MASSMELT

CONTINUOUS THERMAL EXTRUSION SYSTEM

Intrinsic Safety Architecture for Lithium-Ion Battery and Pressurised gas cylinder containment & Anaerobic compaction

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Massmelt 400 with integral bin tipping machine.

1: Executive Summary

The proliferation of discarded consumer electronics—most notably single-use electronic nicotine delivery systems (disposable vapes) and portable power banks—has introduced severe fire hazards into municipal, commercial, and transport-hub waste streams [1]. In conventional mechanical compaction equipment, including rotary drum crushers, vertical balers, and portable compactors, mechanical force routinely breaches cell separators, initiating rapid exothermic thermal runaway. Because these conventional methods leave extensive interstitial air voids (50% to 70% trapped atmospheric oxygen) amidst dry paper and cardboard, short-duration cell failures reliably escalate into sustained, catastrophic facility fires [2].

Even in highly segregated waste streams, and despite heavily penalising commercial parties for non compliance, there is an absolute statistical inevitability that rogue lithium-ion batteries will bypass screening protocols. The systemic frequency of these incidents has triggered an insurance crisis within the UK waste sector, with the Environmental Services Association (ESA) warning that such risks threaten to render certain operations uninsurable. The Massmelt continuous thermal extrusion system provides a definitive engineering mitigation for this unavoidable residual risk [3, 4, 5, 6].

By replacing purely mechanical crush forces with a progressive-load auger, near-total void elimination, in-situ molten polymer encapsulation, integrated chilling, and the endothermic steam-damping capacity of inherent organic waste moisture, Massmelt prevents local cell decomposition from transitioning into an open-flame conflagration. Beyond immediate containment, the system proactively neutralises the conditions responsible for secondary or delayed yard fires. By deoxygenating the waste matrix and discharging a highly dense, thermally buffered extruded log directly into a heavy-duty steel receptacle via an impact-attenuated chute, Massmelt eliminates both immediate lithium-ion flare-ups and the spontaneous combustion risks that plague downstream storage and transport.

2: Characterisation of Battery Ingress in Transit and Packaging Waste

In public-concourse, rail, airport, and food-service waste streams, battery ingress conforms to a distinct, bounded energy distribution [7]. Crucially, the duration of these thermal runaway events is extremely rapid—often lasting under one minute for a standard vape cell and up to three minutes for a high-capacity power bank [8]. In a conventional compactor, this brief, intense energy release acts as the ignition source for the surrounding aerated waste, instantly escalating a one-minute cell failure into a facility fire that can take hours or days to extinguish.

Device Category	Cell Chemistry & Form	Electrical Synery	Runaway Energy (Max)	Approx. Event Duration
Single-Use Vapes (>95%)	Li-Po / 13340 cynlindrical	1.3 - 2.5 Wh	~15 – 30 kJ	< 60 Seconds
Smartphones / Compact Cameras	Li-Po pouch / Li-ion	11.0 - 17.5 Wh	~120 – 190 kJ	1 - 2 Minutes
	Multi-cell 18650/21700	74.0 - 99.9 Wh	~800 – 1,080 kJ	2 - 3 Minutes

3. Failure Modes in Conventional Mechanical Compactors

Standard rotary compactors, crush balers, and static skip compactors inadvertently assemble all three sides of the fire triangle along with an external ignition trigger. The mechanical vulnerabilities manifest in two primary modes:

3.1. High-Shear Point Puncture (Rotary Compactors)

Rotary compactor drums employ protruding hardened steel teeth to grab, pull, and shred bags. When a tooth impinges on a battery casing, it exerts concentrated point loads exceeding several hundred megapascals (MPa). This tears the 15–25 µm microporous polymer separator, potentially provoking an instantaneous internal dead short, localised Joule heating, and violent deflagration.

3.2 Elastic Spring-Back and Loose Packing (Balers and Portable Compactors)

While standard crush balers and portable static skip compactors successfully reduce initial waste volumes, the compression is strictly mechanical and elastic. This violent crushing action—whether from the steel ram itself or the intense friction between compacted waste particles—routinely breaches battery casings, initiating a hidden ignition sequence. Upon retraction of the hydraulic ram, the waste undergoes 'spring-back'. This loose packed matrix leaves abundant interstitial oxygen alongside highly combustible, high-surface-area tinder (paper, napkins, lightweight film). When the compromised lithium cell ultimately vents into this oxygen-rich environment, it rapidly feeds an open flame that can develop either immediately inside the compactor or later in the storage yard. Such conflagrations risk the wider facility and can destroy the compactor itself, melting critical hydraulic lines, drive mechanisms, and electronic control ancillaries.

