SUSTAINABLE RECYCLING INDUSTRIES

Standard Operating Procedures for Environmentally Sound Management of Used Lead-acid Batteries

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For the SRI project:

- Oeko-Institut e.V.
- Ghana National Cleaner Production Centre (GNCPC)
- Mountain Research Institute (MRI)
- Environmental Protection Agency of Ghana (EPA)
- Ministry of Environment, Science, Technology and Innovation (MESTI)

For the Material Stewardship Initiative:

- International Lead Association (ILA)
- Association of European Automotive and Industrial Battery Manufacturers (EUROBAT)
- Battery Council International (BCI)
- Association of Battery Recyclers (ABR)

MOUNTAINRESEARCH INSTITUTE
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EUROBAT ASSOCIATION OF EUROPEAN AUTOMOTIVE AND INDUSTRIAL BATTERY MANUFACTURERS
association of battery RECYCLERS

SRI SUSTAINABLE RECYCLING INDUSTRIES

Turning waste into resources for development

SRI builds capacity for sustainable recycling in developing countries. The programme is funded by the Swiss State Secretariat for Economic Affairs (SECO) and is implemented by the Institute for Materials Science & Technology (Empa) and the World Resources Forum (WRF). It builds on the success of implementing e-waste recycling systems together with various developing countries since more than ten years.

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Acronyms

ABR	Association of Battery Recyclers
BCI	Battery Council International
EHS	Environment, Health and Safety
EUROBAT	European Automotive and Industrial Battery Manufacturers
Empa	Swiss Federal Institute for Materials Science and Technology
EPA	Environmental Protection Agency (Ghana)
EPR	Extended Producer Responsibility
GNCPC	Ghana National Cleaner Production Centre
ILA	International Lead Association
LAB	Lead-acid battery
MESTI	Ministry of Environment, Science, Technology & Innovation (Ghana)
MSI	Material Stewardship Initiative
MRI	Mountain Research Institute
PP	Polypropylene
SECO	State Secretariat for Economic Affairs
SOP	Standard Operating Procedure
SRI	Sustainable Recycling Industries
ULAB	Used lead-acid battery
UNEA	United Nations Environment Assembly
UNICEF	United Nations Children's Fund
WEEE	Waste Electrical and Electronic Equipment
WRF	World Resources Forum

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Executive summary

Lead-acid batteries (LABs) are used in a broad variety of applications and continue to be a major battery technology in all regions or the world. End-of-life management of LABs requires attention as a lack of appropriate controls are likely to cause severe adverse effects to human health and the environment. While processes and technologies for environmentally sound management are available, their uptake and application are still insufficient in many countries, which has also been identified as a key challenge by the international community at the 3rd meeting of the United Nations Environment Assembly (UNEA).

In that context, the Ghanaian Ministry for the Environment, Science, Technology and Innovation (MESTI) and the Environmental Protection Agency of Ghana (EPA) aim to systematically improve the lead-acid battery recycling sector in Ghana. They asked the Swiss-funded Sustainable Recycling Industries Project (SRI) to develop Standard Operating Procedures (SOPs) that will be used as a guide to take the necessary measures for improving environmental and workplace performance in this sector. The SOPs were requested to be structured and developed in a format and style that is practical (covering all process steps), understandable (also for persons with no specific technical know-how), concise (no lengthy texts) and supported with pictures and diagrams.

Furthermore, the SOPs are to be held in a format that allows Ghanaian authorities to adopt them as an official element of its regulatory framework. The SOPs presented in this report fulfil these criteria and have been developed in cooperation between the SRI project and the Material Stewardship Initiative (MSI) initiated by four industry associations, namely the International Lead Association (ILA), the Association of European Automotive and Industrial Battery Manufacturers (EUROBAT), the Battery Council International (BCI) and the Association of Battery Recyclers (ABR).

This report introduces the SOPs and other necessary policy elements for the environmentally sound management of ULABs. The developed SOPs total 37 sheets, each covering one topic relevant for safe and environmentally sound ULAB management, from collection to recycling. The SOPs sheets use a common format and are supported with pictures and diagrams illustrating good practices, contrasted by pictures of unacceptable practices. The sheets are aimed for:

- Operators of collection points, bulk transporters, and ULAB recyclers
- Regulators responsible for defining minimum requirements for environmentally sound ULAB management
- Inspectors responsible for assessing the environmental, health and safety (EHS) performance of operators in ULAB management

A full and permanent implementation of all SOPs significantly increases the probability that ULABs are managed according to high EHS standards minimising the risk for environmental pollution and the development of workplace ill-health.

The SOPs were developed for use in Ghana, but also with a view for a wider use and uptake. Therefore, this version of the SOPs does not contain any specific reference to the regulatory framework of Ghana so that it can also be used in other jurisdictions. Another version entailing references to the Ghanaian legal framework was submitted to the EPA and MESTI.

Keywords

Used lead-acid batteries, recycling, lead, pollution control, standard operating procedures

1 Introduction and background

Lead-acid batteries (LABs) are used in a broad variety of applications such as vehicles, backup-systems, mobile phone networks and off-grid solar systems. Despite Li-ion battery technology gaining market shares in many segments, LABs are still often the dominant battery technology in most economies and projected to continue to play a major role for decades to come.

While being a central battery technology in many transport and energy storage applications, end-of-life management of LABs requires attention as a lack of appropriate controls are likely to cause severe adverse effects to human health and the environment. Processes and technologies for environmentally sound collection and recycling of used lead-acid batteries (ULAB) are available and have been continuously improved by various industry, research and government players in most industrialised countries to minimise possible adverse effects of lead exposure[1] for workers and local communities.

Nevertheless, the uptake and application of such sound processes and technologies is still insufficient in many countries, which can result in severe pollution and adverse health impacts for workers and large parts of the population. A recent study by UNICEF and Pure Earth reported that one third of children suffer from elevated blood lead levels and that one major source of lead exposure is unsound lead-acid battery recycling (UNICEF & Pure Earth 2020). Various cases of pollution highlight that Sub-Saharan Africa is increasingly developing into a 'hot spot' for unsound lead-acid battery recycling (Manhart et al. 2016; Gottesfeld et al. 2018; Anyaogu 14 Dec 2018). The international community has recognized this problem and passed a resolution at the 3rd meeting of the United Nations Environment Assembly raising concerns about the health and environmental impacts of ULAB recycling and encouraging governments to continue their efforts towards the environmentally sound management of ULABs (UNEA 2017).

In a first baseline assessment conducted under the SRI project, it was found that the situation in Ghana is of concern with several ULAB recycling companies failing to meet even basic minimum requirements for environmentally sound management with particular shortcomings in battery breaking and electrolyte management, dust-control, recycling of plastic cases, personal protective equipment, infrastructure for personal hygiene, and proven cases of severely elevated blood lead levels (Atiemo et al. 2016). As a result the Ghanaian Ministry for Environment, Science, Technology and Innovation (MESTI) and the Environmental Protection Agency of Ghana (EPA) asked SRI to conduct training on sound ULAB management for plant managers and factory inspectors, which was conducted in July 2017. During this training, 25 participants from the authorities and the recycling sector were provided with information on basic processes and challenges of ULAB management, as well as robust technical solutions to effectively mitigate pollution and occupational health and safety risks. The training was given by Brian Wilson from the International Lead Association (ILA) and enabled the participants to conduct their own assessments of the ULAB recycling plants. As a result, assessments and improvement plans were developed for all plants in Ghana and agreements signed between plant managers, MESTI and EPA to

[1] Lead exposure can lead to acute lead poisoning with its various symptoms such as impairment of liver and kidney functions, abdominal pain and feeling of weakness. Lead affects the kidneys, the nervous system, the cardiovascular, reproductive and immune system, and causes permanent developmental impairments to children. Severe lead poisoning can have lethal effects.

commit to an improvement process leading to full environmentally sound ULAB management in Ghana.

In the subsequent implementation process, MESTI and EPA asked for further support from SRI, particularly in relation to tools guiding the ULAB recycling industry and facilitating the regulatory tasks of the Ghanaian authorities for this sector. Specifically, MESTI and EPA requested Standard Operating Procedures (SOPs) that will be used as a guide to take the necessary measures to improve environmental and workplace performance in the ULAB-recycling sector. The SOPs were requested to be structured and developed in a format and style that is:

- practical (covering all process steps);
- understandable (also for persons with no specific technical know-how);
- concise (no lengthy texts);
- supported with pictures and diagrams.

Furthermore, the SOPs are to be held in a format that allows Ghanaian authorities to adopt them as official element of its regulatory framework.

In this context, SRI reached out to the newly founded Material Stewardship Initiative (MSI) of the International Lead Association (ILA), the Association of European Automotive and Industrial Battery Manufacturers (EUROBAT), the Battery Council International (BCI) and the Association of Battery Recyclers (ABR) to gain technical and conceptual support for developing such SOPs. The organizations implementing the SRI-Ghana project (Ghana National Cleaner Production Centre (GNCPC), Mountain Research Institute (MRI) and Oeko-Institut) came to an agreement with the Material Stewardship Initiative to jointly develop the SOPs presented in this report and with a view that the material may serve regulatory bodies, industry and civil society organizations to know good environmental and workplace safety practices and to serve as a guide to implement any necessary measures to improve the EHS performance of the ULAB-recycling sector.

The SOPs were developed on the basis of existing good practices in high-standard facilities. While many of the practices where initially developed in industrialized countries, there is also a growing number of cases where these technologies and processes are also successfully applied in emerging economies and developing countries. The SOP development was guided and critically reviewed by policy makers and inspectors from Ghanaian authorities, operation managers of high standard ULAB recycling plants, and government and civil society stakeholders from other African countries. A full list of contributing persons is given in the beginning of this report. The developed SOPs are comprehensive so that their full application will mitigate most pollution and occupational health and safety risks resulting from ULAB recycling. The SOPs are not intended to replace existing guidelines and regulations on ULAB management, but rather to build upon existing material such as those developed under the Basel Convention (UNEP 2003) by the European Union (Cusano et al. 2017) and for North America (CEC 2016) and to translate them into a handbook-like format in-line with the requirements of Ghanaian regulators.

While the work should primarily benefit Ghana, it is recognised that other countries have similar challenges so the material is also made available to other interested parties. Therefore, this version of the SOPs does not contain any specific reference to the regulatory framework of Ghana so that it can also be used in other jurisdictions. Another version entailing references to the Ghanaian legal framework was submitted to EPA and MESTI.

2 General aspects on lead-acid battery recycling

2.1 Economic considerations

Lead-acid batteries contain between 60-65% lead which has a high material value typically ranging between 1,600 and 2,500 US$/mt on the world market (USGS 2020)[2]. For this reason, ULABs have a positive net value and are attractive for scrap dealers and recyclers in most world regions[3]. Experiences with ULAB recycling all over the world have shown that ULAB recycling can be and is a profitable business – independent from the chosen type and recycling methods. Nevertheless, there are differences in the level of profitability, which are mostly rooted in the lead smelting process and the general level of standards of a ULAB recycling facility. Table 1 shows three major types of smelting processes and illustrates that – in unregulated markets with a high availability of ULABs[4] – low standard industrial smelting operations have economic advantages over both, backyard smelting and high standard facilities. These advantages are based on the fact that even low standard industrial smelters can recover >90% of the lead, which is significantly more than with backyard smelting processes. At the same time, low standard industrial smelters can compensate the somehow lower lead recovery rates (compared with high standard facilities) with comparably low investment- and operational costs.

