EWA TECHNOLOGIES GROUP

Saving the environment

Aluminum Recycling - Technologies Comparison Opinion:

ROTARY FURNACE VS. INDUCTION REACTOR

Please find attached our professional opinion regarding a proposed process and production line for recycling scrap aluminum, with a specific focus on material recovered from the aerospace industry.

Relevant references supporting this opinion are listed at the end of the document.

1. INTRODUCTION: RECYCLED ALUMINUM FOR AEROSPACE SUITABILITY

1. Aluminum Alloy Compatibility

- Most scrap aluminum, including beverage cans and aluminum brackets are made from **AA3004 or AA3104** (body) and **AA5182** (lid), which are **different standard** than aluminum used for aerospace.
- Aerospace alloys (e.g., **AA2024, AA7075, AA6061**) have superior strength, fatigue resistance, and corrosion resistance.

2. Purity & Contamination Risks

- Recycled aluminum from cans and other civil uses may contain impurities (e.g., coatings, inks, iron, or magnesium-silicon variations).
- Aerospace requires **high-purity aluminum** with strict control over trace elements. On the second hand, Aerospace requires aluminum-based alloy that containing elements the strangest the ally and reduce corrosion or reactivity of the aluminum.

3. Certification & Processing

- Even if recycled aluminum is re-alloyed into aerospace-grade material, it must undergo:

- **Refining** (remove impurities)
- **Re-alloying** (meet aerospace-grade compositions)
- **Rigorous testing** (mechanical properties, fatigue, fracture toughness)

4. Current Use in Aerospace

- Some **recovered aluminum** (from recycled sources) is used in **non-critical** aerospace components (e.g., interior panels and brackets).
- **Primary (virgin) aluminum** is still preferred for **structural components** (e.g., fuselage, wings).

Conclusion

*While recycled aluminum from scrap cans be refined and re-alloyed for aerospace use, it is **not directly suitable** without extensive processing. The aerospace industry prioritizes **high-performance alloys with guaranteed properties**, so most recycled can aluminum is instead used in automotive, packaging, or consumer goods.*

Table 1 - Summary of comparison table between aerospace-grade aluminum alloys and beverage can aluminum alloys:

Property	Aerospace Aluminum (AA2024, AA7075, AA6061)	Beverage Can Aluminum (AA3004, AA3104, AA5182)
Primary Use	Aircraft structures (fuselage, wings, frames)	Beverage cans (body & lid)
Alloy Series	2xxx (Al-Cu), 6xxx (Al-Mg-Si), 7xxx (Al-Zn)	3xxx (Al-Mn), 5xxx (Al-Mg)
Strength	Very high (e.g., AA7075-T6: ~570 MPa)	Moderate (AA3004-H19: ~250-300 MPa)
Corrosion Resistance	Good (with protective treatments/cladding)	Excellent (due to Mn/Mg content)
Formability	Moderate (requires specialized forming)	Very high (optimized for deep drawing)
Fatigue Resistance	Excellent (critical for aircraft longevity)	Moderate (not designed for cyclic loads)
Thermal Stability	High (retains strength at elevated temps)	Lower (not designed for high-temp applications)
Typical Impurities	Tightly controlled (low Fe, Si, Cu variations)	May contain coatings, inks, and trace contaminants
Recyclability	Yes, but requires rigorous reprocessing	Highly recyclable (but not directly aerospace-suitable)
Cost	High (due to alloying elements & processing)	Low (mass-produced for packaging)
Certification Standards	AMS, ASTM, NADCAP (strict aerospace specs)	Food-grade (FDA, non-structural use)

Summary:

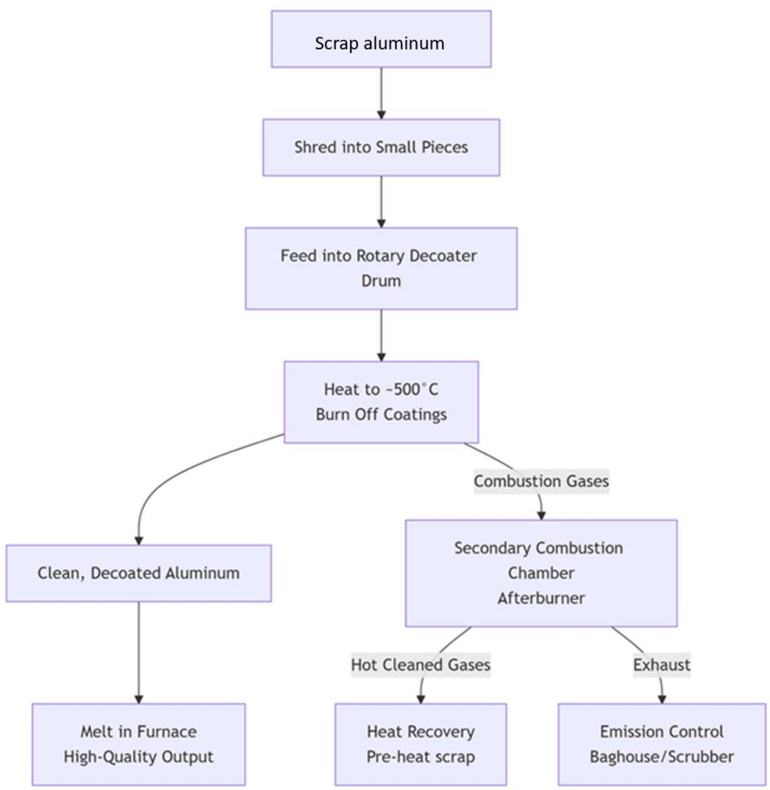
1. **Aerospace alloys** prioritize **strength, fatigue resistance, and reliability** - recycled can aluminum would need extensive refining and re-alloying to meet these standards.

2. **Can aluminum** is optimized for **low-cost formability and corrosion resistance** but lacks the mechanical properties needed for aircraft structures.

3. **Recycling feasibility:** While possible, converting can scrap into aerospace-grade aluminum is **rarely cost-effective** compared to primary aluminum production.

2. SCRAP ALUMINUM RECOVERY PROCESS

General process from recover (recycling) scrap aluminum



Comments:

- Shredding of scrap cans is not necessary and not recommended due to the power consumption. However, when using continuous **Rotary Furnace** for melting, shredding is necessary.
- Compressing the material to **bales** prior melting is recommended, mainly when using Induction reactor.

- Iron magnetic sorting after shredding or prior melting (in case that shredding is not performed) is recommended.
- The rotary furnace must be equipped with a sophisticated **APC** system (afterburner + baghouse + scrubber) **Emission Control system,** this is a **non-negotiable requirement** for environmental compliance. For inductive reactor there is not such demand.

3. SELECTION OF MELTING REACTOR

The heart of the process is the melting reactor.

Table 2 - Comparison Summary

System type	Efficiency	Scrap Flexibility	Scale	Environmental Impact	Cost
Reverberatory	Low	High	Large	Moderate–High	Medium
Rotary	Medium	Very High	Medium	Very High (salt slag)	High
Induction	High	Low–Medium	Small–Med	Low	High
Crucible	Low	Low	Small	Low–Moderate	Low
Shaft	High	Medium	Medium–Large	Low	High

Table 3- Comparison: Induction vs. Rotary Furnace for Aerospace Aluminum Recycling

Parameter	Induction Furnace	Rotary Furnace
Principle	Electromagnetic heating (eddy currents)	Gas/fuel-fired, rotating drum for mixing
Temperature Control	**Precise** (±5°C), rapid heating/cooling	**Less precise** (thermal inertia, slower)
Contamination Risk	**Low** (no direct combustion, inert gas possible)	**Higher** (flux/salt required, risk of oxidation)
Alloy Homogeneity	**Excellent** (EM stirring ensures uniformity)	**Variable** (depends on rotation/flux)
Energy Efficiency	**High** (80-90% thermal efficiency)	**Moderate** (50-70%, heat losses via exhaust)
Mg/Zn Retention	**Good** (closed systems reduce evaporation)	**Poor** (high Mg/Zn loss due to oxidation)
Oxide Formation	**Low** (reduced exposure to air)	**High** (requires salt flux to minimize)

