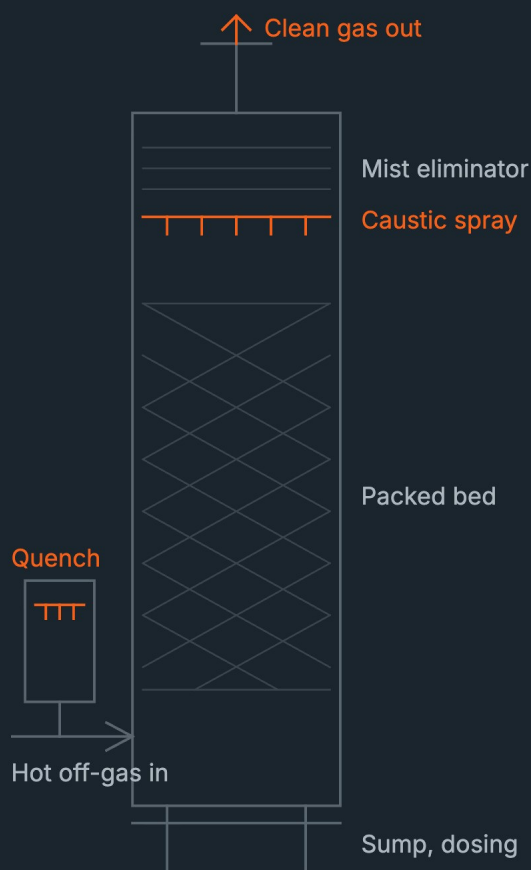


FREE TECHNICAL GUIDE

Off-gas treatment for battery recycling: a guide for pilot plant engineers

What each process stage emits, how to size a quench and caustic scrubber, materials that survive HF, and the data your permit will ask for.



For
Process and pilot
plant engineers

And
EHS and
permitting leads

Covers
Shredding,
pyrolysis,
leaching



Design the off-gas with the process, not after it

Battery recycling off-gas causes trouble for predictable reasons. The scrubber was sized for one stage and the pilot runs another. Hot, fluorine-rich gas meets a plastic tower with no quench. A caustic scrubber is expected to remove solvent vapour it cannot touch. Or the permit asks for figures the pilot never logged. This guide takes each in turn.

Who it is for

Process and pilot plant engineers specifying off-gas treatment for lithium-ion battery shredding, pyrolysis and hydrometallurgical lines, and the EHS leads who sign off the permit.

How to use it

Read it before you fix the pilot layout or ask for quotes. The checklist on page 8 lists the data a supplier needs to size a package properly.

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FIVE THINGS TO GET RIGHT

- 1 Treat each stage as its own duty.** Shredding, pyrolysis and leaching emit different gases.
- 2 Assume fluorine is present.** It comes from the electrolyte salt and the binder.
- 3 Quench before plastic.** Hot gas goes nowhere near a thermoplastic tower until it is cooled.
- 4 Organics need an oxidiser.** A caustic scrubber removes acid gases, not solvent vapour.
- 5 Log the pilot.** Measured data is what sizes the commercial plant and fills the permit.

01 Every route through a lithium-ion cell makes acid gas

The mix changes with the stage, the cell chemistry and the state of charge. Treat these as starting points for a design conversation, then confirm them against your own measurements.

Discharge and shredding

GAS, VAPOUR, DUST

In the gas. Electrolyte solvent vapour (carbonates such as DMC, EMC and EC), HF as LiPF₆ meets moisture, and fine particulate from the shredder.

Design. Particulate capture upstream, then a caustic packed tower for the acid gases. Solvent vapour needs its own stage, and may make the atmosphere ATEX zoned.

Pyrolysis

HOT, FLUORINE-RICH

In the gas. Heating shred or black mass drives off binder and electrolyte: HF and other fluorine species such as POF₃ and PF₅, fluorinated organics and CO.

Design. Thermal oxidiser for the organics, then quench, caustic packed tower, mist eliminator and fan. The most common enquiry we see.

Leaching

MIST AND REAGENT GAS

In the gas. Leach, precipitation and solvent extraction tanks vent acid mist continuously, plus SO₂, NO_x or HCl and chlorine depending on the lixiviant and reductant.