Therefore, countries with sufficient ULAB volumes and an unregulated market are likely to receive investments into industrial recycling and smelting operations. But these investments may be substandard and very polluting in nature. In case companies decide to opt for responsible high-standard investments under such unregulated conditions, they run the risk that they cannot compete on price with their low standard and polluting competitors[5]

[2] Another 5% of typical ULABs are made-up of the polypropylene (PP) case and 10-18% of dilute sulfuric acid, which can both be recycled and sold at a profit. Nevertheless, lead is the most important value carrier of ULABs and the main target materials of recyclers.

[3] Exemptions may be remote areas such as small islands and mountain regions where transport costs to recycling markets are higher than potential revenues.

[4] In economies with limited ULAB volumes and availability, investments in industrial smelting operations are often not viable. Therefore, backyard smelting is still widespread in many smaller developing countries and least developed countries. An availability of at least 24,000 t/a is widely regarded as a minimum quantity for the viability of high standard industrial smelters. Low standard industrial smelters may be profitable already with somehow lower volumes.

[5] In many cases, low standard industrial smelters will be able to pay more for ULABs for recycling compared to high standard operators and will therefore be able to acquire more batteries for recycling.

Table 1: Different types of lead smelting processes in ULAB recycling

Backyard smelting	Low standard industrial smelting	High standard industrial smelting
		
Low investment costs	Mid investment costs	High investment costs
Low operational costs	Low operational costs	Mid operational costs
Lead recovery rate: 50-60%	Lead recovery rate: up-to 90%	Lead recovery rate: > 98%
Very polluting	Very polluting	Environmentally sound

It is therefore of great importance that government regulators set out and enforce clear and ambitious rules that effectively ensure that all recyclers must adhere to high EHS standards as laid out in this document. It needs to be stressed that there are various examples that demonstrate that such ambitious standards do not prohibit investments (as often claimed by dubious lobbyists) but are in turn an effective means to attract more responsible investments.

2.2 The reverse supply chain for used lead-acid batteries

The reverse supply chain for used lead-acid batteries (ULABs) encompasses the collection of used batteries, their transport to recycling facilities and the recycling of all battery components, including lead plates or grids, lead-oxides (also referred to as 'lead-paste'), plastic and the battery electrolyte (also referred to as 'battery acid').

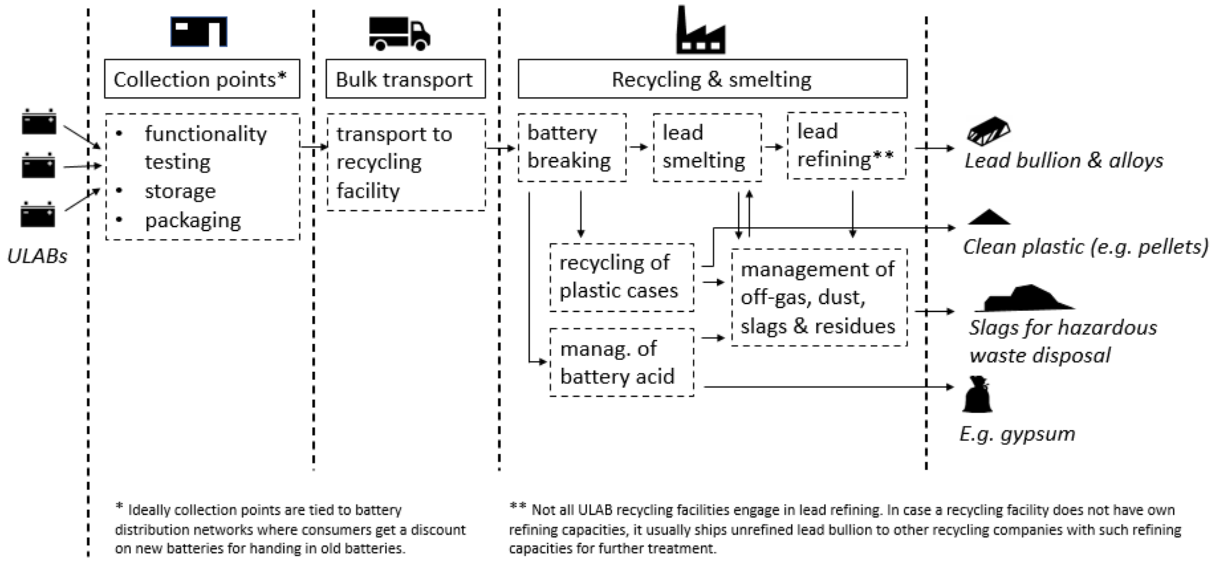

Figure 1: Model reverse supply chain for used lead-acid batteries

To achieve environmentally sound management of ULABs, the reverse supply chain should be arranged as illustrated in Figure 1[6]:

- Used lead-acid batteries are brought to dedicated collection points by users/consumers where they are safely stored and packed for subsequent transport. Collection points are ideally coupled to distribution networks for new batteries (e.g. car repair shops) and tied to an EPR-based collection mechanism where consumers receive discounts on a new battery when handing in a used battery (see section 2.3). Collection points may under no circumstance open or break batteries and shall not conduct any recycling steps themselves. The only permitted operation is functionality testing (including refilling the electrolyte in case this is needed) to identify functional batteries, recharge them, and dispatch them to suitable second-hand market.
- Packed intact ULABs are loaded on dedicated trucks (closed), or sealed leakproof plastic containers and delivered to a recycling facility.
- The recycling of the batteries should ideally be conducted in an integrated facility that conducts all steps around battery breaking, lead smelting, recycling of plastic cases, management of battery acid and the management of off-gas, dust, slags, drosses and residues and in-line with all requirements outlined in this work.

Conducting all recycling steps in such integrated facility is the best way to realize environmentally sound management of the off-gas, and by-products and residues. In that sense no battery breaking and/or acid draining operation should be conducted outside an integrated ULAB recycling plant (unless the battery breaker operates under strict environmental and occupational health standards and can demonstrate that it adopts necessary measures to reduce risks of pollution and occupational ill-health caused by lead emissions).

[6] In many countries (including Ghana) the existing reverse supply chains deviate from this model in various points. This commonly includes battery breaking activities at collection points and insufficient management of battery acid, off-gas, slags and residues.

Investments in a high standard industrial recycling plant are usually economically viable from an annual ULAB volume of 24,000 mt or more. Countries with smaller ULAB volumes may have to consider the export of ULABs to other countries that already have environmentally sound recycling facilities. In this case ULABs should be shipped intact according to the requirements of the Basel Technical Guidelines for the Environmentally Sound Management of Waste Lead-acid Batteries.

2.3 The role of Extended Producer Responsibility

Due to its potentially detrimental environmental and health impacts when not managed properly, ULABs have to be regarded as a priority waste stream with the aim of achieving collection and recycling rates close to or at 100% as specified in section 2.2. To do so, all operators throughout the product and reverse supply chain must contribute to this objective. The battery recyclers will have to implement ambitious environmental and occupational health standards and be regulated and monitored accordingly on the base of the guidelines specified in this document. However, battery producers, importers and distributers must also accept their responsibilities to ensure the products they distributed for sale are managed in an environmentally sound manner at the end of life. This involvement of producers, importers and distributers is commonly based on the principle of Extended Producer Responsibility (EPR), where such companies are held (co-)responsible for the environmentally sound management for their end-of-life products.

For lead-acid batteries, a common and effective implementation of EPR is to require producers, importers and distributers to apply a new-for-old battery exchange policy where customers receive a discount on the purchase of a new replacement battery when handing over a used one (see Figure 2). Furthermore, producers, importers and distributers are required to achieve and demonstrate collection volumes that match their sale and distribution volumes. This model requires that each battery distribution/sales point also functions as a ULAB collection point and that incentives are attractive enough for consumers to use the LAB-ULAB exchange option. Furthermore, these collection points are required to sell the ULABs only to registered and permitted companies who operate on the basis of existing laws and regulations and in line with the requirements of this document. This aspect shall also apply to holders of large battery volumes who may not return their used batteries to collection points but send them directly to recyclers (e.g. mobile network providers, government managed vehicle fleets, managers of electricity backup and storage systems). In Ghana producers and importers must pay an advanced eco-levy on the import of lead-acid batteries in accordance with Act 917. The eco-levy is fed into a national e-waste fund that may be used to support take-back and collection models as illustrated above.

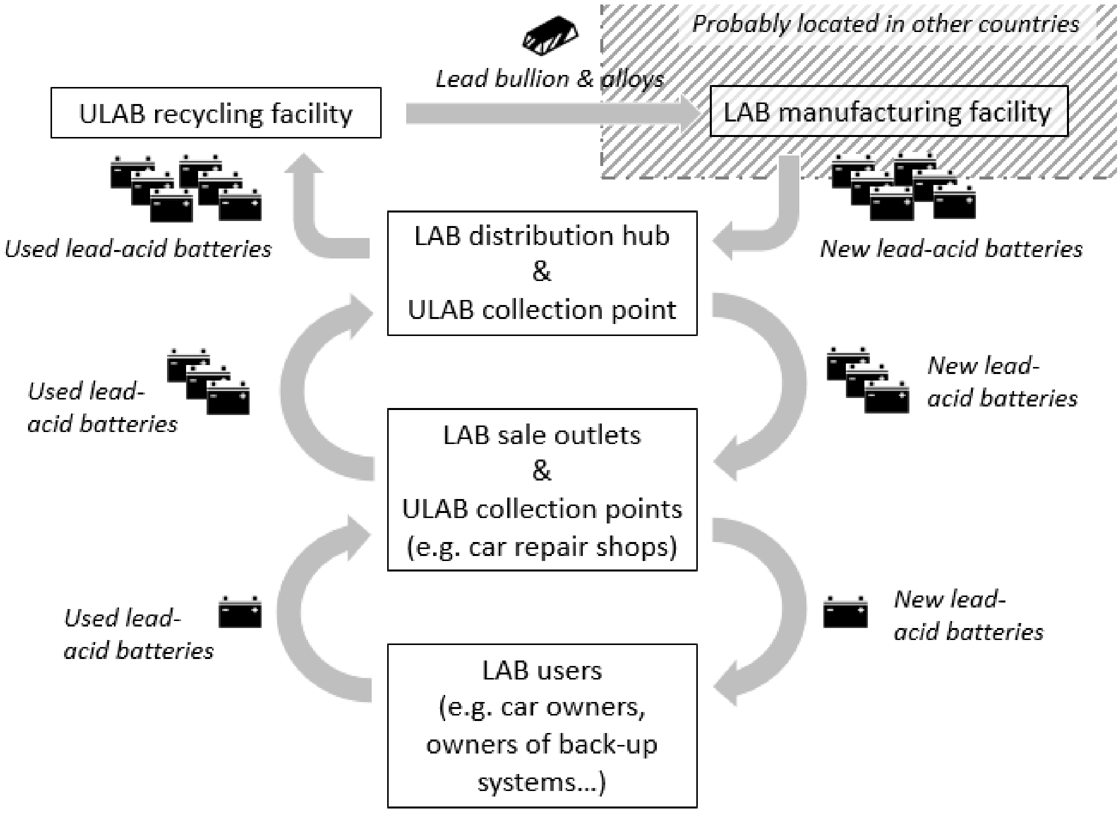

Figure 2: New-for-old battery collection system

2.4 Integration of small scale and informal sector operators

In many countries, small scale and informal sector operators[7] are engaged in the collection and regrettably also the recycling of ULABs. Whilst there may be a role for small scale and informal sector operators in battery collection (e.g. after formalization and appropriate training), it is never appropriate that small scale and informal recyclers have a license to operate as they contribute to significant environmental pollution and occupational ill-health as they do not have the necessary controls to manage occupational lead exposures, effluent discharges and atmospheric emissions. Small scale and informal sector recycling activities are sometimes tolerated by policy makers because they provide a livelihood to underprivileged and poor communities. Naturally, a reform of the ULAB recycling sector needs to take small scale informal sectors into account. To do so, the following aspects should be considered:

- Uncontrolled battery breaking, acid drainage, and lead smelting are sources of extreme pollution and create highly problematic legacy issues (highly contaminated local environment). The adverse effects on human health (workers, neighbouring communities, families of workers) can be significant and are particularly relevant for children who are likely to suffer lifelong irreversible adverse consequences from childhood lead exposure. Any income generated by

[7] Informal sector operators are commonly defined as operators who conduct business activities without proper registration and without paying taxes. Small scale recyclers may or may not be registered with the authorities and conduct small scale lead-acid battery collection and recycling activities indicatively not exceeding 10,000 t of ULABs per year.

informal ULAB recycling is by far outweighed by the cost of the negative consequences to human health and the environment.

