevity.

Rotary drum misalignment is one of the most common causes of drum damage and premature equipment failure, making proper alignment during install key to

operational success. More information on alignment is available on pages 40 and 44.

The proper installment of a rotary kiln is key to process efficiency, prolonging equipment life, and avoiding unnecessary downtime and maintenance. Adequate planning for installation, such as having the appropriate materials, manpower, and equipment on hand, will go a long way in assuring a smooth rotary kiln installation.

DAMAGE PREVENTION

Protecting the rotary kiln is of the utmost importance in maintaining process efficiency, prolonging equipment life, and avoiding costly repairs. If properly maintained and serviced, a high quality rotary kiln should yield very little downtime.

Due to the high heat and process reaction that occurs within a rotary kiln, there are certain wear points to monitor. The main focus points are:

- Refractory degradation or damage
- Burner maintenance or upgrade
- Worn out breeching seals
- Drum misalignment

REFRACTORY DEGRADATION OR DAMAGE

A rotary kiln relies on its refractory liner in order to operate efficiently and maintain the desired temperature within. Refractory is also what protects the shell of the kiln from the high temperatures within.

Unfortunately, refractory liners will begin to degrade over time, causing a loss in kiln efficiency. Also in some

cases, an object, such as hard material buildup, may find its way into the kiln and cause damage to the refractory. The damage may seem minimal, but can cause a material trap or cold spot, resulting in process inconsistencies. Furthermore, since the refractory is meant to absorb the heat before it can come into contact with the drum shell, any thin or damaged areas may result in heat distortion. A distorted drum shell can cause serious damage to several components and will need to be replaced as opposed to repaired. Because of the significant role that the refractory plays in protecting the kiln, routine inspections should be scheduled.

The biggest source of refractory failure is what is called *cycling*. Cycling is the heating up and cooling down of the rotary kiln. Each time the rotary kiln is heated, the refractory expands with the drum. As the rotary kiln is cooled, the refractory also retracts. If a kiln is constantly being turned on and shut down, the refractory can easily become stressed, causing cracks. Cracks can also occur from heating or cooling the kiln too quickly. It is important to try to reduce cycling as much as possible, keeping shutdowns to a minimum. Similarly, cracks can also occur from heating or cooling the kiln too quickly, which also stresses the refractory.

Another source of refractory failure is chemical incompatibility. Refractory is not designed to be able to withstand certain chemicals, for example—chlorides. Chlorides can aggressively attack refractory, causing excessive wear because of their corrosive nature. When these chemicals are identified up front, refractory can be designed to handle such aggressive corrosion.

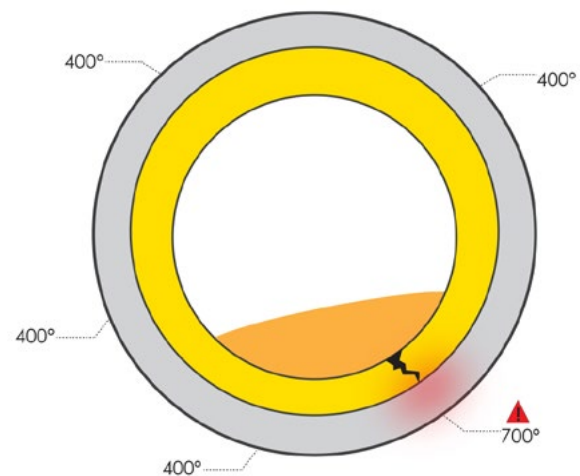


A thermal imaging tool is used to look for potential hot spots on a rotary kiln. As expected, the combustion chamber, at left, exhibits the hottest area of the kiln.

Similarly, failure can also occur when a rotary kiln is used for something the refractory was not designed for, particularly when it comes to abrasive materials. Like corrosion, refractory can be designed to combat an abrasive material, but if not prepared for in the initial design, can have devastating effects.

For these reasons, feedstock analysis is an important component in maintaining rotary kiln refractory. A change in feedstock should be accompanied by a thorough analysis to ensure minimal damage. Signs of refractory damage or failure can be difficult to recognize. And since damage can accelerate quickly, regular monitoring is critical to catching problems early. Any potential signs of damage should be addressed immediately to avoid escalation of an issue to a more severe situation.