Design. Packed tower or multi-stage scrubber with pH and ORP dosing, and mist elimination sized for the droplets.

Black mass handling

MAINLY DUST

In the gas. Fine metal-bearing dust from drying, sieving and transfer, with residual electrolyte if the material was not fully treated.

Design. A dust filter first. A scrubber only where acid gas or residual vapour is also present.

WHERE THE FLUORINE COMES FROM

Researchers at the University of Birmingham, writing for IOM3, identify two main sources: the PVDF binder and the LiPF₆ electrolyte salt. LiPF₆ can hydrolyse to HF in moisture during disassembly, and both decompose to fluorocarbons and HF at high temperature, needing additional off-gas treatment.

KEEP APART

Do not combine stages into one scrubber until their chemistries are checked. Leach vents carrying chlorine or reductant gases, and solvent-laden shredder extract, can each make a shared sump unsafe or ineffective.

02 Sizing a quench and caustic scrubber

Behind a pyrolysis furnace and thermal oxidiser, the usual train is quench, caustic packed tower, mist eliminator and fan. Each element is sized for a different reason.

IN Hot off-gas From your oxidiser	01 Quench Cools and saturates	02 Caustic tower Absorbs HF and acids	03 Mist eliminator Stops carry-over	OUT Fan to stack Within your limit
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ELEMENT	WHAT SIZES IT	WATCH FOR
Quench	Inlet temperature and flow; cools the gas to a temperature the plastics downstream can tolerate	The quench itself sees the hottest gas; water supply must be secure, with a trip if it fails
Packed tower	Gas flow sets the diameter; inlet load and outlet target set the bed depth and liquor rate	Even liquor distribution; peak flows during furnace start-up and purges, not just steady state
Caustic liquor	NaOH dosed to a pH setpoint; HF forms sodium fluoride in solution	Fluoride forms insoluble salts with calcium, so hard make-up water can scale packing; consider softened water
Bleed	Salt build-up in the sump	Fluoride-bearing effluent: plan its treatment or disposal route from day one
Mist eliminator	Droplet size leaving the tower	Fouled pads cause carry-over that counts as emission at the stack test
Fan	Pressure drop of the whole train, plus the draught your process needs	Wetted parts in suitable plastic; position relative to the tower affects leaks

HONEST SCOPE

A caustic scrubber removes acid gases such as HF. It will not destroy solvent vapour, fluorinated organics or carbon monoxide. Those need a thermal oxidiser upstream, or a carbon stage where loads are low.

03

HF decides the materials. Temperature decides which plastic.

Hydrogen fluoride attacks glass, silica and silicate-based materials, so anything common elsewhere in process plant has to be checked before it goes in the wetted path.

MATERIAL	IN BATTERY RECYCLING OFF-GAS SERVICE
Polypropylene (PP)	The workhorse for HF and caustic liquor after the quench. Published chemical resistance tables rate it for hydrofluoric acid up to around 80°C.
PVDF	Hotter or more concentrated duties, and parts nearest the quench. Rated in the same tables to around 100°C, with reduced service life at the top of the range.
Glass, silica, ceramic	Never in the wetted path. That includes ceramic packing, glass sight glasses and glass-filled plastics.
GRP / FRP	Only with a corrosion liner rated for HF. The glass reinforcement itself must never see the gas or the liquor.
Stainless steel	Structure, frames and dry parts. Not for wetted service with HF or chlorides.

Why it matters for people

HSE guidance EH40 sets a UK workplace exposure limit for hydrogen fluoride (as F) of 1.8 ppm over 8 hours and 3 ppm over 15 minutes. A failed seal or cracked part on an HF line is a safety event, not just a maintenance job.

Check every wetted part

- Vessels, packing and supports
- Spray nozzles and distributors
- Pumps, valves and seals
- Instrument wetted parts and probes
- Fan casing and impeller
- Gaskets and sight windows

TEMPERATURE Pyrolysis and oxidiser off-gas arrives far hotter than any thermoplastic can take. The quench is what lets the rest of the train be plastic, so design them together, and trip the process if quench water fails.