- Compared to industrial recycling plants, small scale and informal ULAB recycling (and particularly lead smelting) have low recycling efficiencies for lead and other embedded materials: While most industrial plants can recycle over 90% of all input materials from a battery, small scale operations and informal sectors often achieve no more than 50-60% with the remainder being lost to the environment causing pollution. These differences in recycling efficiencies strongly support recycling in industrial plants. In fact, many small scale and informal sector operators started to realize that they can earn more by supplying ULABs to higher performing smelters rather than conducting their own recycling operations.
- While small scale operations and informal sectors should never be permitted to undertake ULAB recycling, they are often very efficient at battery collection as they usually maintain good networks with (formal and informal) vehicle repair centres and scrap markets. Therefore, it should be considered to grant informal players an active role in battery collection, including the delivery to dedicated collection / handover points. Naturally, the collectors will need to receive appropriate compensation for the collected batteries. This (monetary) incentive must be high enough to discourage the collectors from setting up their own polluting recycling activities.
- To keep ULABs away from small scale and informal recycling, governments should consider collection systems as described in section 2.3, including monetary incentives that can enable the formal sector to out-compete small scale and informal players. Governments should also avoid extra duties or taxes on purchases of scrap batteries in such official collection systems, as informal players would avoid them and get a relative advantage.
- In the absence of any opportunity to engage in ULAB collection, consideration must be given as to how to assist small scale and informal businesses and their communities to facilitate a transition to an alternative source of income. Failure to provide retraining or alternative employment might lead to a return to small scale and informal ULAB recycling.

2.5 Enforcement in reverse supply chains characterised by informal operators

Although differences in recycling efficiencies and the associated market dynamics are creating interlinks between small scale and informal sector operators and industrial recyclers in many countries already (see section 2.2), many small scale and informal operators still engage in practices such as draining the battery acid and breaking and dismantling the ULABs prior to providing materials to the recycler/smelter. These practices are unacceptable and, in most situations, cannot be undertaken in an environmentally sound manner when conducted outside an integrated ULAB recycling plant. Small scale and informal operators usually conduct these processes for the following reasons:

- The battery acid makes up 18 - 30 % of a ULAB's weight. By draining the acid prior to transportation, operators are trying to maximize the number of ULABs per truckload / shipment. For the same reason, some small scale and informal recyclers even decide to ship lead material only (grid metallics, terminal posts…) and conduct their own battery breaking and dismantling operations.
- Scrap dealers and industrial recyclers often do not compensate for battery acid and ask suppliers to drain batteries prior to delivery. Batteries delivered with acid are compensated at lower rates, and lead scrap from ULAB-dismantling is compensated at higher rates.

It is imperative that these polluting practices are eliminated. While an EPR system can be an important step in this direction (see section 2.3), it is quite unlikely that small scale and informal sector recycling will completely disappear with such a system. Therefore, policy makers will have to consider additional enforcement strategies. Environmental policies are difficult to enforce in informal and small scale settings where operators do not need permanent structures and who may escape enforcement by relocating activities. It is also worth mentioning that informal sector operators are often quite diverse and large in number so that enforcement is even more challenging. In that context it is worth considering a regulatory and enforcement approach leveraging the central position of industrial ULAB recyclers.

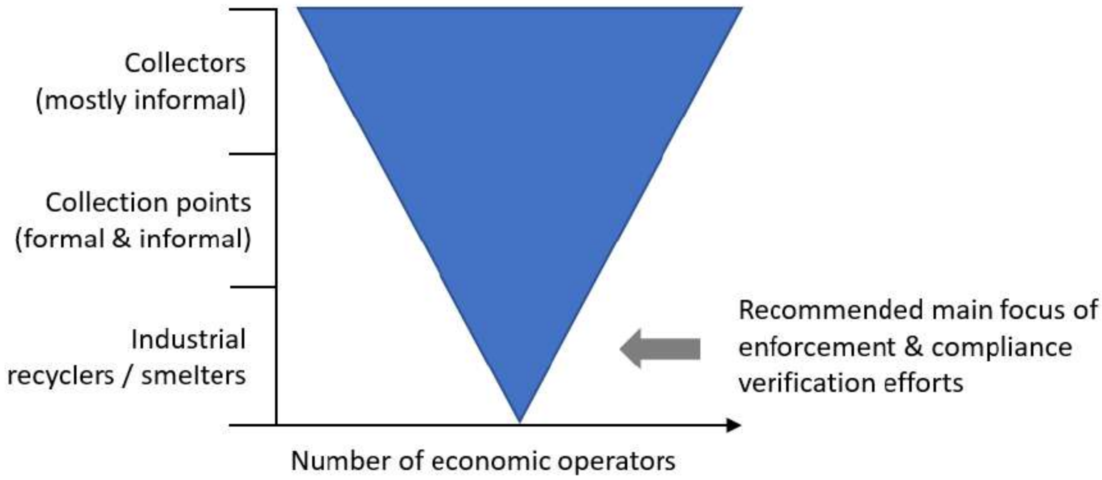

Figure 3: Indicative number of economic operators along the ULAB reverse supply chain

As indicated in Figure 3, even large countries only have a limited number of industrial ULAB recycling facilities (secondary lead smelters) and these facilities can be connected to small scale and informal operators as they buy ULABs or lead scrap from the local market and scrap traders that often care little about the provenance of the materials they trade. Consequently, these industrial facilities need to be closely monitored by the environmental authorities in all aspects of their operation (e.g. by using the requirements of this document). At the same time, these facilities should clearly adopt responsible sourcing policies to positively influence their ULAB supply chain: They should inform and educate their suppliers to bring intact batteries together with the acid and packed according to B.1.2. At the same time, they should introduce a compensation structure that incentivises the delivery of intact batteries with acid and disincentivizes acid drainage and pre-delivery battery breaking. While such a change in the supply chain might not be implemented from day one, regulators should impose phased targets and check their compliance. Such targets may involve (but might not be limited to) the benchmarks and timeline indicated in Table 2.

Table 2: Exemplary phased targets for ULAB recyclers to improve ULAB-sourcing and deliveries

Timeline	Requirements
Immediate	• The recycling company informs all suppliers that ULABs shall be delivered intact, with acid and packed.
Within 12 months	• Lead scrap, such as plates and terminals from ULABs will not accepted by the recycler any more • The proportion of batteries delivered with acid has increased to 60%
Within 24 months	• The proportion of batteries delivered with acid has increased to >90% • All batteries are delivered well packed according to SOP B.1.2.

Such targets and related monitoring will help to shift the domestic reverse supply chain away from polluting practices. While authorities may additionally make efforts to regulate and control collection points and collectors, enforcement and compliance verification is likely to be more effective if applied to material sourcing practices of the industrial ULAB recyclers and battery producers.

3 Using the SOPs

The SOPs are designed to give concise and understandable information on most aspects of ULAB management that are relevant from an environmental, health and safety perspective.

3.1 Target groups

The SOPs sheets use a common format which aims at giving a comprehensive overview on each aspect (see Figure 4). The sheets are aimed at three main types of stakeholders:

- Operators of collection points, bulk transporters, and ULAB recyclers
- Regulators responsible for defining minimum requirements for environmentally sound ULAB management
- Inspectors responsible for assessing the environmental, health and safety performance of operators in ULAB management

3.2 Ambition level & link to emission benchmarks and monitoring

A full and permanent implementation of all SOPs significantly increases the probability that ULABs are managed according to high EHS standards minimising the risk of environmental pollution and development of workplace ill-health. In the best case scenario the SOPs are applied thoroughly throughout a geographic setting or country, and this would encourage the sector to utilise higher standards of industrial smelting as described in section 2.1. and the ideal reverse supply chain described in section 2.2.

It needs to be noted that the SOPs do not provide emission benchmarks and related measurement procedures (e.g. for lead, arsenic and sulphur dioxide). Many countries have such mandatory regulatory benchmarks (ILZSG 2014) and these SOPs shall by no means replace them, or give rise to the impression that national emission monitoring and benchmarks would not be required. Mandatory benchmarks, emission monitoring and process-oriented tools such as these SOPs are complementary methods designed to steer and regulate health, safety, and environmental aspects of ULAB management.

3.3 Use beyond Ghana

The SOPs provided in this document were primarily developed for the use in Ghana, but also with a view for wider use and uptake: ULAB management faces similar challenges in many countries, and – due to the quite uniform design of lead-acid batteries – optimized collection, transport and recycling patterns are also similar across the globe. Therefore, the SOPs may well serve other countries in their attempts to improve ULAB management and recycling. While the term *Standard Operating Procedures (SOPs)* goes back to the request of government organizations in Ghana, other countries may use the content under different heading (e.g. Technical Guidelines) whatever is appropriate in the given context.

In general, it is believed that the SOPs may be used on a voluntary basis but may also be rendered a mandatory nature through adoption of complementary regulation.

3.4 Format & structure

Each aspect is classified either under 'general requirements' (all sheets with an A-number), or 'technical requirements along the recycling process' (all sheets with a B-number). The sheets are structured in a unform manner as illustrated and explained in Figure 4.