Parameter	Induction Furnace	Rotary Furnace
Reliability	**High** (minimal moving parts)	**Medium-low** (complicate, heavy mechanic)
Capital Cost	**High** (complex electronics)	**Lower** (simpler design)
Best For	**High-purity alloys**, critical aerospace parts	**Heavily contaminated scrap**, bulk recycling

4. EMISSION CONTROL

Melting process of scrap aluminum not involve emission, unless the scrap aluminum is panted or coated. Induction melting furnaces generate virtually no *combustion process emissions* because they are not heated by burning fuel. However, they can still produce significant *fugitive emissions* from the materials being melted.

There are mainly 3 sources of emission in the entire aluminum recycling system: 1. Decoating process; 2. Heating of the melting reactor; 3. Oxidation of impurities upon melting process.

The Core Reason: The Heating Mechanism

This is the most critical point. An induction furnace works like an **electric transformer**:

- **Power Source:** It uses electricity to generate an alternating magnetic field.
- **Induced Current:** This magnetic field induces powerful electrical currents **within the metal charge itself** (the scrap or alloy).
- **Resistance Heating:** The electrical resistance of the metal to these currents causes it to heat up from within, melting itself.

Why this leads to "no combustion emissions":
There is no flame, no burner, and no fuel (natural gas, oil, propane) being burned to create heat. Therefore, there are zero emissions from fuel combustion. **This means no:**

- Nitrogen Oxides (NOx)
- Sulfur Oxides (SOx)
- Carbon Monoxide (CO) from fuel
- Particulate Matter (PM) from fuel
- Carbon Dioxide (CO_2) from the energy source*

***Note on CO_2:** While the furnace itself produces no CO_2, the *power plant* generating the electricity might. This is known as an "indirect emission" and is a separate consideration from direct furnace emissions.

2. The Critical Caveat: Emissions from the Charge Material

While the *heating method* is clean, the *materials being melted* are not. This is where emissions can and do occur. These are called **"fugitive emissions"** or "process emissions."

If you melt scrap metal (like aluminum cans with paint, or dirty iron castings with oil and sand) in an induction furnace, the heat will cause any contaminants on or in the metal to volatilize or burn. This can create:

- **Volatile Organic Compounds (VOCs):** From oils, greases, paints, and plastics.
- **Particulate Matter (PM):** Smoke, soot, and fine dust from burning organics and inorganic coatings.
- **Metallic Fumes:** For metals with low vaporization points (e.g., zinc from galvanized steel, magnesium from certain aluminum alloys), the metal itself can vaporize and then oxidize into fine fumes.
- **Dioxins/Furans:** Can form under certain conditions from the combustion of chlorinated compounds (e.g., PVC plastic).

Key Point: These emissions are a function of the **charge material's cleanliness**, **not the furnace type**. A dirty charge will create emissions in any furnace, induction, rotary, or reverberatory.

By decoating process of the scrap aluminum prior melting, this emission is totally eliminated.

3. Why Induction Furnaces Have a "Low-Emission" Reputation

The confusion arises because induction furnaces are almost always used with **clean charge material**.

1. **Charge Quality:** Induction furnaces are typically used for:
   - Melting precisely controlled alloys in a foundry.
   - Using pre-treated, high-quality scrap.
   - Re-melting clean ingots.
     Because the heating is internal, any non-conductive material (like paint, plastic, or moisture) doesn't get heated effectively and can cause operational problems (like explosions from steam). This naturally incentivizes operators to use clean, dry charge.

2. **Contrast with Fuel-Fired Furnaces:** A rotary furnace, for example, is specifically designed to melt the dirtiest, most contaminated scrap (e.g., entire aluminum with coating, paint and plastic liners). It has a roaring gas flame that directly impinges on the charge, violently burning off the contaminants and creating massive volumes of combustion products *in addition to* the emissions from the charge. **The induction furnace avoids the entire category of emissions from that roaring flame.**

3. **Emission collection system**

   The induction furnace system is equipped with a smoke collector connected to a scrubber. The scrubber is designed to treat any potentially harmful emissions. This system was designed to ensure **zero emissions**.