Sources: HSE EH40/2005 Workplace exposure limits (4th edition, 2020); published PE, PP, PVDF and ECTFE chemical resistance tables. Confirm every material against the specific duty.

04 Run the pilot so the commercial plant sizes itself

A pilot that logs its off-gas properly hands the commercial design measured numbers instead of assumptions. It also gives the permit application real data.

Why capacity is coming now. The EU Batteries Regulation sets material recovery targets for waste batteries:

LITHIUM RECOVERY

50% → 80%

end 2027 → end 2031

COBALT, NICKEL, COPPER

90% → 95%

end 2027 → end 2031

RECYCLING EFFICIENCY

65%

lithium-based batteries, end 2025

Source: Regulation (EU) 2023/1542, as summarised by the IEA policy database. Pilots proving recovery today become the permitted plants of 2027 to 2031.

Log this during the pilot

- Off-gas flow and temperature, including start-up and purges
- Inlet HF and other acid gases by stage
- Outlet concentrations at the stack
- Caustic consumption and pH setpoint
- Bleed rate and fluoride content
- Pressure drop across bed and eliminator

What a pilot skid should give you

- Scrubber, sump, dosing, fan and panel on one frame
- Wired and wet-tested before it leaves the factory
- On site: ducting, power and water only
- Instruments that log the data on the left
- A recorded design basis for the scale-up
- Signed commissioning record of setpoints

PROGRAMME

Caldera pilot skids are typically delivered 18 to 20 weeks from approved drawings. Build that into the funding milestones early: off-gas treatment is often the last package ordered and the first one the permit asks about.

05

Numbers, in writing, before you buy

Regulators judge off-gas treatment on what leaves the stack. The regime differs by country, but the questions about your scrubber are much the same.

COUNTRY	REGIME
England	Environmental permit. The Environment Agency handles Part A1 installations and waste operations; local councils handle Part A2 and Part B. Applications must include proposals for monitoring emissions.
France	ICPE regime for classified installations, with conditions set for the site.
Germany	Federal Immission Control Act (BImSchG) permits, with emission requirements under TA Luft.

Ask for this on the datasheet

- Design flow and temperature at each stage
- Inlet concentration for HF and each acid gas
- Predicted outlet concentration for each
- Caustic, water use and bleed rate
- Pressure drop and fan duty
- Materials of every wetted part

Plan the monitoring

- Sample ports on a straight run of stack
- Safe, permanent access to the ports
- Periodic or continuous, as the permit sets
- In England, MCERTS-accredited stack testing
- pH, flow and level records kept
- Signed commissioning record on file

CONTINUOUS OR PERIODIC

GOV.UK guidance notes that periodic monitoring alone may be acceptable depending on the process, and that continuous monitoring is expected where emissions vary too much for occasional samples to be representative. Batch pyrolysis often does.

WARNING SIGN

A quote that gives a removal percentage but no outlet figure for HF. Percentages depend on the inlet; your permit is written in concentration at the stack.

Sources: GOV.UK, Check if you need an environmental permit; GOV.UK, Monitoring stack emissions. Your permit conditions take precedence over general guidance.

06 The checklist for a quote you can trust

Send what you have; an engineer can fill gaps on a call. Battery recycling processes are often proprietary, so we sign your NDA before any process data changes hands.

- | | |
|---|---|
| ☐ Process stages you are piloting, and which vent to the scrubber | ☐ Off-gas flow in m ³ /h at normal and peak, and its temperature |
| ☐ Gas analysis or expected HF, acid gas and organic load | ☐ Upstream equipment: oxidiser, filter or condenser |
| ☐ Emission limits or the permit regime that will apply | ☐ Hazardous area classification, if solvents are present |
| ☐ Utilities: power, water quality and effluent route | ☐ Scale-up plan: target capacity and timing |



TALK TO AN ENGINEER

Tell us what is coming off your process

Send the gas, the flow and the limit you have to meet. A process engineer will reply within 4 working hours and tell you what will work, and what will not, before anyone talks about price.

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