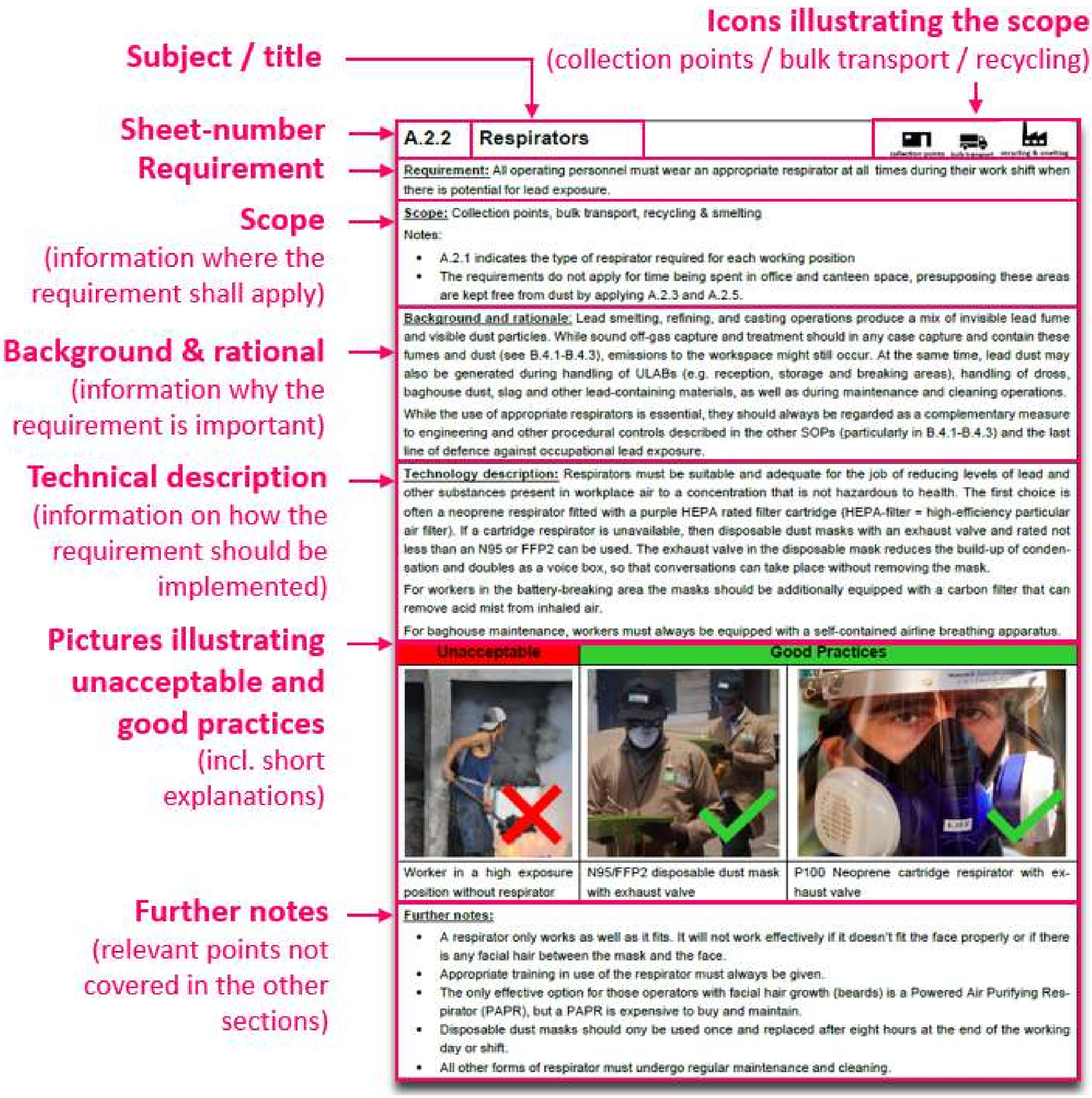

Figure 4: Structure of SOP sheets

It is important that not all sheets and requirements do apply to all parts of the reverse supply chain. The related information is given under 'scope' and in the graphical icons in the upper right part of each sheet. An overview on the scopes of SOP-sheets is given in Table 3.

Table 3: Overview on the scopes of SOP-sheets

SOP-number and topic		Applicable scope		
		collection points	bulk transport	recycling & smelting
A.1.1	Location of plant			X
A.1.2	Licences & permits		X	X
A.1.3	Community & stakeholder interaction			X
A.2.1	Personal protective equipment (PPE)	X	X	X
A.2.2	Respirators	X	X	X
A.2.3	Amenities			X
A.2.4	Personal behaviour	X	X	X
A.2.5	Housekeeping (incl. cleaning & dust control)	X		X
A.2.6	Occupational health surveillance			X
A.2.7	Blood lead testing			X
A.3.1	Safety policy	X	X	X
A.3.2	Regular safety inspections & audits	X	X	X
A.3.3	Safety & hygiene training	X	X	X
A.3.4	Health & safety risk assessments	X	X	X
A.3.5	Accident & incident records & investigations	X	X	X
A.3.6	Permit to work & lock-off system for maintenance			X
A.3.7	Fire precautions & emergency response plan	X	X	X
B.1.1	ULAB storage	X		X
B.1.2	Packaging for bulk transport	X	X	
B.1.3	Bulk transport of ULABs		X	
B.2.1	Battery breaking			X
B.2.2	Desulfurization			X
B.2.3	Furnace technology			X

B.2.4	Furnace charge preparation			X
B.2.5	Furnace charging			X
B.2.6	Smelting			X
B.2.7	Furnace tapping			X
B.2.8	Lead refining & alloying			X
B.2.9	Casting refined lead & leads alloys			X
B.3.1	Management of battery electrolyte	X	X	X
B.3.2	Recycling of plastic cases			X
B.4.1	Filter plant / baghouse & off gas treatment			X
B.4.2	Management of baghouse dust and fume			X
B.4.3	Monitoring & maintenance of baghouse filter plants			X
B.4.4	Management of furnace residues (slags)			X
B.4.5	Management of effluents			X
B.4.6	Management of other wastes	X	X	X

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Standard Operating Procedures for Environmentally Sound Management of Used Lead-acid Batteries

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A.1.1	Location of plant	recycling & smelting

Requirement: A ULAB recycling plant must be located at a site that minimises the risk of population lead exposure and/or environmental contamination.

Scope: Recycling & smelting

Background & rationale: Site selection is a key requirement for any ULAB recycling operation and is essential to minimise the risk of environmental and population lead exposure. Most important is to avoid proximity to any existing farmland, residential areas, businesses, or organisations, such as a hospital, schools or food and related processing plants. Site selection must also take local climate and topography into account to minimise risks from flooding, landslides, rock falls, avalanches, and tidal surges. Site selection must also ascertain the utility and energy requirements and availability because certain fuels, such as gas or oil, may not be readily available, and electricity, may be unreliable.

Technical description: For selecting the location for a ULAB recycling plant, the following criteria should be adopted:

- Note the previous or current use of the site to avoid building a smelter over an underground mine or an abandoned hazardous or municipal waste dump with unstable ground.
- Where possible, select a designated industrial zone with a protected cordon where other functions (e.g. residential houses, hospitals, and schools) cannot be built. If an industrial zone is unavailable, select a brownfield site that has been remediated such that any legacy hazardous waste issues have been addressed.
- A ULAB recycling plant may be constructed on contaminated ground (e.g. previous smelting activities), but it is recommended to thoroughly assess and document prior contamination levels, with a view to remediation and also check site stability for subsidence.
- An alternative to an industrial zone or brownfield site is to choose a location with an already existing lead battery manufacturing plant, because the environmental and health issues associated with lead emissions and discharges will already have been dealt with and the site licensed for lead use.
- The plant's road transport links must be suitable for heavy haulage of ULAB's and dispatching of lead ingots.
- Avoid sites that have fauna or flora sensitivities or features that cannot be disturbed, such as nesting sites or animal and bird migrating routes.
- Ensure that any prospective site is not located upstream or close to a groundwater source or an aquafer used to supply drinking water.
- Do not build a lead smelter in a valley where fugitive air emissions might be trapped under certain unfavourable weather conditions.
- Do not select a location in a flood plain unless the site and access roads are above the flood plain.
- Make sure that the area selected is stable and not subject to seismic activity, such as earthquakes, sink holes, erosion, landslides and volcanic eruptions.
- Avoid sites where there are options for or possible future encroachments of residential housing or farming.

For existing ULAB recycling plants that do not comply entirely with the above criteria, solutions must be found that might involve (but might not be limited to) civil engineering work to improve ground stability, improving access roads, enclosing the smelting and refining operations and so on, and adopting mitigating measures to possibly relocate other functions by mutual consent with affected communities or people; relocating plant and conducting a thorough site remediation.

<table>
<tr><th>Unacceptable</th><th>Good Practice</th></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td>A ULAB recycling plant is located adjacent to a densely populated residential area, which is unacceptable as fugitive air emissions will directly impact the health and wellbeing of the local community.</td><td>A ULAB recycling plant located in a designated industrial zone and well removed from residential areas. The surrounding land is not used for agriculture.</td></tr>
<tr><td colspan="2"><u>Further notes:</u> -</td></tr>
</table>

A.1.2 Licences & permits

bulk transport recycling & smelting

Requirement: ULAB recycling plants should only operate with valid business, environmental, health & safety licences / permits in accordance with the prevailing national and local laws.

Scope: Bulk transport, recycling & smelting

Background & rationale: Licencing / permitting of industrial activities is a core element of environmentally sound management because it ensures that mandatory standards and benchmarks on issues such as tax payment, emission controls and health and safety are adhered to. Licencing / permitting procedures also have the dual function that:

- Responsible government agencies can assess and confirm compliance with statutory requirements.
- That – by issuing/extending a licence – responsible government agencies and inspectors fulfil the co-responsibility that all necessary health, safety and environmental (HSE) safeguards have been met.

Technical description: The various types of required licences (sometimes also referred to as 'permits') and the processes necessary to obtain and extend these licences are subject to national legislation and will vary from country to country. Operating a secondary smelter/ULAB recycling plant, most countries require licences for business, fire, environment and health & safety. Additional licences may be needed depending on specific national legislation (e.g. licences for food standards if a canteen is provided).

Licencing is needed for industrial activities (e.g. ULAB recycling) and commonly also for companies or individuals involved in bulk transportation/shipment of ULABs. For such ULAB transportation, vehicles usually must be licenced to carry hazardous waste. Exemptions may be possible, e.g. where ULABs are being transported in UN approved leakproof containers (see B.1.1).

Before the start of the operation, granting an environmental licence is typically conditional to the completion of an Environmental Impact Assessment (EIA) that identifies potential risks and adverse impacts on the environment, and effective design measures to mitigate these risks. While Environmental Impact Assessments are an important tool, they are prepared during the planning phase and are not operational health, safety and environmental (HSE) assessments.

Therefore, most countries require periodic renewal of licences (1 to 5 years) and use conformity assessment inspections (also referred to as 'audits') to gain insights into day-to-day operations and the level of compliance with applicable health, safety and environmental (HSE) standards and benchmarks.

In general, a licencing procedure entails shared responsibilities:

- It is the responsibility of the ULAB transport company or secondary smelter / ULAB company to plan and conduct operations in line with national legislative requirements (including a site decommissioning plan), and to submit applications complete with all necessary supporting information.
- It is the responsibility of the authorities to process the licence application in time and to thoroughly check if all requirements are met, which should require thorough inspection of facilities, processes and operating practices.

The granting of a licence also means that the designated regulatory authority confirms that operations are in-line with their specific legislative requirements and that it is convinced that – provided the licenced procedures are followed – the operations are safe and will not cause any harm to human health or the environment.

Good Practice

Government inspectors during a HSE compliance verification audit. Thorough physical inspections like this are an indispensable element of compliance verification and the process of granting/extending operating licences.

Further notes:

- When applying for, and issuing a license for a ULAB recycling plant, it is essential to also consider sufficient and licenced disposal facilities for hazardous furnace slags (see B.4.4). In case such approved disposal facilities are not available in a given setting, the recycling plant must work with local authorities to facilitate the provision of appropriate and approved disposal facilities.
- To estimate the required disposal capacities for furnace slags, the following rule of thumb can help in the planning and licensing stage: Recycling and smelting of 1,000 t of ULABs generates between 250 and 350 t of slags. Therefore a secondary smelter / ULAB recycling plant with a planned capacity of 12,000 t/a requires slag disposal capacities for 36,000 t for 10 years of operation.

A.1.3	Community & stakeholder engagement	recycling & smelting

Requirement: Local communities and potentially affected stakeholders shall have access to information about the recycling processes, associated HSE risks and the mitigation measures in operation. Moreover, they should have the opportunity to articulate any concerns at any time in the life of the recycling plant in an open and anonymised way.