4. The Massmelt Mitigation Architecture.

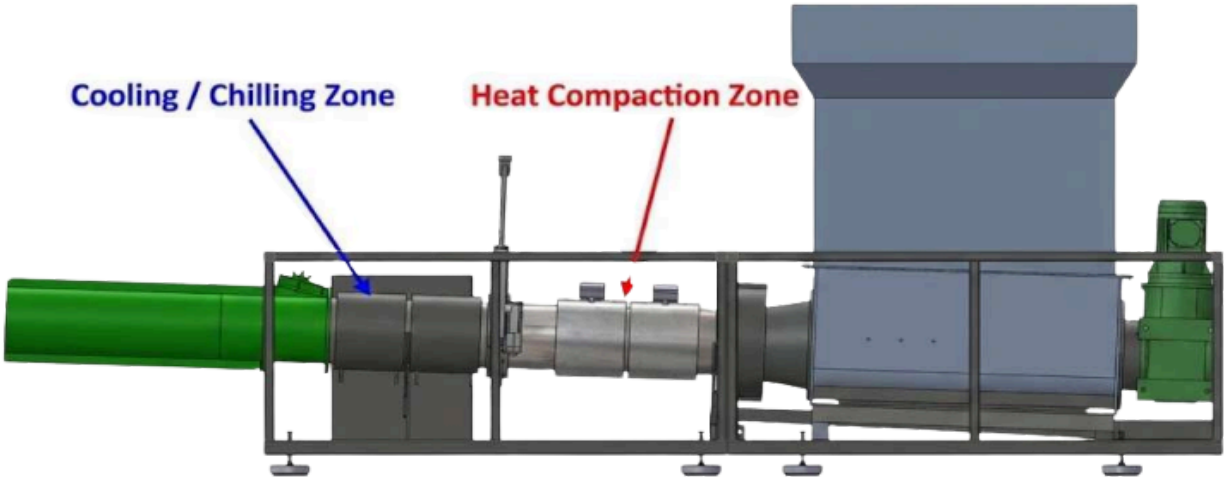


Figure 1: Skeletal Render of Massmelt System indicating Heat Compaction and Cooling Zones.

Underpinned by a progressive architectural lineage of international patents, the Massmelt system replaces destructive mechanical impact and elastic compaction with continuous, enclosed thermal densification.

4.1 Progressive Load Geometry and Cushioned Infeed.

Waste entering the Massmelt feeds into a continuous auger with progressive flight geometry. Loose cardboard, food cartons, and flexible packaging form a protective cushion around the battery during entry. Forces are applied as distributed axial and hoop stresses. Cells are flattened progressively along their longitudinal axes rather than pierced across their cross-sections, preventing violent separator shredding.



Figure 2: Internal view of the Massmelt auger and progressive load geometry

4.2 Empirical Void Elimination and Atmospheric Oxygen Starvation

As the auger drives waste through the heated barrel, the flight depth tapers, generating severe mechanical compaction alongside thermal softening. Trapped air is driven backward toward the low-pressure feed throat and safely extracted.

Empirical trials comparing fast-food station waste demonstrate the vast disparity in void elimination. Waste initially processed by a rotary compactor yielding a volume of 0.942 cubic metres was subsequently reprocessed through the Massmelt system, achieving a final extruded volume of just 0.157 cubic metres—an 83.3% absolute reduction in volume.



Figure 3: Empirical volume reduction. 0.942 m³ rotary compacted waste reduced to 0.157 m³ via thermal extrusion.

This extreme densification mathematically demonstrates the almost complete expulsion of interstitial air, validating the highly anaerobic nature of the Massmelt matrix. While a lithium-ion cell contains internal cathode oxidisers sufficient for its own internal decomposition, surrounding municipal waste cannot burn without atmospheric oxygen. In this near zero-void matrix, open-flame ignition of adjacent waste is physically impossible.

4.3 Heterogeneous Matrix Binding and In-Situ Polymer Encapsulation

In open-air aerobic environments, hydrocarbon-based plastics are traditionally viewed as highly combustible fire accelerants. However, within the anaerobic confines of the Massmelt barrel, their physical behaviour fundamentally changes.