4. **Why Induction Furnaces Are Cleaner than Rotary furnace**

   Induction Furnaces

   ✅ **No Direct Combustion** – Uses electricity (can be renewable).
   ✅ **Closed System** – Reduces oxidation and particulate release.
   ✅ **Precise Control** – Less overheating = fewer NO_x/SO_x risks.
   ✅ **No Flux Required** – Avoids fluoride/salt emissions.

   Rotary Furnaces

   ❌ **Fuel-Dependent** – Natural gas/diesel = CO_2, NO_x, SO_x.
   ❌ **Open Melting** – More dross, oxidation, and PM.
   ❌ **Flux Required** – Salt fluxes release HF and chlorides.
   ❌ **Burns Contaminants** – Coatings/labels create dioxins.

Table 4 - Summary: Induction vs. Fuel-Fired Furnace Emissions

Emission Type	Induction Furnace	Fuel-Fired Rotary Furnace
Combustion Emissions (from the heat source)	**None** (uses electricity)	**Very High** (NOx, SOx, CO, CO_2 from fuel)
Process Emissions (from the scrap itself)	**Low to Moderate** (but only if charge is dirty)	**Very High** (the furnace is designed to burn off dirty charge)
Typical Use Case	Melting clean(er) charge, precision alloys	Melting heavily contaminated scrap (e.g., UBCs)
Total Direct Emissions	**Very Low** (when used with clean charge)	**Very High** (requires massive pollution control systems)

Conclusion:

*An induction furnace produces **no direct combustion emissions** because it uses electricity, not fire, to create heat. Its "emissions" are solely dependent on the cleanliness of the metal being melted.*

*It is this combination of an inherently clean heating process and its typical use with clean raw materials that gives induction melting its deserved reputation as a **low-emission metallurgical process**. In order to prevent potential emission, the reactor equipped with gas absorption and treatment system.*


5. SUMMARY AND RECOMMENDATION

This document's primary goal is to evaluate the two leading technologies for recycling scrap aluminum by presenting their respective advantages and disadvantages. The objective is not to declare one technology as universally "good" or "bad", both are capable of valorizing scrap aluminum, but rather to identify the optimal choice based on specific criteria.

Fuel-Fired Melting (The Traditional Method)

- This is the old, well-known way to melt metal.
- It can use many types of fuel (like gas, oil, or even biomass).
- The type of fuel doesn't change the quality of the final aluminum. However, the choice of fuel is very important today because it environment foot-print, and the need to mitigate **carbon dioxide and other harmful emission** to comply the new regulation.
- Fire heating means energy loss and **expensive emission-controlling equipment**.

2. Induction Melting (The Modern Method)

- This method uses electric field to create heat, meaning clean process with minimal energy loss.
- The way the furnace heats the metal, **without open fire**, is the biggest difference.
- This heating method controls the quality of the recycled aluminum, eliminate oxidation and sludge, optimized energy use, and significantly reduce maintenance costs, in terms of service, energy consumption (no loss of heat), lack of need for expensive facilities Emissions treatment.

Fuel-fired melting or Rotary Furnace is a traditional technology, with a history **as long as human use of copper and iron**. From a purely metallurgical perspective, the specific fuel source, be it biomass, fossil oil, synthetic oil, or gas, is largely irrelevant to the final metal quality. However, in our modern context, where environmental impact is a paramount concern, the choice of energy source transcends mere economics; it is a critical decision affecting global sustainability and quality of life.

The heating mechanism, specifically, the combination of furnace type and heating mode, is critical. It directly determines the quality of the recycled product (primarily its homogeneity), operational costs, and maintenance requirements.
Considering the input parameters, most of which are **outlined in Table 3**, the analysis strongly suggests the superiority of **inductive technology over the traditional Fuel-Fired**

Rotary Furnace

The **Fuel-Fired Rotary Furnace** is a well-established, low-capital-cost technology. However, to use an analogy: ***a rotary furnace is like a diesel generator in your backyard, its exhaust is immediately***

visible and detectable. In contrast, an Induction Furnace is comparable to a silent, clean electric vehicle.