Scope: Recycling & smelting

Background & rationale: ULAB recycling is a heavy industry and numerous past cases of environmental pollution and population exposure can give rise to concerns over potential adverse health effects to local populations and/or workers from neighbouring industries, as well as negative impacts on ecosystems and livelihoods. Also, traffic to and from a recycling facility can be a matter of concern for communities living close to access roads. Such concerns must be taken seriously and an appropriate mode of community engagement is required where local communities and other potentially affected stakeholders can raise their concerns and where the recycling company can address the issues in a transparent and honest manner that provides insights into its industrial activities and pollution control measures.

For individuals that live or work in proximity to a facility, or downstream of prevailing winds or water run-off, regular community blood lead testing should be considered (see A.2.7) as part of a community engagement program.

Stakeholder engagement should also entail interaction of ULAB recyclers with their supply chain (transporters, collection points) to ensure that ULAB deliveries comply with B.1.1-B.1.3 so that all batteries are delivered intact (with electrolyte) and correctly packed.

Technical description: The mode of community and stakeholder engagement will vary depending on the cultural background, sensitivity and location of the facility. In general, communication media must be chosen that are accessible to all stakeholders, and where all parties feel at ease. Stakeholder engagement shall be made through periodic consultation and information events (e.g. townhall meetings), and with interactive systems were stakeholders can retrieve information and file requests and concerns in a personal and anonymised form (e.g. via an ombudsman or an online portal).

It is important that stakeholder concerns are taken seriously and that measures are taken to mitigate them. It is paramount that control measures described in A.2, A.3 and B.1-B.4 are central elements in this context. In many regions regular facility perimeter particulate lead in air (and any other hazardous substances) monitoring is required as part of the site permitting process. Further analytical measures such as monitoring surface water quality and soil sampling and testing may be conducted, and the results of all such monitoring made public in case related concerns have been raised. To ensure credibility and transparency all sampling and analytics should be conducted by independent third parties using approved scientific sampling and measurement procedures. Beyond this, also free periodic community blood lead testing should be considered to be offered to individuals that live or work in proximity to the facility, or downstream of prevailing winds or water run-off (see A.2.7).

With regards to interaction with ULAB suppliers, the plant management must clearly specify the expectation that ULABs will be delivered with acid and correctly packed (in line with B.1.2 and B.1.3).

Good Practice

Public health specialists working with the plant management and addressing a local community group that are concerned about the potential adverse health effects of emissions and discharges from a nearby ULAB recycling plant. The most important aspect of community relations is to listen to any concerns and in response, be honest and take all necessary measures to reassure local populations that their health and wellbeing is important.
Further notes: -

A.2.1	Personal protective equipment (PPE)	collection points · bulk transport · recycling & smelting

Requirement: All operating personnel must wear appropriate personal protective equipment during their work shift. Any visiting/office personnel must also wear appropriate PPE if there is potential for lead exposure.

Scope: Collection points, bulk transport, recycling & smelting

Note: The requirements do not apply for time being spent in any administration offices or a canteen, presupposing these areas are free from lead dust by applying A.2.3 to A.2.5. Also, during ULAB transportation, PPE does not need to be worn constantly but should be available for all situations where ULABs are handled.

Background and rationale: Recycling of lead batteries is a heavy industry with multiple hazards for operating personal. While these hazards can be mitigated by a broad variety of measures described in this document, appropriate personal protective equipment (PPE) is indispensable. Dependent of the workers' tasks and position, PPE will afford a degree of protection from lead dusts and fumes, acid, heat, falling objects, noise and any other potential physical impacts.

Technical description: The following table specifies the recommended PPE combination for each process, operation or maintenance task:

Process / working position	Respirator[1]				Works Clothing				Head Gear			Gloves				Footwear		Others		
	Neoprene respirator with dust cartridges[2]	Neoprene respirator with dust cartridges or dust mask[3]	N95/FFP2 with carbon filter	Self-contained air-line BA	Long-sleeved cotton drill	Long-sleeved cotton drill with plastic apron	Long sleeved cotton drill with leather apron	Waterproof full body coverall	Safety helmet (Hard hat)	Bump hat	Full body coverall with integral hood	Nitrile gloves	Foundry gloves	Heat resistant gloves	Rigger gloves	Boots with steel or carbon fibre toe protection	Waterproof boots toe protection[4]	Safety goggles, glasses or visor	Sealed face visor	Ear defenders
Administration[5]																				
ULAB collection, packaging, transport		X			X							X				X		X		
ULAB reception		X			X				X			X				X		X		
ULAB breaking		X	X			X			X			X					X	X		X
Charge preparation	X				X				X[8]						X	X		X		X
Smelting	X						X		X[8]				X			X		X		X
Refining and casting		X			X				X					X		X		X	X	X
Recycling plastic cases		X			X				X			X				X		X		X[6]
Effluent treatment plant					X				X			X					X	X		
Baghouse maintenance[7]				X				X			X	X				X			X	
Housekeeping		X			X				X[8]	X[5]					X	X		X		

1 See A.2.2 for more details
2 Rated at least P2
3 At least P2 or N95/FFP2
4 Toe protection by steel or carbon fibre
5 In case administration staff enters any part of the recycling plant, the PPE requirements of this plant section also applies to administrative / visiting personnel
6 For personnel operating at or close to a shredder
7 Note: The baghouse should never be entered by any personnel for any other reason than maintenance
8 Depending on the circumstances: Safety helmet for all operations in areas with overhead mobile equipment, such as a crane or hoist

Unacceptable	Good Practices	
		
Furnace operator charging a furnace without appropriate PPE: that is - no dust respirator, no leather apron, no head cover of any description, no safety goggles and he is also wearing badly fitting trousers that might impair movement in the event of an emergency evacuation.	Worker in the ULAB breaking section wearing long sleeved overall with plastic apron, nitrile gloves, safety helmet with visor, waterproof safety boots (not shown) and a neoprene cartridge dust respirator fitted with a carbon filter to protect the operator from any acid mist as well as lead dust.	Maintenance engineer prepared to enter a baghouse to check the filter bags wearing an impermeable full body coverall with integrated hood, gloves and leggings, waterproof boots (not shown), a full face mask attached to self-contained breathing apparatus.

Further notes:

- It is important that PPE are provided to workers and visitors for free and in sufficient numbers
- Each worker should have his/her own set of PPE
- Appropriate training must be given on the correct use of PPE.
- Trousers should always be worn outside the boots so that dust, objects and liquids cannot get into the boots. Additionally, spats may be used for that purpose in critical positions such as lead smelting.
- PPE shall be regularly cleaned, maintained and replaced if needed
- PPE shall be washed after every shift (apart from disposal dust marks that should be replaced after at each shift (see A.2.2)
- Contaminated PPE should never be taken home by the employee
- Signs should be displayed that describe the PPE requirements in each operating area

A.2.2	Respirators	collection points · bulk transport · recycling & smelting

Requirement: All operating personnel must wear an appropriate respirator at all times during their work shift when there is potential for lead exposure.

Scope: Collection points, bulk transport, recycling & smelting. Notes:

- A.2.1 indicates the type of respirator required for each working position. This sheet provides further details to support the correct choice of respirator and its application.
- The requirements do not apply for time being spent in office and canteen space, presupposing these areas are kept free from dust by applying A.2.3 and A.2.5.

Background and rationale: Lead smelting, refining, and casting operations produce a mix of invisible lead fume and visible dust particles. While sound off-gas capture and treatment should in any case capture and contain these fumes and dust (see B.4.1-B.4.3), emissions to the workspace might still occur. At the same time, lead dust may also be generated during handling of ULABs (e.g. reception, storage and breaking areas), handling of dross, baghouse dust, slag and other lead-containing materials, as well as during maintenance and cleaning operations.

While the use of appropriate respirators is essential, they should always be regarded as a complementary measure to engineering and other procedural controls described in the other sheets (particularly in B.4.1-B.4.3) and the last line of defence against occupational lead exposure.

Technical description: Respirators must be suitable and adequate for the job of reducing levels of lead and other substances present in workplace air to a concentration that is not hazardous to health. The first choice is often a neoprene respirator fitted with a purple HEPA rated filter cartridge (HEPA-filter = high-efficiency particular air filter). If a cartridge respirator is unavailable, then disposable dust masks with an exhaust valve and rated not less than an N95 or FFP2 can be used. The exhaust valve in the disposable mask reduces the build-up of condensation and doubles as a voice box, so that conversations can take place without removing the mask.

For workers in the battery-breaking area the masks should be additionally equipped with a carbon filter that can remove acid mist from inhaled air.

For baghouse maintenance, workers must always be equipped with a self-contained airline breathing apparatus.

Unacceptable	Good Practices	
		
Worker in a high exposure position without respirator	N95/FFP2 disposable dust mask with exhaust valve	P100 Neoprene cartridge respirator with exhaust valve

Further notes:

- A respirator only works as well as it fits. It will not work effectively if it doesn't fit the face properly or if there is any facial hair between the mask and the face.
- Appropriate training in use of the respirator must always be given.
- The only effective option for those operators with facial hair growth (beards) is a Powered Air Purifying Respirator (PAPR), but a PAPR is expensive to buy and maintain.
- Disposable dust masks should ony be used once and replaced after eight hours at the end of the working day or shift.
- All other forms of respirator must undergo regular maintenance and cleaning.

A.2.3	Amenities	recycling & smelting

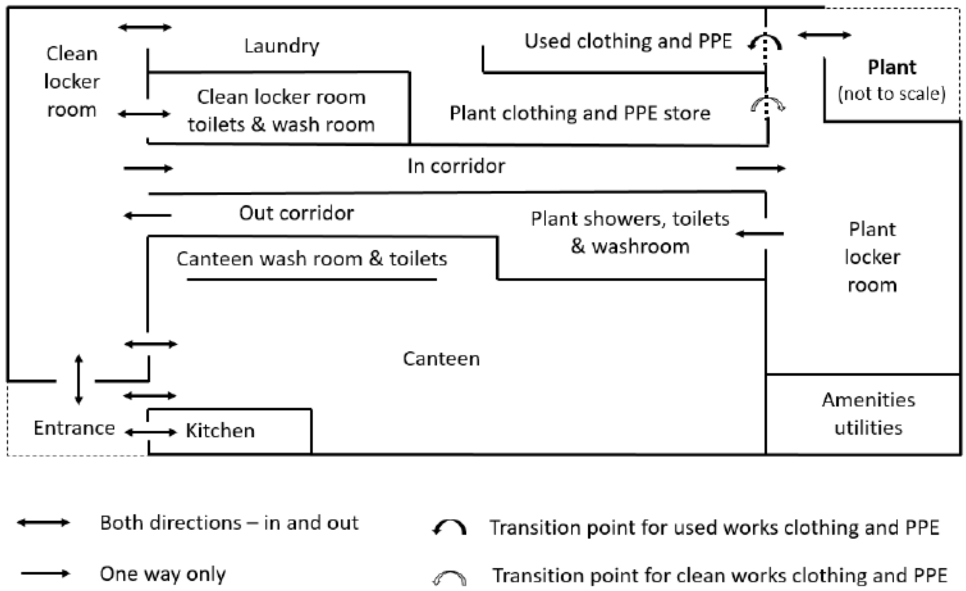
Requirements: The facility must provide an amenity block with changing rooms and washing facilities that effectively prevent lead dust from being transported from the factory to the clean areas (such as the canteen, office buildings and areas outside the plant) on working clothes and/or adhesion to hands and hair. An in-house laundry must ensure that workers are provided with clean working clothes at the beginning of every day or shift.