Aside from regular inspections by a customer service engineer, one easy way to help extend the life of a rotary kiln is to check for hotspots regularly. This can be done by picking a spot on the rotary kiln shell, and



The image above illustrates a hot spot on the rotary kiln shell, indicated by an increase in temperature on the shell's exterior.

holding a temperature gun in place. As the rotary kiln rotates, that spot should be the same temperature for the entire circumference of the shell; readings of 400°, 400°, 700°, 400° would indicate a potential issue.

A hotspot on the shell of the rotary kiln indicates a failure in refractory. Left unnoticed, this could lead to severe damage to the rotary kiln shell.

In addition to circumference temperature being the same in a given location, there should be a gradual shift in temperatures from one end of the kiln to the other, not a drastic change, which could also indicate a problem.

When permissible, operators or a customer service engineer from the original equipment manufacturer should inspect the refractory from the inside of the drum to check for the start of any potential cracks or wear while the unit is shut down.

BURNER MAINTENANCE OR REPLACEMENT

While you may have selected a high quality, reliable burner, it is still possible for issues to occur. Parts such as the burner nozzle, burner cone, and burner sensors may need to be replaced for the kiln to continue operating as designed. In the case of an older rotary kiln, it may be beneficial to upgrade the burner. Burner technology is constantly progressing and a new burner may result in greater energy efficiency and material output, making for a cost-effective upgrade.

WORN OUT BREECHING SEALS

The main function of the breeching seals on a rotary kiln, no matter the style, is to prevent outside air from entering the kiln. FEECO kilns are specifically designed to funnel exhaust air along with dust to a controlled area. Similarly, the design is configured to discharge the maximum amount of process material, while still maintaining the desired internal temperature. This also means keeping cool, ambient air from entering the drum; breeching seals prevent outside air from mixing with the controlled combustion air inside of the kiln. Worn-out seals can alter this precise system, resulting in poor dust control and varying kiln temperatures.

This can lead to added plant clean-up and process inconsistencies.

DRUM MISALIGNMENT

Misalignment can occur naturally over time, or as a result of improper installation. No matter how the misalignment happened, it should be re-aligned before operation continues in order to prevent further damage. More information on rotary kiln alignment is available in the following section.

GENERAL KILN MAINTENANCE

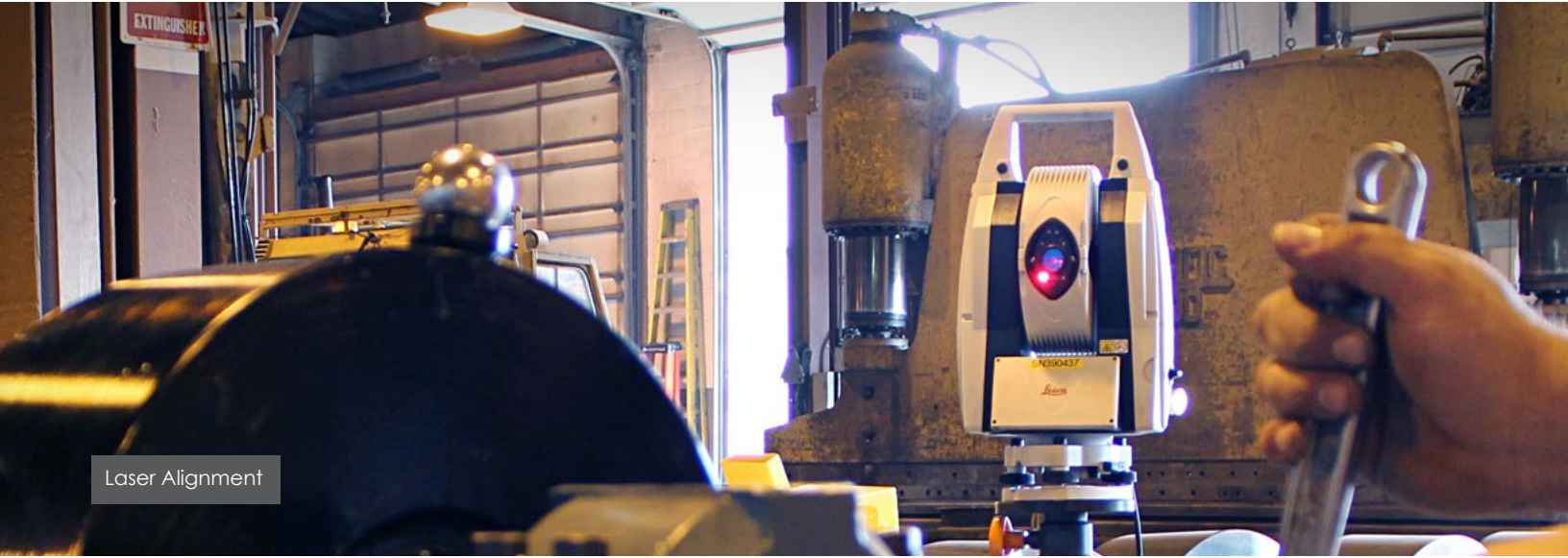
Since a rotary kiln is, in many ways, similar to other rotary drum equipment, many of the same preventive maintenance procedures apply, and should be routinely performed by the on-site maintenance staff.