Transit and commercial waste streams are inherently heterogeneous, typically comprising paper, cardboard, organic matter, and an available thermoplastic fraction (such as LDPE, HDPE, and PP) of approximately 20% to 25%. At barrel operating temperatures (130°C–170°C), this available 20–25% plastic fraction does not combust; instead, it transitions into a highly viscous melt. Rather than forming a pure, homogeneous polymer slurry, it acts as a molten binder distributed throughout the diverse waste matrix. Under immense mechanical pressure, this molten fraction is mobilized, flowing into remaining micro-voids and encapsulating foreign bodies, including compromised battery casings.

As the material is extruded, this polymer fraction preferentially forms an approximately 4 mm plastic coating along the log's longitudinal surface. While the sheared ends of the log remain open, this smooth outer coating acts as a vital physical barrier, insulating the internal contents from external flame impingement and acting as a dielectric potting agent to prevent external electrical arcing.



Figure 4: The 4 mm plastic coating formed during in-situ polymer encapsulation.

(See Figure 2 for source material)extrusion.

4.4 Integrated Cooling and Solidification Zone

To ensure operational safety and maintain the structural integrity of the densified matrix, the extruded log immediately passes through an integrated cooling or chilling zone prior to discharge. If the log were to exit directly at the core processing temperature of nearly 200°C, it would present a severe burn hazard to operators and risk thermal expansion (spring-back) as internal gases attempt to escape.

The dedicated chilling zone rapidly cools and solidifies the molten polymer skin. This locks the internal waste matrix in its highly compressed, void-free state—permanently negating the expansion effects seen in conventional balers—and ensures the exterior of the log is structurally sound and safe to touch upon entering the discharge receptacle.

4.5 Moisture-Driven Endothermic Quenching

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4.6 Active Fire Suppression via Conveyance and Anaerobic Quenching

In the event that an external ignition or a rogue battery vent establishes a fire within the aerobic infeed hopper (skip), standard fire suppression equipment is designed to activate to mitigate smoke generation. Crucially, the Massmelt system does not rely solely on external suppression. Rather than halting and allowing the fire to persist in the hopper, the machine continues to operate, actively conveying the burning material forward.

The auger draws the ignited waste out of the aerobic hopper and forces it into the deoxygenated barrel. In this context, the entire barrel acts as an anaerobic quenching zone. Deprived of atmospheric oxygen and subjected to the severe compressive forces and endothermic dampening of the internal waste matrix, the conveyed fire is rapidly starved and extinguished, preventing structural damage to the machine.

5. Prevention of Secondary Yard Fires and Spontaneous Combustion

Beyond the immediate threat of lithium-ion point-punctures, conventional waste processing is highly susceptible to delayed yard fires and spontaneous combustion. The Massmelt system actively disrupts these failure pathways:

5.1 Reduced Flammability via Surface Area Modification

Loose, shredded, or finely divided organic materials possess an extremely high surface area-to-volume ratio, allowing for rapid heat transfer and quick oxygen access. The Massmelt extrudes waste into dense, solid logs. This dramatic reduction in surface area limits volatile release and creates a 'heat sink' effect, making it exceptionally difficult for localised external heat to propagate and sustain ignition.

5.2 Deoxygenation and Arrest of Aerobic Self-Heating

When organic matter is compressed under immense pressure, interstitial air is physically squeezed out. Oxygen is a mandatory component for aerobic microbial activity—the primary catalyst for exothermic self heating in organic waste piles. By stripping the matrix of interstitial voids and simultaneously subjecting it to a 200°C skin thermal treatment, the microbial 'engine' responsible for spontaneous combustion is severely retarded.

While eventual oxygen ingress is inevitable over extended periods, the strict lack of interstitial voids strongly inhibits exothermic action. This structural density significantly delays microbiological activity, mitigating the risk of self-heating over a considerable storage period. In empirical observations, extruded logs have remained stable in storage without mishap for up to 12 months.

6. Regulatory Compliance and Insurance Viability (UK Context)

The National Fire Chiefs Council (NFCC) alongside compliance schemes such as Valpak report that lithium-ion battery fires now cost the UK economy well over £100 million annually. The sheer frequency of these events in waste streams—exacerbated by highly combustible environments in conventional rotary and RoRo compactors—has triggered a severe regulatory and insurance crisis. This risk profile applies universally across all major international waste handling operations. [11,12]

6.1 Operational Scrutiny and Business Interruption

Under enforcement by environmental regulators (such as the Environment Agency in the UK), a severe waste fire triggers immediate operational suspension pending EA investigation, site clearance, permit variation, and Fire Prevention Plan (FPP) re-approval [9, 10].