Scope: Recycling & smelting

Background and rationale: In the factory area, workers are commonly in contact with lead particulates when working with ULABs or any associated recycling processes. Lead particulates attach to working clothes, body and hair. If changing rooms and washing facilities are not provided and used, such “take-away lead” contaminates canteens, resting areas and also the homes of workers and their families.

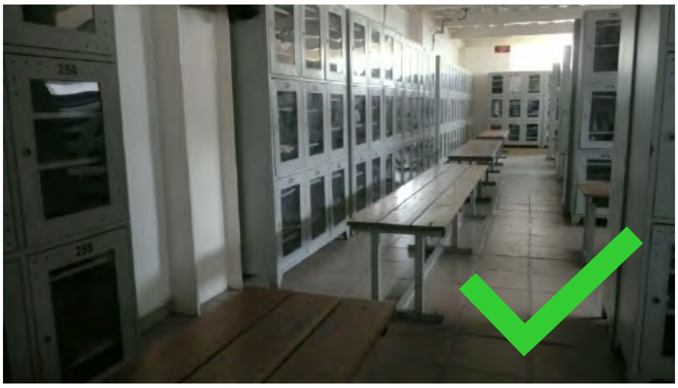
Technical description:

- All workers must change into fresh working clothes on arrival at the factory and lock their private and clean clothes into a safe and uncontaminated space in the clean section of the change rooms.
- At the end of the working day/shift, workers must take off their dirty working clothes (to be cleaned in an inhouse laundry) shower and change back into their clean private clothes.
- It is important that the changing room and shower facilities are arranged in a way that clean private clothes and contaminated working clothes are never mixed. A suitable changing room layout is provided below.
- Male and female change rooms and showers must be separate and segregated.
- Workers must be provided with clean towels and soap in sufficient numbers and quantities.
- For meal breaks, workers should ideally go through the same changing and showering-process or change into a clean canteen overall. Under no circumstances should workers enter a canteen with contaminated working clothes and without washing their hands and face.



The one-way system layout above ensures that all workers entering the facility can take off their personal clothing and lock them away with their belongings before putting on fresh works clothing provided by the in-house laundry. When leaving the factory workers must pass through a shower before gaining access to their clean personal clothing. One-way turnstiles can be installed to ensure personnel follow the correct pathway through the changing rooms.

The canteen must be kept clean and tidy and – as illustrated in the sketch above – only accessible from the plant after taking a shower and changing into clean clothes. Canteens shall be equipped with an air conditioner with a high-efficiency particulate air filter (HEPA-filter) that generates a slight excess pressure. Such a system effectively prevents dust contaminating the canteen when doors are opened.

Unacceptable	Good practices
	 
This changing room is provided for workers but is not equipped with any lockers or a shower and in the absence of any one-way system there is every prospect that contaminated working clothes will come into contact with clean clothes. Workers at this plant are required to wash their own works clothing themselves, and drying the clothing in the open air on site can never replace the quality and reliability of a central in-house laundry	The first picture is the locker room on the plant side of the changing room. The lockers have glass windows so that the workers can see if all the required PPE has been replenished since the previous shift and if not return to the safety store before changing into works clothing. The second picture is the shower section of a changing room. Entry is from the plant side locker room. The exit from the showers leads to the clean side change room.

Further notes:

- It is recommended that the amenity block includes the kitchen, canteen, plant clothing store and in-house laundry for working clothes and PPE (see layout above).
- In addition to changing rooms and washing facilities as described above, emergency eye wash station and/or shower must be installed close to factory sections where workers may be contact with battery acid and/or high levels of lead dust (also see B.2.1).
- It is important that workers are properly educated on the importance of maintain high levels of personal hygiene. Pictograms and repeated training can help to raise and keep up awareness (see A.2.4).

A.2.4 Personal behaviour

collection points, bulk transport, recycling & smelting

Requirement: All personnel working in or visiting a facility where ULABs are handled should behave in a manner conducive to their health and safety and of their colleagues.

Scope: Collection points, bulk transport, recycling & smelting

Background and rationale: Each phase of ULAB management carries inherent health and safety risks, but the risks can be reduced if operators and anyone visiting a facility where ULAB breaking/smelting/refining are managed adopt personal behaviours that are conducive to safe and hygienic operations.

Technical description:

The following rules are paramount for any person working at or visiting a facility where ULABs are managed:

1. Wear the correct respirator for the job and ensure a good seal around the face and nose (see A.2.2).
2. Face masks are ineffective if the wearer has facial hair, so clean shaven is the preferred option, but if that is not possible, then the wearer must use an airstream helmet or equivalent
3. Wear appropriate clothing for the job and never work on or visit a ULAB recycling plant in home going clothes (see A.2.1)
4. Keep hands clean and fingernails short so as not to harbour any lead dust in the pores or under the nails.
5. Arrive at the plant for work having eaten a meal within the previous hour - lead dust is more readily absorbed by an empty stomach.
6. Wear clean work clothes every day or shift and never work or tour the plant in clothes worn at home.
7. Leave workwear at work, never take any works clothing or PPE/safety equipment home
8. Shower after every shift or at the end of the day and wash with soap or shower gel.
9. Apply lead risk control measures when working by following the correct working procedures and keep the workplace clean, dust-free and tidy.
10. Always comply with safe working practices, such as tethering ladders, never entering a confined space without a banksman or working at heights without a harness.
11. Never sweep up dust with a broom. Use a hose and water or a local vacuum unit with a HEPA filter (see A.2.5).
12. Do not wear contaminated work clothes in the canteen.
13. Wash hands, arms and face with soap and water before eating and drinking
14. Ensure that you drink enough so that you are hydrated at work
15. When at work, do not smoke, drink alcohol or take drugs other than those prescribed by a medical practitioner.
16. Attend appointments for medical surveillance as required (see A.2.6 & A.2.7).

Unacceptable	Good Practices	
		
Work clothing washed and drying in a contaminated factory environment	Washing hands (and also arms and face) with soap and water before eating and/or drinking	Shower and change out of works clothing after work so that you leave the plant in clean personal clothing. Note: In the left picture, mask and goggles are not applied correctly

Further notes:

- There are numerous interlinks with related aspects, including those laid-out in A.2.1, A.2.2 and A.2.3

A.2.5 Housekeeping (incl. cleaning & dust control)

collection points recycling & smelting

Requirement: The facility must be kept clean at all times, and dust accumulation must be prevented in all parts of the facility. This is achieved through a combination of level, easy to clean factory floors, uncluttered site arrangements, correct storage of chemical and scrap, regular wet cleaning and dust capture. Vehicles must also be cleaned to remove any residual dust before leaving a recycling plant.

Scope: Collection points, recycling & smelting

Background and rationale: Uptake of lead dust through inhalation or hand-to-mouth behaviour (e.g. eating, smoking…) is a significant pathway for occupational lead exposure for workers and persons visiting a ULAB collection point or recycling plant. Second, only to effective emission controls (see B.1- B.4) and hygiene measures (see A.2.1 - A.2.4), a clean factory environment is an essential requirement to minimise lead exposure. Wet cleaning techniques must be employed to avoid stirring up dust, which will increase short- and mid-term occupational exposures. Cleaning efforts should also anticipate potential battery electrolyte (dilute sulphuric acid) spills and make sure nobody comes into contact with such spills. By cleaning all vehicles leaving a recycling plant, the dispersion of lead dust into the surrounding environment is prevented.

Technical description: All areas of the facilities need to be equipped with a smooth but slip-proof impermeable floor that allows thorough wet cleaning. The floor covering must be free from any cracks to avoid the accumulation of dust particles. A liquid capture and drainage system must ensure that no cleaning fluids leave the plant untreated. All areas of the facility need to be kept tidy with no unnecessary equipment and material placed/stored in a walkway or mobile plant drive through, as this will complicate cleaning measures and allow dust accumulation in corners and niches. Ideally, working areas should be kept permanently damp so that dust particles stick to the ground and cannot be stirred up into the air.

Brooms must never be used to remove dust. Manual or mobile ride on dry and wet vacuum equipment is required (see picture).

Outgoing vehicles should be cleaned with high pressure water hoses with a particular focus on cleaning the vehicles tires.

Cleaning water must be treated in the facility's effluent treatment plant to avoid lead or acid discharge to the environment (see B.4.5). In collection centres that do not have an effluent treatment plant, hazardous effluents and dusts must be captured and sent to ULAB recyclers for treatment.

Integrated ride on dry and wet sweeper with HEPA filter.

Unacceptable		Good Practice
		
There is a significant and unacceptable accumulation of dust in the facility. Every movement of labour and machinery inevitably stirs up dust and exposes workers to lead. Further shortcomings are linked to the absence of designated storage areas and walkways, hence the chaotic storage of materials (e.g. lead ingots) is leading to more dust accumulations.	The factory floor is uneven and broken, thereby not allowing thorough wet cleaning. In addition, materials and equipment are stored in an unorganised manner without adequate separation to facilitate thorough cleaning making dust control virtually impossible.	The floor is level, smooth but slip-resistant, clean, dust-free and has just been damped down. Walkways, storage areas and mobile plant drive-throughs are clearly marked with yellow lines. Equipment, by-products and materials are all stored in their designated areas, thereby providing easy access to the area for cleaning and obstruction-free exit in the event of an emergency evacuation.

Further notes:

- In the battery breaking area, the floor must also be acid-resistant.
- To avoid any dust leaving the factory, the building can be set under negative pressure so that any contaminated air will always be directed into the facility (e.g. through doors). The outgoing airstream should be filtered, and the dust collected and recycled through the plant's furnace.

A.2.6	Occupational health surveillance	recycling & smelting

Requirement: All employees shall be offered an annual medical examination. In the case of employees' health issues related to their occupational activities, root causes must be identified and mitigated, and medical support, advice and, where necessary, treatment given.

Scope: Recycling & smelting

Background and rationale: ULAB recycling is a heavy industrial activity with numerous processes that may cause detrimental effects to the health of employees (also including part-time workers). Although compliance with the requirements of A.2.1-A.2.5, A.3.3 and B.1 - B.4 will minimise or mitigate health risks, health surveillance or monitoring is essential to ensure that all risk management measures are effective. Occupational health monitoring will also help ensure that any work-related health issues do not worsen and that employees receive adequate medical treatment.

Technical description: Occupational health monitoring starts with a medical examination and a documented record of any health issues upon initial employment. Such an initial examination is required to generate a health baseline that will allow qualified medical staff to differentiate occupational-related health issues from activities and issues that might have been present before engagement.

Regular follow-up health monitoring with a frequency of 6-12 months should be offered to all employees. Health monitoring must be conducted by a qualified occupational health specialist (medical doctor, nurse) and the services should be provided free of charge maintaining patient record confidentiality.

Occupational health monitoring may be combined with blood lead testing (see A.2.7) but shall not replace it. Medical records shall be made available to the examined persons and be filed by the medical team. In case of identified health issues related to occupational activities, facility management must be informed in a way that preserves the dignity and privacy of the employee/patient(s).

Workers with medical issues related to their occupational activity should be protected and found suitable alternative remedial employment as far as is practical and receive appropriate medical support and treatments. In addition, efforts must be taken to address the root causes of the issues and in line with A.3.2 to A.3.5.

Good Practice

Lead can cause many adverse health issues and so the key to managing the health of workers is to reduce their exposure and also promote healthy lifestyle choices.