This includes:

- Lubricating bearings
- Changing gear box oil
- Rechecking/Defining backlash

More extensive maintenance should be done with the assistance of a customer service engineer on-site. Depending on the manufacturer you work with, a variety of field services will likely be available to help keep your rotary kiln operating efficiently. This could include:

- Annual inspections
- [Tire and wheel grinding](#)
- Gear replacements
- Spare part installations
- Routine maintenance checks
- Training programs



Laser Alignment

The [FEECO Customer Service Team](#) offers a range of services to assist you with all of your parts and service needs, from start-up and installation support, to process and equipment audits, and even field services and custom retrofits.

A LOOK AT MODERN ROTARY KILN ALIGNMENT METHODS

As one of the most common (and most treatable) causes of rotary kiln damage, proper alignment is critical to the overall longevity of the kiln. Alignment touches all components, promoting wear on all parts. In addition to increased wear, problems have the potential to escalate into major damage and even premature equipment failure.

For this reason, in order to maintain operational efficiency and prolong the life of your rotary kiln, routinely inspecting a kiln to assess alignment should be a part of your regular maintenance program, and any alignment issues addressed promptly. And while the process of aligning a rotary kiln is not new, recent

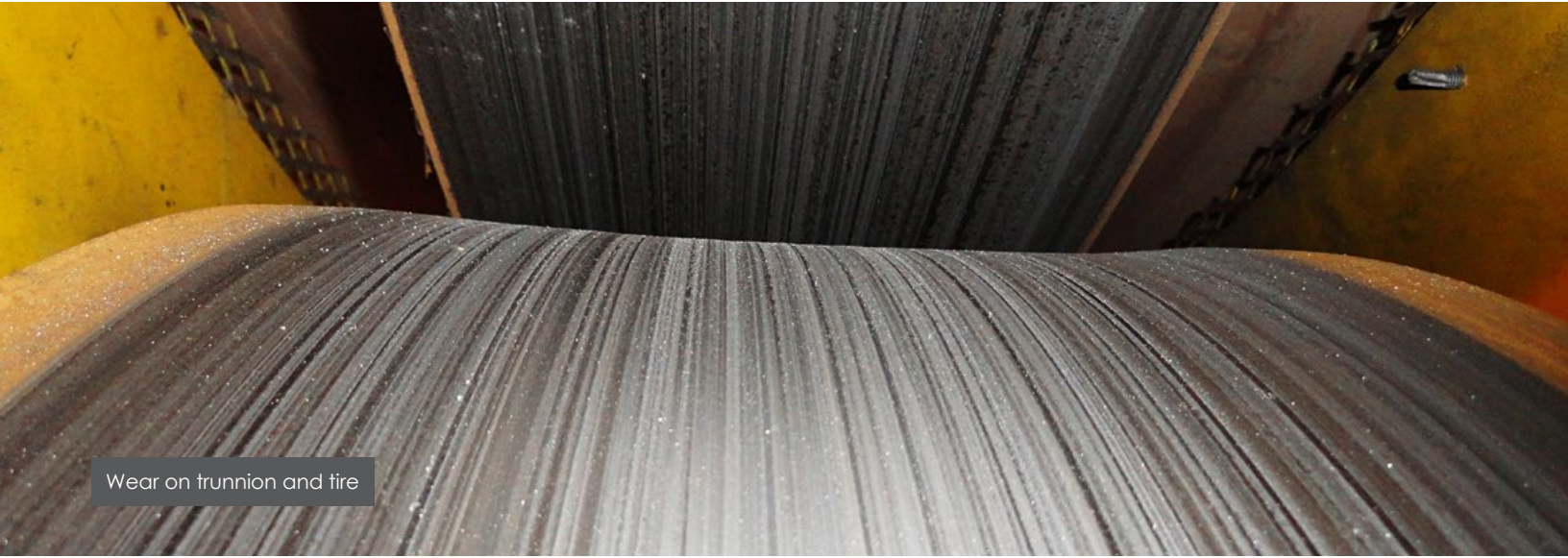
advancements have made alignments more effective than ever.

