Custom Thermal Solutions for Rare Earth Recovery

Scaling from Laboratory to Production with Rotary Kiln Systems

The accelerating global demand for Rare Earth Elements (REEs), driven by applications in electric vehicles, renewable energy systems, and advanced electronics, has intensified the need for efficient extraction and recovery processes. However, conventional thermal equipment often fails under the chemically aggressive and high-temperature conditions associated with REE processing. This paper presents an overview of customized thermal solutions provided by SH Scientific, focusing on lab-scale and pilot-scale rotary kiln systems designed for rare earth recovery. Emphasis is placed on system customization, material selection, and operational adaptability in both urban mining and primary ore processing contexts.

01

Introduction

The global transition toward electrification and renewable energy technologies has significantly increased the demand for Rare Earth Elements (REEs), including Neodymium and Dysprosium. These elements are critical components in permanent magnets, batteries, and electronic devices.

In response to tightening supply chains, industries are actively developing new extraction methodologies. These include both traditional ore refinement and emerging urban mining approaches that recover REEs from electronic waste. Despite advances in chemical extraction techniques, a persistent limitation remains: standard thermal processing equipment is often unable to withstand the harsh chemical and thermal environments inherent to REE recovery processes.

To address this challenge, SH Scientific (LabandFurnace.com) provides customized rotary kiln systems designed for laboratory and pilot-scale applications, enabling reliable and continuous thermal processing under demanding conditions.

> Standard thermal processing equipment is often unable to withstand the harsh chemical and thermal environments inherent to REE recovery — driving the need for engineered, customizable solutions.

