THERMSTAR SYSTEM ™ TECHNICAL WHITE PAPER

Reliable Heat Recovery from Particulate-Laden Exhaust Airstreams

Prepared for: Mechanical Engineers, Energy Engineers, and HVAC Design Professionals

Executive Summary

Recovering thermal energy from particulate-laden exhaust airstreams has historically been one of the most challenging applications in heat recovery engineering. While conventional heat recovery technologies often perform well in clean-air applications, many experience fouling, pressure-drop increases, growing maintenance requirements, and declining performance when exposed to particulate-laden exhaust air.

The **ThermStar System**™ was developed to address these environments through the integration of Lepido® heat recovery technology, engineered thermal delivery systems, controls providing measurement & verification capabilities.

Lepido®, with forty plus patents, utilizes Particle Repellent Geometry (PRG) technology designed to maintain useful heat recovery performance and pressure-drop stability over extended operating periods in particulate-laden exhaust air streams.

The Challenge

Across facilities, large quantities of thermal energy are discharged and vented to the atmosphere through exhaust systems every day. In many of these environments, exhaust air contains particulate matter creating challenging operating conditions for traditional heat recovery systems. Combine this with high levels of humidity and traditional systems quickly fail.

As a result, the majority of these facilities have concluded that heat recovery in these applications is either impractical or uneconomic due to maintenance concerns.

Why Conventional Heat Recovery Systems Struggle or Fail

Traditional heat recovery systems are generally designed to maximize heat transfer through increased surface area.

Examples include:

- Plate heat exchangers.
- Finned-tube heat exchangers.
- High-density coil arrangements.

These approaches can perform effectively in clean-air environments. However, in particulate-laden exhaust streams, plate and fin geometries can create airflow patterns and low-pressure regions that increase the likelihood of particle contact with heat-transfer surfaces, contributing to fouling and pressure-drop growth over time.

As fouling accumulates, facilities frequently experience:

- Reduced heat transfer performance.
- Growth in air-side pressure drop.
    - Less air flow.
    - Increased fan energy consumption.
- More frequent cleaning requirements.
- Operational downtime.
- Eventual bypassing or abandonment of the heat recovery system.

Thus, for facility operators, the issue is not whether heat can be recovered on Day One. The issue is whether heat recovery can remain practical and economical after weeks and months of continuous operation in this particulate-laden environment.

A Different Design Philosophy

Lepido® represents a different heat exchanger design philosophy engineered specifically for particulate-laden exhaust streams. Rather than relying on filtration to protect heat-transfer surfaces, the design is intended to operate directly within dirty-air environments while maintaining useful heat recovery performance and pressure-drop stability over time.

To achieve these objectives, the design balances several competing engineering considerations:

- Particulate flow through capability enabled by the Particulate Repellent Geometry (PRG).
- Heat recovery performance.
- Pressure-drop stability.
- Low maintenance requirements.
- Long-term reliability.

This design philosophy is embodied in the patented Particle Repellent Geometry (PRG). PRG utilizes a staggered tube arrangement and CFD-optimized airflow paths that encourage particles to remain entrained in the airstream and pass through the heat exchanger rather than accumulating on energy-transfer surfaces.

Particle Repellent Geometry (PRG) Explained

The Lepido® heat exchanger, manufactured by Enjay Systems of Sweden with forty plus patents, utilizes the following:

- A finless tube geometry.
- Airflow passages that have been CFD optimized.
- Staggered tube arrangements.
- A greater quantity of smaller diameter and longer tubes than traditional heat exchangers providing similar amount of heat transfer surface area as traditional coils.
- Counterflow heat-transfer architecture.

As airflow accelerates around the tubes, particles are encouraged by the tube geometry to remain within the primary airflow stream rather than contacting and adhering to thermal surfaces. Enjay's engineering analysis identifies avoidance of Coandă-effect-driven surface attachment as a key contributing mechanism in this process. The objective is not filtration, instead its particle flow-through while generating high levels of heat transfer.