IMPROVED ROTARY KILN ALIGNMENT METHODS

Many kiln alignment methods exist on the market today. However, they all work to achieve the same goal: align the trunnion wheels with the centerline of the drum in accordance with the overall slope of the drum. This ensures that the entire load of the kiln is distributed evenly across all components, promoting balanced, efficient operation and the least amount of wear possible.

[Rotary kiln alignment](#) methods have come a long way in the recent past. The traditional method of alignment involves hand measuring various points and then using a variety of calculations to determine the adjustments needed. This process is effective, but slow, and ripe with potential for error.

Although this method is still widely used today, new laser tracking systems have taken alignments to a new



Wear on trunnion and tire

level, making precision alignment faster and more accurate than ever before possible.

Laser tracking systems use laser beams to establish a 3D spatial map of the equipment. In tandem with state-of-the-art software programs, this method of alignment offers precision results in significantly less time with greatly reduced potential for error.

WHEN KILN ALIGNMENT IS NEEDED

As mentioned, rotary kilns can fall out of alignment for a number of reasons. Kiln misalignment could be a result of structural issues such as sinking foundations, shifting steel, or processing environment issues such as the amount of humidity or even dust in the air. The myriad of reasons for which a kiln can fall out of alignment can make misalignment difficult to predict. For this reason, regular inspections should be performed by on-site personnel to catch any signs of misalignment at their onset, before they have a chance to escalate. Inspections should also be performed by the original equipment manufacturer at regular intervals, typically on an annual basis. Recording any misalignment issues

and how they were treated is best practice and can be useful in helping to predict future alignment issues and treatment methods.

As discussed, alignment is also necessary at installation. During installation, care must be taken to account for the hot kiln load; a hot kiln under operational load will behave much differently than a cold, empty kiln. Aligning a cold kiln without taking into account the thermal stresses and operational load of production conditions can result in a misaligned kiln.

Kilns should also be realigned after any major components, such as trunnion wheels, have been replaced or resurfaced, as this can cause the kiln to fall out of optimal alignment as well.

Furthermore, if process conditions have changed, the kiln may also require realignment. A change in process conditions can affect the load on the kiln; because the kiln was designed and aligned for specific operating parameters, a change in conditions will likely require realignment.

SIGNS THAT A ROTARY KILN IS OUT OF ALIGNMENT

There are many signs that can indicate when a kiln is out of alignment. It's important to note that these signs could be indicative of other issues as well, and only a trained professional can determine what the true cause is. Signs that a kiln is out of alignment can include:

- Wear after tire or trunnion surfaces have been recently repaired/resurfaced.
- Chattering or vibrational noises
- Excessive wear or damage to the tire/wheel
- Excessive wear or damage to the thrust roller
- Excessive wear or damage to the pinion/girth gear

HOW THE ROTARY KILN ALIGNMENT PROCESS WORKS

FEECO Customer Service Engineers are highly skilled in assessing and performing alignments using the latest techniques in rotary kiln alignment methods, including the use of a laser tracking system. The typical FEECO rotary kiln alignment method follows this progression:

STEP ONE: OBSERVE THE DRUM

The Customer Service Engineer will observe the drum under normal operating conditions. During this time, the engineer will examine a number of factors that can indicate the alignment of the kiln, the overall health of the kiln, and to what extent misalignment has potentially affected the system thus far. This will likely include observing:

- Auditory abnormalities such as chattering or grinding noises
- Visual abnormalities or signs of wear on shell, tires,

trunnion wheels, thrust rollers, girth gear or other drive components, etc.