Pilot Scale Rotary Kiln — System Layout

Model: SH-FU-267RKG2400 · Engineering drawing reference

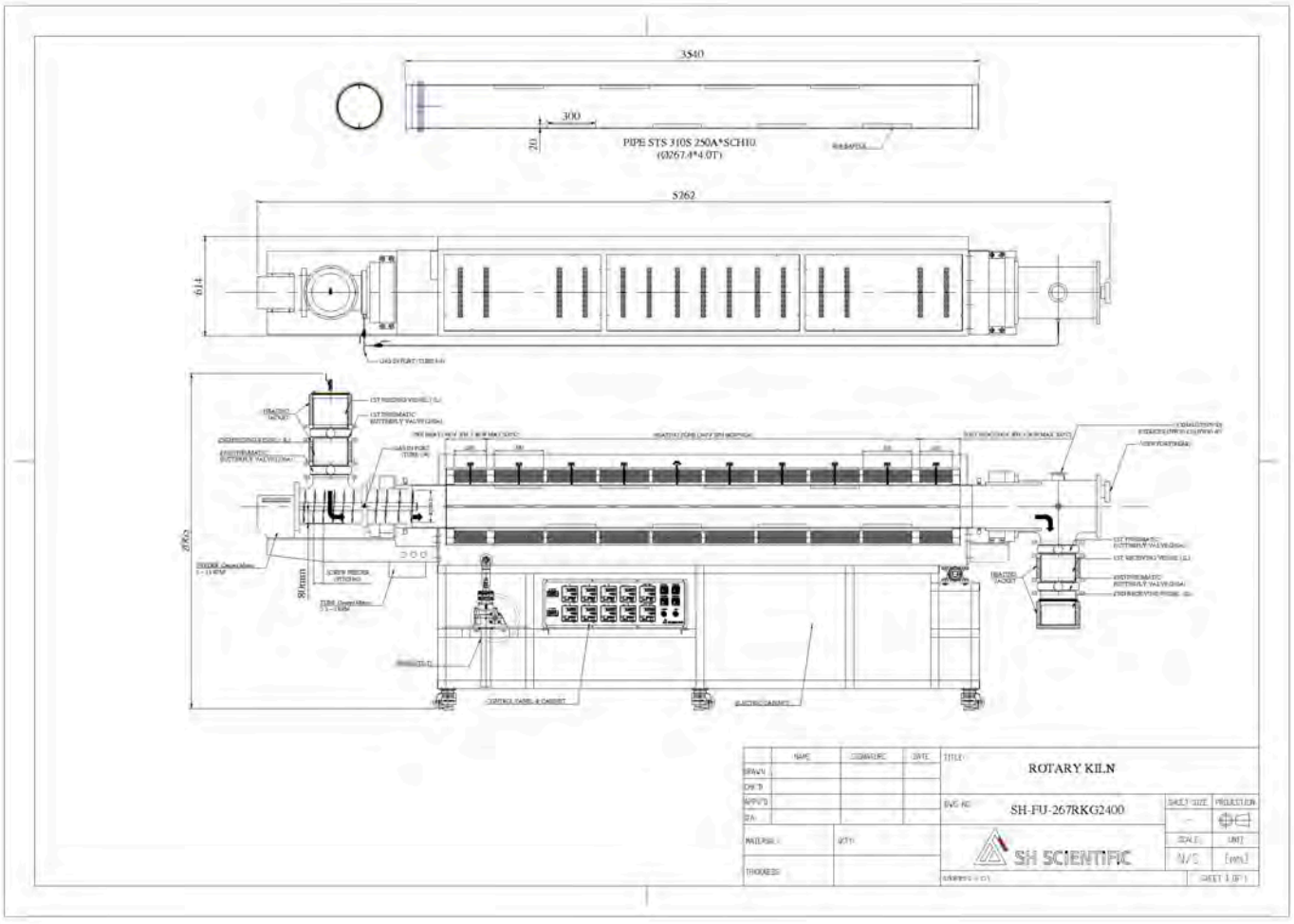


FIGURE 1

Layout of the SH-FU-267RKG2400 pilot scale rotary kiln. Key components include the dual-stage feeding vessel, screw feeder, multi-zone heating section (pre-heat / 8-zone main heating / post-heat), 267.4 mm OD STS 310S rotary tube with internal baffles, and the dual-stage receiving vessel with pneumatic butterfly valves. Total length: 5,262 mm.

02

Engineering Approach to Thermal System Design

2.1 Customization for Research and Scale-Up

The transition from laboratory-scale experimentation to pilot-scale production requires precise control over multiple process variables, including:

Production up to 50 to 100+ kg/h

Advanced Atmosphere Control

Premium Inconel & Nickel Tubes

SH Scientific adopts an engineering-partner approach, working directly with researchers and process engineers to tailor thermal systems to specific proprietary processes. Rotary kilns offered through LabandFurnace.com serve as adaptable baseline platforms that can be extensively customized.

Observation window for real-time monitoring of sample distribution

AVAILABLE CUSTOMIZATIONS

01

Multi-zone heating configurations

Precision thermal control across 2 to 16 independent zones

02

Industry Standard Stainless Steel 310S

Standard 100/120/140mm OD
Pilot-scale 167/216/267/318mm OD

03

Premium Inconel & Nickel Tubes

Standard 100/120/140mm OD
Pilot-scale 167/216/267/318mm OD

Such features enable researchers to replicate and optimize complex thermal processes with a high degree of control.

03

Application Case Studies

3.1 Urban Mining and Magnet Recycling

In the e-waste recycling sector, the recovery of REEs from end-of-life magnets presents a complex, multi-stage process. This includes:

01	02	03	04	05
Removal of nickel plating	Mechanical crushing	Solvent-based extraction	Filtration	Final calcination

The calcination stage is critical, as it converts processed materials into rare earth oxides. This process requires precise and uniform thermal conditions, typically around 900°C.

To meet these requirements, systems comparable to SH Scientific's 1200°C Rotary Tube Furnace (lab-scale rotary kiln), including models such as the 100RTG and 120RTG, are utilized. These systems provide:

- Stable and uniform temperature control
- Programmable heating segments
- Controlled atmospheric conditions

Such capabilities are essential for maximizing oxide yield and ensuring process reproducibility.

03

3.2 Primary Ore Processing (Bastnaesite Refinement)

> In contrast to urban mining, primary ore processing involves continuous high-throughput operations. For example, processing bastnaesite ore requires thermal systems capable of sustained operation at temperatures up to approximately 800°C.

A North American mineral processing facility required a robust solution capable of continuous operation under these conditions. SH Scientific delivered a system analogous to its Pilot Plant Rotary Kiln, including configurations such as the 267RTG model.