Furthermore, while an **induction reactor can reliably process scrap aerospace aluminum back to raw material meeting aerospace standards**, the same level of quality assurance and recovery purity **cannot be confidently guaranteed** with a rotary reactor system.

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5. References

1. General Aluminum Recycling & Aerospace Material Standards:

- **ASM Handbook, Volume 2A: Aluminum Science and Technology:** ASM International. (2018). *Aluminum Science and Technology*. ASM Handbook, Vol. 2A.

  Summary: *The definitive guide on aluminum production, alloy families, processing, and recycling. It covers the metallurgical principles behind melting, impurity control, and the impact on mechanical properties.*

- **Aerospace Material Specifications (AMS): SAE International. (Various).** Aerospace Material Specifications (AMS). e.g., AMS 2772 (Heat Treatment of Aluminum Alloys), AMS 4025 (Aluminum Alloy 2024 Sheet and Plate).

  Summary: *These standards dictate the strict chemical composition, mechanical property, and quality assurance requirements that any aluminum alloy must meet for use in aerospace applications, whether from primary or recycled sources.*

2. Melting Technologies & Process Comparisons

- **Schmitz, C. (2014). Handbook of Aluminum Recycling.**

  Summary: *A comprehensive resource dedicated to all aspects of aluminum recycling. It contains detailed chapters on the design, operation, and efficiency of different furnace types, including direct comparisons between induction and rotary furnaces, their energy consumption, and melt loss figures.*

- **Kvithyld, A., et al. (2008). "Recycling of New Generation Aluminium Alloys". TMS (The Minerals, Metals & Materials Society).**

  Summary: *Discusses the specific challenges of recycling high-performance alloys (like 2xxx and 7xxx series), including the loss of magnesium and zinc and the need for precise melt control to maintain alloy integrity.*

3. Environmental Impact & Emissions Data

- **International Aluminum Institute (IAI).** IAI. (2023). *Life Cycle Inventory Data and Environmental Metrics for the Primary Aluminum Industry* and *Global Recycling Data*.

  Summary: *The IAI is the foremost authority on global aluminum production data. They publish extensive life-cycle assessment (LCA) data, including the energy consumption and greenhouse gas emissions for both primary production and recycling routes. Their data is the source for the common statistic that recycling saves ~95% of the energy compared to primary production.*

- **European Environment Agency (EEA): EEA. (2021). EMEP/EEA Air Pollutant Emission Inventory Guidebook - Chapter on Metal Production.**

  Summary: *Provides detailed emission factors (e.g., kg of NOx/ton of aluminum melted) for different industrial processes, including various types of aluminum melting and holding furnaces. This is a key source for comparing the emission profiles of different technologies.*

4. Aerospace-Specific Recycling & Quality Control

- **Boysen, B., & Schreyer, T. (2019). "Closed-Loop Recycling of Aerospace Aluminum Alloys". Light Metal Age.**

  Summary: *Industry trade journals like Light Metal Age often feature case studies from major manufacturers (Alcoa, Constellium) on their closed-loop recycling initiatives for aerospace scrap, highlighting the technologies and quality control measures used*.

- **NADCAP (National Aerospace and Defense Contractors Accreditation Program)**

  Summary: *While not a public reference, NADCAP audits and accredits special processes like heat treating and chemical processing. Their stringent requirements drive the need for high-purity, well-controlled melting practices in the aerospace supply chain, making induction furnaces the preferred choice.*

5. Technical Papers on Furnace Technology

- **Rudnicki, J., et al. (2001). "Electromagnetic Stirring in Induction Furnaces for Aluminum Melting". Journal of Materials Processing Technology.**

  Summary: Academic papers delve into the advantages of electromagnetic stirring in induction furnaces, which is critical for achieving the chemical homogeneity required in aerospace alloys.