Offering regular medical check-ups for all workers is the key to managing their wellbeing and ensuring that the workforce is in the best physical and mental condition to contribute to the success of the business.

Further notes:

Exposure to lead is a major occupational health risk in ULAB recycling plants. Next to blood lead testing (see A.2.7), the following symptoms can help to identify exposure:

- Lack of appetite and loss of weight
- Nausea
- Feeling of weakness/fatigue
- Pain or tingling in the hands and/or feet
- Abdominal pain
- Diarrhoea
- Constipation
- Impairment of liver and kidney functions
- Low haemoglobin
- High blood pressure

A.2.7 Blood lead testing

recycling & smelting

Requirement: All employees must undergo periodic blood lead testing. In case one or more employees feature elevated blood lead levels, immediate action must be taken to reduce lead exposure.

Scope: Recycling & smelting

Background and rationale: Blood lead levels are the most reliable indicator of occupational lead exposure. Regular and systematic measurement and documentation of worker blood lead levels enable identifying any shortcomings in engineering, emission controls, PPE function, industrial hygiene or working practices. Elevated blood lead levels are an important warning that should trigger a review of workplace risk management processes and hygiene measures. In some cases immediate action may be necessary to ensure workers with elevated lead in blood levels are removed from further lead exposure to mitigate risk of any severe long-term adverse health impacts.

Technical description:

Blood lead tests must be conducted for all personnel working in a ULAB recycling facility. Frequency of blood lead testing shall depend on the working position and associated risk of lead exposure and whether an alert level has been exceeded during the previous blood samples.

Working position and risk level		Recommended minimum test interval	Recommended minimum test interval after exceeding an alert or limit value
High risk	Workers in battery breaking area, lead smelting, melting and refining, around off-gas treatment systems, and in maintenance work of related equipment, especially baghouses	3 months	1 month
Medium risk	All other workers in battery recycling	3-6 months	1 month
Low risk	Office jobs, canteen and laundry	6-12 months	1 month

Blood lead test results shall be documented and made available to the medical officer or nurse (see A.2.6), the person tested and the company management (respecting patient confidentiality). Anonymised records of blood lead test results must always be available to be presented to inspectors of responsible authorities.

It is recommended that the monitoring system uses alert and limit values, where defined corrective actions are to be taken to avoid further lead exposure to individuals that could be damaging to their health. In case there are no national benchmarks for occupational blood lead levels, it is recommended to apply at least the following, additionally linked to a continuous improvement program to bring levels to international norms.

Benchmark levels		Required actions
Alert level	>20 µg lead /dL blood	Work practices and potential lead exposure pathways should be carefully assessed and immediate action taken to reduce exposure
Limit value	>30 µg lead /dL blood	In addition to the action above, it should be accessed whether it is necessary to assign the individual to a task or job with a significantly lower risk of lead exposure until their blood lead levels have normalised

It must be noted that the levels above only apply to adults and not to women of child-bearing age. Children should under no circumstance work or be present in a ULAB recycling facility. Care should be taken to limit lead exposure of women of child-bearing age to an absolute minimum, ideally not exceeded the levels of the general population, that is, not above 5 µg lead /dL blood.

Workers with elevated blood lead levels should be protected against dismissal and receive appropriate counselling, guidance, retraining where necessary and health treatments if appropriate.

Only trained medical professionals should be involved in employee blood sampling and care should be taken to protect against transmission of blood born disease. Accredited test laboratories employing appropriate quality control procedures should be used to analyse blood samples. If there are no testing capacities available in a country, field testing equipment can be used as a temporary measure.

Good Practice	
	
Venous blood sampling and laboratory analysis using atomic absorption spectrometry by an accredited and QC controlled laboratory is the best method of testing for lead in employee blood. In the absence of such facilities, testing in-house using a portable testing kit such as the LeadCare II could be considered.	LeadCare II allows rapid testing on-site and requires only a simple finger stick at the point of care. It can be used as a screening method that does not require skilled laboratory personnel for its operation. It can be used when transport of blood samples to an appropriate reference laboratory is difficult.
Further notes: • In case it cannot be avoided that a ULAB recycling facility is located in proximity to residential areas (see A.1.1), the plant could offer blood lead testing to local residents.	

A.3.1 Safety policy

collection points | bulk transport | recycling & smelting

Requirement: A safety policy must be in place that outlines the working practices and procedures necessary for a safe working environment in all parts of the operation.

Scope: Collection points, bulk transport, recycling & smelting

Background and rationale: The primary objective of a safety policy is to prevent or reduce the risk of accidents and injuries in the workplace. Accordingly, the policy must set out how all the required working practices and procedures are designed to protect those involved directly or indirectly with the recycling of ULABs. Registered businesses in most countries are required by law to have an effective safety policy. The key to an effective safety policy is its implementation through various communication, training and inspection activities.

Technical description: A safety policy has three main sections:

1. **Statement of intent**: States the safety policy objectives in the workplace and includes a commitment by the company or organisation to provide a safe place of work, in line with the objectives.
2. **Responsibilities**: Identifies the roles and responsibilities of employees in the company or organisation for implementing the safety policy and monitoring performance. The section should list:
    a. Names of those with specific safety responsibilities and contact details
    b. Contact details for emergency services, e.g., fire, police and ambulance
3. **Policy Implementation**: Details of the procedures and arrangements explaining how the objectives of the safety policy will be achieved, including:
    a. A description of how the safety policy will be displayed and implemented in and around the work-place
    b. A description of how safety signs relevant to the job or equipment on site will be displayed
    c. Written instructions for safe working for every job or task
    d. A list of the appropriate safety equipment (incl. PPE) to be issued and mandatory used for every job or task
    e. Specific plans for regular safety inspections, audits and hazard spotting and reporting (A.3.2)
    f. Provision for induction safety training for all employees, contractors, and visitors (A.3.3)
    g. Tangible plans to provide off and on the job safety training for employees and contractors (A.3.3)
    h. Definitive plans to conduct risk assessments for every job and task in the ULAB recycling chain (A.3.4)
    i. Mandatory protocols for accident reporting and investigation (A.3.5)
    j. A protocol for maintenance of the plant and power Lock-Off (tag out) procedures (A.3.6)
    k. A description of essential measures for fire and explosion prevention (A.3.7)
    l. A description of the provisions for fire drills and training for first aid firefighting (A.3.7)
    m. An outline of a disaster plan and emergency evacuation procedures (A.3.7)
    n. Dates for the continuous review and update the safety policy
    o. Details of the company or organisation’s liability insurance
    p. An outline of the complaints procedure

It is important that the implementation of a safety policy is constantly monitored and reviewed, and subject to continuous improvement. Communication on the importance of safety at work needs to be a regular weekly activity for workers and a part of the standard induction procedure for visitors to the plant in an understandable language and presentation style. Safety trainings include an understanding about risk assessments, safety induction, safety inspections, accident reporting and investigations and fire drills.

<table>
<tr><th>Unacceptable</th><th>Good Practice</th></tr>
<tr><td>


</td><td>


</td></tr>
<tr><td>The company tries to absolve itself of any responsibility for the safety of the workforce or any person on the site. In most countries such a policy is illegal and companies are required to take responsibility for safety on site.</td><td>This company displays the Safety Policy, the Liability insurance certificate, the Fire and Emergency evacuation procedures, Safety news briefs, safety hints and advice, particularly with regards to hands. This notice board is updated every week.</td></tr>
<tr><td>


</td><td>


</td></tr>
<tr><td>The signboard asks operators to keep the factory clean, but only refers to littering of banana peels. The notice neglects the fact that eating should generally be prohibited anywhere in a ULAB recycling plant (apart from the canteen).</td><td>Safe working practices and the plant rules with regard to Personnel Protective Equipment (PPE) are presented at the entrance to the operating area in a clear, relevant, concise, and visible easy to read text.</td></tr>
<tr><td colspan="2"><u>Further notes:</u>
Important elements for safety policies are further specified in A.3.2-A.3.7.</td></tr>
</table>

A.3.2 Regular safety inspections & audits

collection points bulk transport recycling & smelting

Requirement: Regular internal site safety inspections and safety audits must be conducted.

Scope: Collection points, bulk transport, recycling & smelting

Background and rationale: Frequent safety inspections are an integral component of a Safety Management Program Safety inspections are a quick and effective way to identify workplace safety hazards. A safety audit provides an in-depth evaluation of the effectiveness, efficiency and reliability of the safety systems related to ULAB collection, transport and recycling.

Technical description: The persons carrying out internal safety inspections and audits must be trained to do so. In any case, safety inspections and audits should only be carried out in situations where it is safe to do so (see also A.3.6 on lock-off systems).

Safety Inspections should be carried out:

- By a person familiar with the operations, the process and the company safety policy
- Regularly and at least quarterly for every process or task (results to be reported and signed)
- When there is a change of equipment, new working practice and after plant maintenance
- Following an accident or near-miss
- In a manner that does not interfere with ongoing operations or maintenance
- At the place of work and not remotely from the office or any other offsite location
- With cooperation of the workforce
- Using a standardised and periodically reviewed safety checklist appropriate to the job, task, or process.
- When the plant, equipment or process is operating.
- During maintenance work to check the isolation and lock-off procedures
- Such that fire precautions, utility supplies and disaster plans (see also A.3.1) are included.
- To include a survey of the PPE in use
- So that each inspection is recorded and any safety issues resolved as a priority matter.
- In a manner that respects the workers and those personnel working on the site.
- Such that operators or engineers working in the area or on the process being inspected are given immediate feedback as to the outcome of the inspection.

Safety Audits should be carried out:

- At least on an annual basis for every process or task
- By safety specialists and, if necessary, an independent third party, e.g. when introducing a new item of plant, equipment or a new process.
- To ascertain whether all operations comply with applicable safety legislation and company policies.
- To check the effectiveness of operational training programs, including safety induction.
- To review the accident and near-miss statistics to identify trends or incident hot spots.
- So that the accident investigations are studied to ensure any issues arising are resolved.
- To make sure the workplace risk assessments and safe working procedures are up to date.
- So that each audit is recorded and any safety issues resolved as a priority matter.
- Such that any person responsible for resolving any safety issues identified during the audit is assigned

Good Practice	
	
A specified plant safety inspection is carried out every week on the job and in the workplace by a trained person who knows and understands the process and the working practices. The workers are also involved and provided with feedback and any recommendations to improve safety.	The company's safety audit takes an overview of the policy, the strategy and effectiveness by identifying the standards, collecting and collating all the safety data, comparing performance to the standards, making recommendations to improve performance and providing ongoing reviews and audits. Documents are made available for inspection.

Further notes:

- There is various supporting material to facilitate safety inspections and audits in industrial plants. Amongst others, guidance is given by the International Organization for Standardisation's standard on occupational safety (ISO 45001).

A.3.3 Safety & hygiene training

collection points bulk transport recycling & smelting

Requirement: All operations in the ULAB recycling supply chain must provide employees, contractors and visitors with a safety and hygiene induction before entering the workplace.

Scope: Collection points, bulk transport, recycling & smelting

Note: The level and content of the safety and hygiene induction will vary and depend on whether the person or persons are going to work on-site or visit the operation.

Background and rationale: A comprehensive safety and hygiene induction training ensures that workers and visitors are fully informed about the organization, the hazards, the risks, and personal responsibility to comply with the outlined company measures and procedures designed to protect them and all others on site. Safety and hygiene training should follow on a regular basis throughout employment.