Because this regulatory recovery process rarely concludes within a year, specialist waste insurance brokers strongly mandate that operators carry business interruption indemnity periods of 24 to 36 months to survive the operational downtime, compounding the initial property losses and halting essential public infrastructure

6.2 The Uninsurability Threshold

The Environmental Services Association (ESA) has warned that without fundamental engineering reform, certain waste processing operations face becoming entirely uninsurable. Even when insurance is retained following a compactor fire, the lack of intrinsic containment mechanisms results in punitive premium increases—often exceeding 40% to 50%—and mandated increases in separation distances that heavily constrain operational site capacity.

By proactively removing the mechanism of mechanical ignition and providing absolute anaerobic containment, the Massmelt system directly satisfies strict regulatory guidelines and restores underwriting confidence. It transforms a volatile, potentially uninsurable hazard into a controlled, compliant process that protects long-term commercial viability.

7. Drive Train Efficiency, Insulation, and Thermal Dynamics

The mechanical and thermal efficiency of the Massmelt architecture provides significant operational advantages alongside its safety profile:

- High-Torque / Low-Energy Mechanics: The system incorporates a high-ratio reduction gearbox, generating immense operational torque while running at approximately 8% of the energy consumption of a comparably sized standard extruder machine. This low-speed, high-torque approach not only reduces overhead costs but ensures the slow, progressive deformation of batteries rather than violent, high-speed sheering.

- Thermal Insulation and Capacity: The Massmelt barrel and continuous auger represent a massive thermal capacitor. The total steel mass in the compaction zone is between 500 and 600 kg. Even under the theoretical assumption that the entire energy release of a 100 Wh cell was transferred exclusively to the steel barrel, the bulk temperature rise across the processing assembly is less than 4°C. The entire heated barrel is fully insulated to minimise external heat loss, heavily optimising thermal efficiency and ensuring the surrounding operational environment remains safe.