- Contact points such as thrust rollers, trunnion wheels, gear mesh and grease pattern, etc.

STEP 2: SHUT DOWN THE KILN AND GATHER POSITIONING DATA

The Customer Service Engineer will then ask for the drum to be shut down in order to perform the data collection part of the process. Performing the alignment while the kiln is shut down and locked out ensures a safe working environment is established. A laser tracking unit is positioned at various points along the kiln. The tracker communicates with a base from the various positions to establish spatial coordinates and a 3D model of the kiln. Diameter and face profiles of tires and trunnions give a detailed picture of the kiln's positioning. This is all tracked and recorded using an advanced software program.

STEP 3: ANALYZE THE RESULTS

Once all measurements have been taken, the engineer can begin to analyze the results. The software program visualizes the rotary kiln and the corresponding measurements so the engineer can see exactly where and how much adjustment is needed.

STEP 4: ADJUSTMENT

Once the engineer has determined where and how much adjustment is needed, there are two options for adjust-



ment to achieve proper alignment: shimming and skewing.

Shimming involves adding “shims,” or metal plates, under trunnion bearings in order to adjust the elevation of the trunnions. Shims are available in varying heights to accommodate any amount of adjustment needed.

Skewing is carried out by moving the bearings in or out in order to align the trunnion with the centerline of the drum. Unlike shimming, this method does not require the drum or trunnion wheels to be lifted. In some situations, it may be necessary to use both techniques to achieve alignment.

STEP 5: PERFORM DRUM TRAINING TO ACHIEVE PROPER FLOAT

Float refers to the positioning of the drum between thrust rollers. Thrust rollers prevent the drum from drifting by riding on the downhill and uphill edges of the tire with little to no contact with the riding ring/tire. The thrust rollers are mounted with about ¼” of tolerance from the tire. The drum should ride evenly between the thrust rollers, not pushing harder on one than the other.

Drum training is done by skewing the trunnion bearings until proper float is achieved.

ADVANTAGES TO A FEECO KILN ALIGNMENT

In addition to our state-of-the-art laser tracking alignment system, there are a number of advantages to having a FEECO Customer Service Engineer perform the alignment on your rotary kiln:

Complete System Integration: Unlike many rotary service providers that look at components in isolation, the FEECO method of alignment looks at how the various components (trunnion wheels, bearings, thrust rollers) perform together as a whole.

Hassle-Free Alignment: While other service providers may require the surrounding support equipment to be moved, FEECO Customer Service Engineers can perform an alignment on a rotary kiln in place, because of our ability to measure coordinates around support equipment such as plumbing or electrical components.

Our system allows us to develop a spatial map of the system and supporting equipment without the hassle of having to clear the area.

Detailed Reports: FEECO also provides a detailed report of the alignment, including the state of the kiln before and after the alignment. This provides valuable benchmark data for monitoring the overall health of the kiln, as well as a starting point for future alignments.

Unmatched Rotary Kiln Expertise: Perhaps the greatest advantage to working with FEECO for your alignment needs is that we’re not just experts in alignment; we’re experts in inspecting, diagnosing, and treating all aspects of a rotary kiln. For example, you may suspect a misalignment issue, when really the damage is related to thermal expansion issues, sinking foundations, or other factors. FEECO can inspect your kiln and diagnose any mechanical or operational failures, and then resolve those issues.