Field experience and case studies have demonstrated the effectiveness of this approach in maintaining useful heat recovery performance and pressure-drop stability in unfiltered particulate-laden airstreams.

Pressure-Drop Stability

In contrast to traditional designs, Lepido® has been engineered to maintain low and predictable pressure-drop characteristics over time. By minimizing particle accumulation within the heat exchanger core, airflow pathways remain substantially open, helping preserve both airflow performance and energy recovery capability. Case studies and field experience have demonstrated stable pressure-drop performance over extended operating periods.

Sensible and Latent Heat Recovery

Many particulate-laden exhaust streams contain both sensible and latent thermal energy, depending upon the relative humidity levels. When operating conditions permit condensation to form on the heat recovery coil, Lepido® can recover both:

- Sensible heat from the exhaust and,
- Latent heat from moisture going through a phase change becoming condensate.

In applications with moisture laden airstreams, latent energy recovery can represent a significant portion of total recovered energy. As a result, total recovered energy exceeds what would be predicted through dry-temperature recovery analysis.

Design Summary

Lepido® was engineered to balance particle flow-through capability, pressure-drop stability, and useful heat recovery performance within particulate-laden exhaust airstreams. Its air channels between tubes are open enough to allow most particles to pass through the heat exchanger, while the quantity and geometry of the tubes provide the heat-transfer surface area required for effective energy recovery.

ThermStar System ™ Architecture

The **ThermStar System**™ integrates multiple components into a complete engineered heat recovery platform that is then installed by your contracting partners.

Components within the overall system typically include:

- Lepido® heat recovery unit,
- **HeatCore HX**™ thermal delivery coil(s),
- Hydronic run-around liquid loop containing a mix of polypropylene glycol and water OR high temperature fluids,
- Circulation pump,
- Controls and automation,
- **ThermStar**™ **Power Intelligence** SaaS monitoring platform.

The system is designed to convert:

Available Heat
↓
Recovered Heat
↓
Delivered Heat
↓
Fuel Savings (Energy cost and Scope 1 carbon emission reductions)

Simulation Tools

As part of our service offerings to owners, engineering firms and partner companies, **ThermStar**™ has a robust and proven heat recovery simulation tool kit. **ThermStar**™ evaluates each application by matching the thermal energy available within the exhaust stream (source) to a specific heat utilization point (sink). Simulations consider exhaust airflow, temperature, humidity, operating schedules, pressure-drop characteristics, and thermal delivery requirements to estimate recoverable energy, fuel savings, and system performance.

Maintenance Considerations

Typical maintenance activities may include:

- Visual inspections.
- Differential pressure monitoring in the provided SaaS system.
- Periodic cleaning using established duct-cleaning and coil cleaning practices (no chloride-based cleaners).
- Inspection of drains and piping connections.
- Glycol solution typical hydronic heating system testing and maintenance.

In many applications, cleaning schedules remain consistent with existing ventilation-system maintenance requirements and require less than one hour of time every 90 days.

Field Proven Experience

Lepido® technology has been deployed in more than two hundred (200) installations, and growing, in Europe. Active deployments are underway across North America across a broad range of commercial and industrial sectors.

Applications have included:

- Food Services,
- Industrial laundries,
- Food and beverage production facilities,
- Manufacturing environments including paint operations, synthetic turf production, and other thermal process applications.

Field experience has demonstrated:

- Consistent heat recovery performance over prolonged time periods.
- Minimal and stable pressure-drop characteristics over extended operating intervals.
- Reliable operations with predictable maintenance requirements.

Conclusion

Lepido®'s Particle Repellent Geometry represents a distinct and intentional engineering approach—one focused on particulate flow-through management, pressure-drop stability, and long-term useful heat recovery. By integrating Lepido® technology with engineered delivery systems, controls, and measurement & verification capabilities, **ThermStar System**™ enables facilities to reclaim thermal energy that has traditionally been considered inaccessible. This recovered energy can then be quantified and delivered to beneficial uses within the facility resulting in reduced operating costs, fuel consumption, and associated Scope 1 emissions.