KEY FEATURES

01
2 to 16 heating zones scaling production up to 100+ kg/h

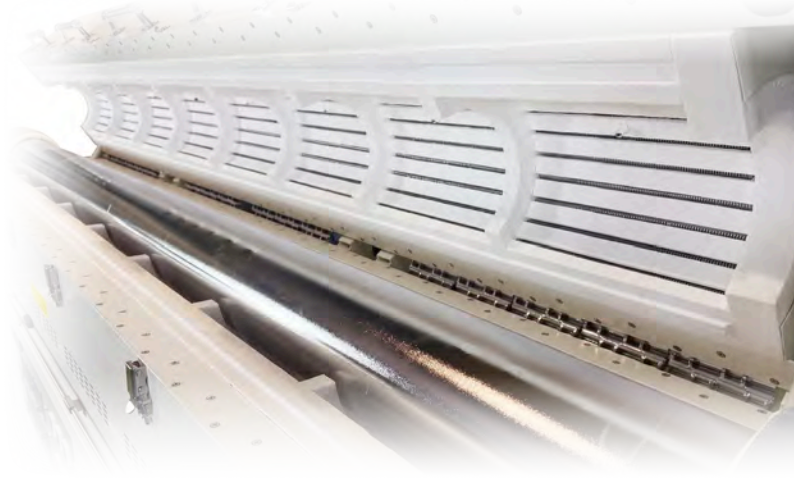
02
Maximum operating temperatures of 1000°C

03
Adjustable incline angles and rotation speeds

These features allow precise control over material residence time, optimizing yield while minimizing downtime and maintenance requirements.

04

Material Challenges in Thermal Processing



4.1 Corrosion and Thermal Fatigue

Thermal processing in REE recovery environments involves exposure to corrosive off-gassing and sustained high temperatures. These conditions frequently lead to:

- Material degradation
- Thermal fatigue
- Reduced equipment lifespan

Standard thermal equipment is often unable to withstand these combined stresses, necessitating the use of advanced materials.

4.2 Material Selection and Customization

4.2.1 · BASELINE STANDARD

Stainless Steel 310S

To address baseline requirements, Stainless Steel 310S is commonly used in SH Scientific rotary kiln systems. This material provides:

- High structural robustness
- Resistance to oxidation and corrosion
- Reliable performance in continuous operation up to 1000°C
- Standard tube in 100/120/140mm OD
- Pilot-scale tube in 167/216/267/318mm OD

For example, the 267RTG model incorporates a heavy-duty 267.4 mm outer diameter 310S tube, making it suitable for demanding pilot-scale applications.

4.2.2 · ADVANCED ALLOYS

Inconel and Nickel

For more chemically aggressive environments, standard stainless steel may not provide sufficient resistance. In such cases, SH Scientific offers custom-fabricated systems utilizing:

- Inconel & nickel-based alloy tubes
- Unparalleled resistance to chemcal attacks
- Available in lab-scale tube 100/120/140mm OD
- Pilot-scale Tube Size 167/216/267/318mm OD

These materials offer enhanced resistance to chemical attack and high-temperature degradation. Their use significantly reduces maintenance frequency, prevents structural failure, and extends equipment lifespan under severe processing conditions.

05

Integrated Role of Thermal Equipment

Thermal systems serve as a central component in rare earth processing workflows. Their performance directly impacts:

01
Process efficiency

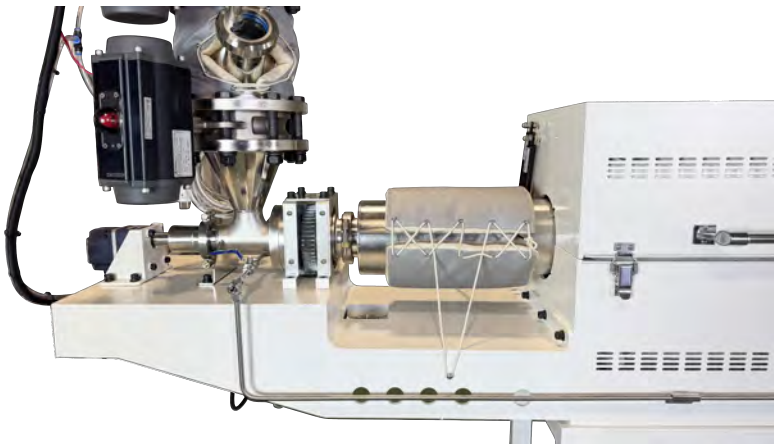
02
Product yield

03
Operational reliability

Effective system design must account for:

- Thermal stability
- Chemical compatibility
- Mechanical durability
- Process scalability

By combining customizable design with advanced material selection, SH Scientific systems enable reliable operation across both research and production environments.



06

Conclusion

The recovery and processing of Rare Earth Elements present significant thermal and material challenges that cannot be addressed using standard equipment. Customized rotary kiln systems provide a viable solution by enabling precise control over process conditions while maintaining structural integrity under harsh environments.

Through tailored system design and the use of advanced materials such as Stainless Steel 310S, Inconel, and Nickel alloys, it is possible to achieve reliable and scalable thermal processing. As demand for REEs continues to grow, such customized thermal solutions will play an increasingly important role in both urban mining and primary resource extraction.