FEECO Indirect Kiln

Customer Service Engineers can also perform a variety of other drum health checks while on-site, including:

- Drum Shell Ovality Checks
- Drum Shell Thickness Tests
- Coupling and Shaft Alignments
- Refractory Inspection
- Seal Inspections
- Checking Backlash
- Burner Inspection

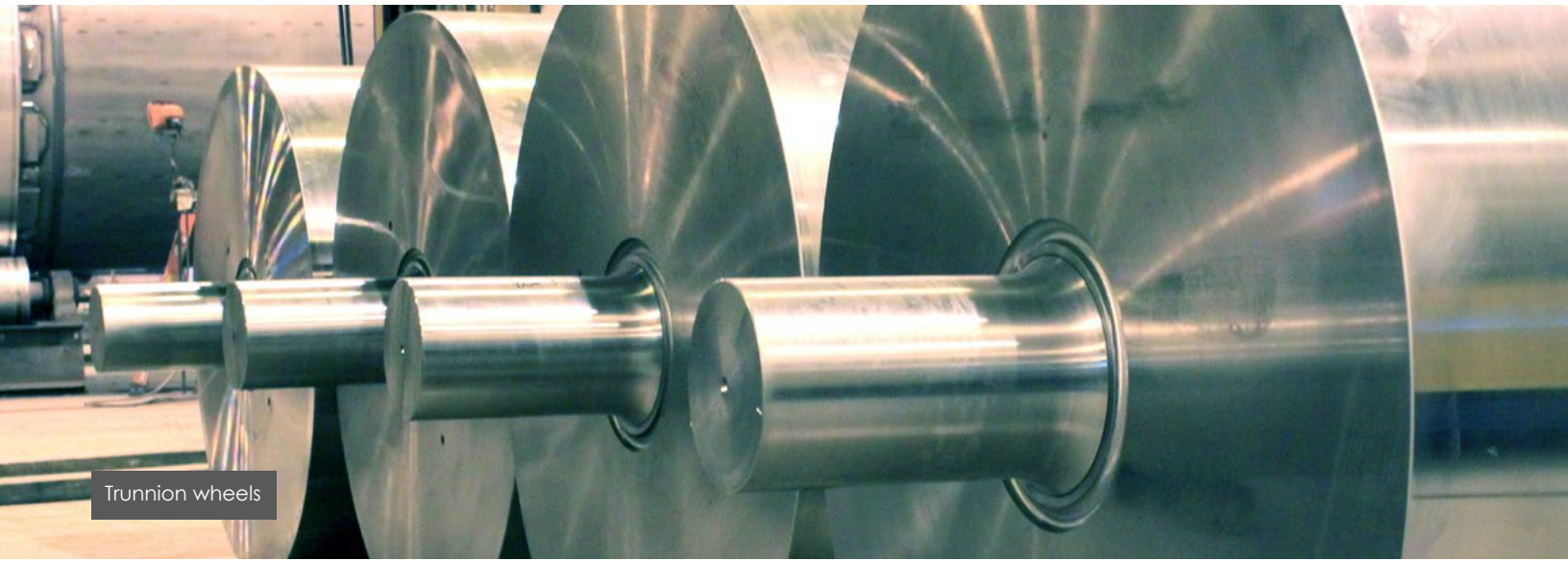
Rotary kiln alignment methods have come a long way in the recent past, making alignments faster and more precise than ever before. Routine inspections and re-alignment (in the event of misalignment) should be a part of your regular maintenance program in order to keep your kiln running efficiently for years to come. The FEECO Customer Service Team can inspect, diagnose, and treat any issues you may be experiencing with your rotary kiln, including misalignment—no matter what brand of equipment you have.

CONCLUSION

CHOOSING A MANUFACTURER | ADDITIONAL RESOURCES



Installation of a FEECO rotary Kiln



Trunnion wheels

WHAT TO LOOK FOR WHEN CHOOSING A ROTARY KILN MANUFACTURER

Rotary kilns are a significant investment in any thermal processing operation, requiring precision engineering and quality fabrication. Finding a manufacturer that can meet your unique needs can be a challenge. What follows is a guide covering some of the key factors to consider when selecting a rotary kiln manufacturer.

PROCESS DEVELOPMENT CAPABILITIES

Finding a manufacturer that can work with you to develop a process that meets your specific process and product goals is critical, because in many cases, the application is custom. It is for this reason that it is important to find a company that will work with you every step of the way during product and process development. These steps include:

- Running pilot tests on your material to gather valuable data and develop a process that

produces the exact product you're looking for.

- Providing scalability options to help develop the process to produce the quantity and quality required for full-scale production.