8. Discharge Phase: Attenuated Discharge and Hermetic Log Receiver

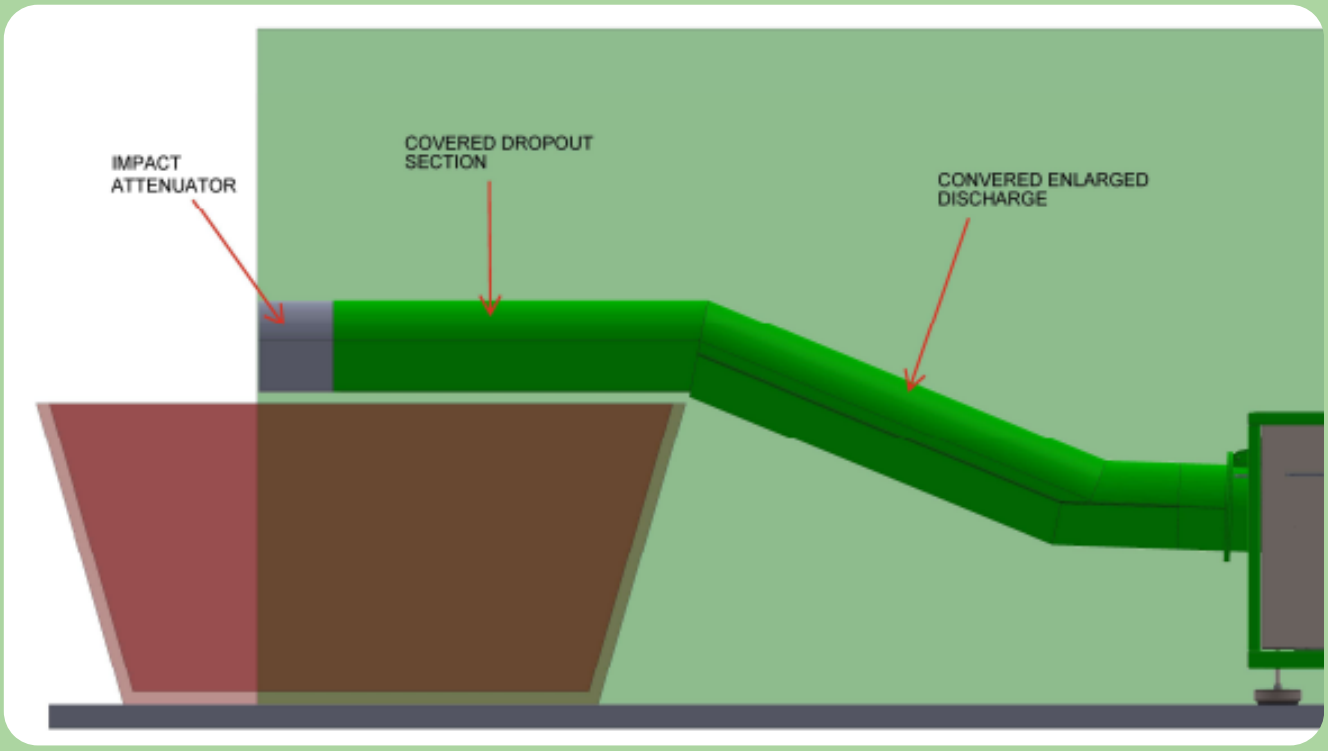


Figure 5: Discharge Chute with Covered Dropout Section and Impact Attenuator.

At the discharge end of the system, the extruded log passes through a covered, enlarged discharge chute equipped with a covered dropout section and a terminal mechanical impact attenuator. This attenuator is explicitly designed to safely de-energise the log and absorb kinetic shock in the highly unlikely event of a delayed explosive reaction post-extrusion.

Parameter	Conventional Compactors (Rotary, Ram, Portable Compactors)	Massmelt Thermal Extruder
Primary Mechanical Action	Shearing teeth / Elastic ram pressing	Continuous rolling auger
Discharge Kinetic Protection	None	Covered dropout & Impact attenuator
Atmosphere around Cell	Aerobic (50-70% air voids, spring-back)	Anaerobic (near 0% void log)
Fire Damage Risk to Machine	High (destroying hydraulics/controls)	Negligible (solid steel barrel containment)
Polymer State	Cold, dry, combustible loose film	Molten, encapsulating matrix
Water Content Role	Leachate pool (biological hazard)	Latent heat vapourisation sink
Maxiumum Reaction Temp	Uncontrolled flame (>1,0000°C)	Thermally buffered (<2200°C)
Output State	Loose, aerated bags or blocks in skips	Rock-solid, impermeable log
Delayed Rekindling Risk	Critical operational hazard	Physically impossible

Following the attenuation zone, the log shears or drops directly into a dedicated, heavy-duty steel collection bin. The log is mechanically isolated from ambient station air and loose packaging. The steel receptacle provides an impenetrable structural firebreak compliant with stringent rail basement and building regulations, ensuring safe logistics to RDF or recycling facilities.

9. Conclusion

While conventional mechanical compactors, rotary crushers, and RoRo skip compactors successfully reduce initial waste volumes, they inadvertently act as accelerators for lithium-ion battery fires. By combining mechanical cell puncture with an oxygen-rich, dry-tinder environment caused by elastic spring-back, these traditional volume-reduction methods expose facilities and critical machine components to severe fire damage.

In contrast, the Massmelt system achieves unparalleled volume reduction through an architecture that provides an inherently safe, passive containment environment. Designed for continuous or batch processing directly at the point of waste generation, the system eliminates the severe risks associated with transporting loose, volatile transit waste to centralised Materials Recovery Facilities (MRFs).

This passive containment architecture was tested during an extreme, real-world 'perfect storm' scenario in late 2025. Rogue compressed gas cylinders bypassed screening and violently ruptured under prolonged heat during an operational blockage. While the solid steel barrel successfully contained the primary blast and completely prevented fire or operator injury, the rapid pneumatic expansion resulted in an unplanned kinetic ejection of waste from the open discharge chute. Rather than relying on operational fortune, this anomaly provided the precise empirical baseline to engineer the definitive safeguard: the Terminal Arrestor System (Impact Attenuator), explicitly designed to cap the discharge and safely absorb all such kinetic force.

Through cushioned progressive feeding, near-complete void elimination, integrated cooling logic, and moisture-driven endothermic quenching within an anaerobic barrel, Massmelt de-energises rogue cells without open-flame deflagration. By encasing the remnants in solid extruded logs, retarding biological self-heating for extended storage, and discharging into sealed steel bins via the kinetic impact attenuator, the system fundamentally engineers out instantaneous lithium battery fires, mitigates unforeseen explosive gas cylinder anomalies, and prevents delayed spontaneous yard fires, securing critical infrastructure from catastrophic risk.

10. References

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