ADVANCED THERMAL PROCESSING KNOWLEDGE

Rotary kilns are powerful systems, requiring a precise balance of several dynamics to produce the desired product results. Selecting a manufacturer that is well versed in advanced thermal processing knowledge and experience will ensure the best results. Furthermore, without the proper engineering and design, rotary kilns do have the potential to be dangerous. Confidence in the thermal processing knowledge of the manufacturer is a must so that you can be confident that the process and the equipment will not only operate efficiently for years, but will also remain safe for continued production.

PROVEN ROTARY KILN DESIGN

A rotary kiln manufacturer with proven equipment is essential when selecting a company to design and

build your rotary kiln. The difference between proven and unproven design may not be obvious at first, but there are things you can look for to help validate their claims. One aspect to look for is a service division; this usually means that the manufacturer's equipment has been around long enough to require replacement of old worn-out components. Additionally, asking for case studies or project profiles can give you an idea of projects they've been successful with, as well as the types of applications they've worked with previously.

HIGH QUALITY FABRICATION

Quality materials and fabrication standards are crucial for a long lasting rotary kiln. Any shortcuts taken during engineering or fabrication will resonate throughout the life of the kiln, causing unnecessary downtime, process inefficiencies, and likely costly repairs or replacement.

ONGOING SUPPORT

When choosing your rotary kiln manufacturer, it is important that the company provides the necessary support for the purchased equipment in a variety of areas, including:

- Installation & Start-up
- Training (operation and routine maintenance)
- Spare Parts

A rotary kiln manufacturer should be experienced in servicing their equipment, offering a variety of services to keep your rotary kiln operating efficiently for years to come. The ability to have the original equipment manufacturer perform these services offers an advantage over kiln service companies; the original equipment manufacturer is most familiar with the operation of your unique system, and how it should best be maintained.

To ensure maximum efficiency and potential from your rotary kiln investment, select a company that will provide a high quality rotary kiln. Thermal processing knowledge, concept testing, innovative design, and high quality manufacturing all play a vital role in the production of a premium piece of equipment.

FEECO is a leader in custom thermal processing systems. We can help you develop a process around your unique project goals in our batch and pilot testing facility. We can then use the gathered data to scale up the process to full-scale production and manufacture a custom rotary kiln to suit your exact processing needs. We also offer a highly skilled Customer Service Team to assist with everything you need to keep your rotary kiln running for years of reliable performance.

ADDITIONAL RESOURCES

For further information or reading on thermal processing and rotary kilns, we have provided some additional resources below. Please note that the inclusion of any resource or company is not an endorsement and the views of that resource do not reflect those of FEECO International.

ASSOCIATIONS & PUBLICATIONS

Industrial Heating

www.industrialheating.com

American Institute of Chemical Engineers (AIChE)

www.aiche.org

Process Heating

www.process-heating.com

Heat Processing

www.heat-processing.com

BOOKS

Rotary Reactor Engineering

by Daizo Kunii and Tatsu Chisaki

ISBN-13: 978-0444530264

Rotary Kilns: Transport Phenomena and Transport Processes

by Akwasi A Boateng

ISBN-13: 978-0750678773

Perry's Chemical Engineers' Handbook, 9th Edition

by Don W. Green and Marylee Z. Southard

ISBN-13: 978-0071834087

ABOUT FEECO

FEECO International, Inc. was founded in 1951 as an engineering and equipment manufacturer. We are recognized globally as an expert in industry-leading process design, engineering capabilities (including everything from process development and sample generation, to feasibility studies and detailed plant engineering), custom equipment manufacturing, and parts and service. We serve a range of industries, including fertilizer and agriculture, mining and minerals, power/utility, paper, chemical processing, forest products, and more. As the leading manufacturer of processing and handling equipment in North America, no company in the world can move or enhance a concept from process development to production like FEECO International, Inc.

The choice to work with FEECO means a well-rounded commitment to quality. From initial feasibility testing, to engineering, manufacturing, and parts and service, we bring our passion for quality into everything we do.





For more information on rotary kilns, material testing, custom equipment,
or for help with your thermal process or problem
material, contact FEECO International today!

US Headquarters

3913 Algoma Road | Green Bay, WI 54311 USA

Phone: 920-468-1000

[FEECO.com/contact](https://www.feeeco.com/contact)