Technical description: Safety and hygiene training should contain the following information:

- A brief explanation of the process and the site layout showing pedestrian and vehicle access routes.
- The Health and Safety Policy summarising key points for employees, contractors, and visitors.
- That it is every person's responsibility to follow the mandated health and safety rules when on site.
- An explanation of the specific risks applicable to employees, contractors, and visitors.
- An explanation of the Lock-Off / Isolation procedure and how it works for all employees (see A.3.6).
- An explanation of the safety signs around the site.
- PPE that must be worn, depending on whether the person is working at or visiting the site.
- A demonstration of how to wear the appropriate PPE correctly.
- An explanation of the changing system if the visitor or contractor is going onto the site.
- An explanation of how the meal and drinks break systems work.
- Policy on smoking, drinking alcohol or consuming recreational drugs when on site.
- An explanation of the emergency procedures and site evacuation process.
- A description on how to report illness, an accident, injury or near miss

At the end of the Induction training program

- Invite inductees to ask questions if further clarification is required.
- Check that the inductees have understood the rules and regulations.

Invite inductees to sign the induction register to confirm attendance and understanding.

Good Practice

Face to face interactive Safety and Hygiene Induction briefing allows the trainers to check for understanding and invite questions from the employees, contractors or visitors.	The Company's Safety and Hygiene Induction program should be comprehensive, structured, and sufficiently tailored to include the requirements and rules applicable to employees, contractors and visitors.
Further notes: -	

A.3.4 Health & safety risk assessments

collection points bulk transport recycling & smelting

Requirement: Health & safety risk assessments must be completed and available for every process or task in the ULAB management chain.

Scope: Collection points, bulk transport, recycling & smelting

Background and rationale: In many countries, health and safety risk assessments are a legal requirement. Practical risk assessments not only reduce the level of occupational lead exposure and the likelihood of incidents and accidents occurring, they also demonstrate to employees and external bodies, such as government agencies and communities within the immediate vicinities, that appropriate measures have been implemented to protect workers and anyone involved in the ULAB recycling process to provide a safe working environment and facility.

Technical description:

Definitions:

- Accident: an unplanned event that results in lost time, damage, injury, and may be fatal.
- Hazard: something that has the potential to cause harm in the short or long term.
- Risk: the probability of an incident and likely severity in terms of lost time, damage, injury or fatality.

The Six-Step Health and Safety Risk Assessment Process:

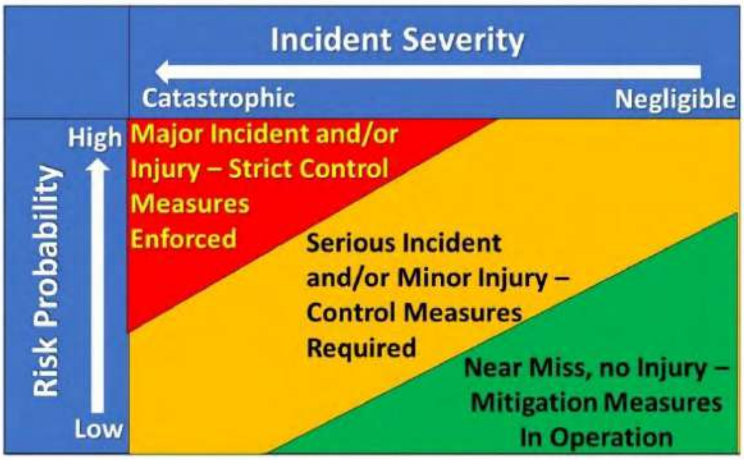
1) Identify and list the potential occupational health and safety hazards for each job or task.
2) Identify who might be harmed by the hazards, directly or indirectly, and how.
3) Evaluate the severity and probability of each risk.
4) Determine the necessary control or mitigation measures required to reduce or eliminate the risk.
5) Implement the control and/or mitigation measures and brief or train the workers.
6) Periodically review the risk assessments and the control/mitigation measures and revise if required.

The risk assessment should be documented and available for inspection.

Risk assessments are related (but not necessarily limited to) the following processes and working positions:

- ULAB manual handling (heavy lifting), temporary storage and packaging
- Transportation of ULAB
- ULAB reception and breaking.
- Smelting and refining operations.
- Vehicle and plant maintenance, including electrical installation and repairs.
- Working at heights and in confined spaces.
- Offices, particularly sedentary IT operations.
- Fire drills, firefighting, and emergency evacuation.

Good Practice



Risk Assessment Matrix

A risk assessment matrix, is a visual depiction chart that plots the Risk Probability from low to high on the vertical axis against the severity of any incident on the horizontal axis. Where the outcomes of a high risk incident falls in the red zone and can result in a major injury or catastrophic event, strict control measures must be enforced. Where the risk and severity assessments are in the yellow zone, control measures will be required and those in the green zone require mitigation.

Start the risk assessment process by identifying the health and safety hazards and risks; then list who will be affected and how; followed by a risk evaluation; then identify the control measures necessary to mitigate the risks; then the implementation and training phase, followed up by a periodic review and update as required.

Further notes:

The following form may be used to structure and document risk assessments:

Specimen Health and Safety Risk Assessment Form

Name of assessor						Date							
Time			Work area/Process										
Job / Task being assessed													
What are the hazards?	Who might be harmed?	How might workers be harmed?	Existing risk control measures	Risk rating			Additional control measures required	New risk rating (Residual)			Action required – date and responsibility	Risk Assessment Review Date	
				High	Med	Low		High	Med	Low			
Review date						Signature							

A.3.5	Accident & incident records & investigations	collection points bulk transport recycling & smelting

Requirement: All accidents and unplanned incidents must be recorded and investigated.

Scope: Collection points, bulk transport, recycling & smelting

Background and rationale: The purpose of accident and incident records and investigations is to improve health and safety performance by identifying and eliminating the immediate and underlying reasons for, or causes of an accident, an unplanned event that might have put workers at risk or damaged equipment. Ultimately, implementing the recommendations of an effective accident and incident recording and investigation procedure will reduce the incidence of unplanned events, injuries and financial losses associated with damaged equipment.

Technical description:

Definitions:

- Incident - near miss: an unplanned event that might have caused downtime, damage, injury, or a fatality.
- Accident: Unplanned event that has caused lost time, damage, injury, or a fatality
- Root cause: the fundamental, underlying, system-related reason why and how an incident occurred.
- Corrective action: action that eliminates the reasons for or the cause of an unplanned, unwanted event

The eight-step approach to accident and incident recording and investigation:

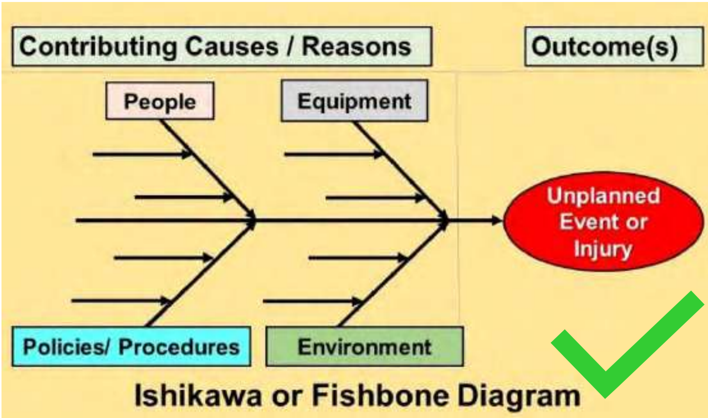
- Instigate a blame-free culture in the workplace so that all unplanned events and injuries are reported and recorded.
- Train supervisors and safety personal in accident and incident investigation.
- Investigate all recorded incidents and accidents to ascertain the root cause of all unplanned events.
- Establish all the facts and, whenever possible, visit the scene of the event.
- Use the Ishikawa or fishbone methodology to identify all the contributing and underlying causes (see picture below).
- Report the conclusions of the accident or incident investigation to the appropriate supervisor / line manager.
- Make recommendations for action to eliminate the root cause or causes.
- Implement corrective action.

Accident/incident investigation checklist

- ✓ Investigate an accident or unplanned event as soon as possible after it has been reported.
- ✓ Ensure the area or location of the incident to be investigated is safe to enter and examine.
- ✓ Note the date – time – location – or process/activity in operation.
- ✓ Write down or record an event summary with the names of witnesses and anyone involved or injured.
- ✓ Establish the timeline of events with a note of the actions of those involved.
- ✓ Make a list of the machinery or tools in use and the safety procedures in place.
- ✓ Note the use of any PPE or specialist safety equipment in use.
- ✓ Determine if any statutory regulations apply and if they were observed or broken.
- ✓ Find out if a maintenance permit to work and lock-off procedure was applicable and in place (see A.3.6.)
- ✓ Note the prevailing environmental conditions – lighting, noise, housekeeping, weather.
- ✓ Check the working practice for the work where the incident occurs for compliance with instructions.
- ✓ Find out if there were any deviations from the safe working practice instructions and, if so, why.
- ✓ Check the risk assessment for the tasks or work where the incident occurred for validity.
- ✓ Check the training records to ascertain if the workers involved were trained for the work.
- ✓ Examine any safety signs or hazard warning notices.
- ✓ Take photographs and measurements if necessary.
- ✓ Use the Fishbone investigation process to establish all of the contributing factors (see picture below)
- ✓ Find out if there have been any previous incidents like the one under investigation.
- ✓ Identify the immediate and underlying causes or reasons for the unplanned incident,
- ✓ Determine how the risk of an incident, unplanned event or personal injury can be avoided in future.
- ✓ Report the outcome of the investigation to all concerned and the appropriate supervisor in the company
- ✓ Make short- and long-term recommendations to reduce the risk of an unplanned event occurring again.
- ✓ Implement all necessary corrective actions, brief the workers, and retrain or retool as necessary.

- ✓ Conduct a risk assessment of the new working procedures or processes.
- ✓ Review the working arrangements for similar work or processes.

Good Practice



An Ishikawa (or fishbone) diagram should be used once all the facts have been collected and the circumstances, particularly the chain of events leading up to the incident have been established. The fishbone diagram provides a graphical representation of all the major contributing factors to the incident, including those involved, the equipment or tools being used, the polices or job instructions and the working conditions.

Accident investigators must never jump to conclusions or make assumptions about the events leading up to an accident or incident, Always ask open ended questions such as, how did the event occur and why, what happened, when and when did the event occur, and who was involved?

Further notes:

- It is advised to develop and use a standardised format for accident and incident recording and investigation. The following sample may serve as a blueprint.

Accident / Incident Investigation Form

A. Accident / Incident Data		
Persons / workers involved:	Position:	Process:
Work Location		
Date of Accident / Incident	Time of Event	Witnesses
Name (s) of Investigator	Equipment / Tools in use	
B. Accident / Incident Description		
Instructions: Obtain written and/or recorded statements from those involved or reported the event. Ascertain what happened? What was the immediate cause of the accident / incident? Find out if there were any contributing factors? Reconstruct the timeline and chain of events that led to the incident. When documenting the facts, include answers to the following questions:		
1. Where did the accident / incident happen and who was involved? Provide a full description.		
2. What was happening at the time of the accident / incident and why was it taking place?		
3. What were the events leading up to the accident / incident? Establish the Chain of events.		
4. What was the immediate cause and how did it happen? What were the mechanics, equipment or tools involved?		
5. Describe any injuries incurred or damage to plant or equipment.		
C. Accident / Incident Conclusions		
Review all facts - apply a root cause analysis to establish the immediate and underlying cause of the accident/incident		
D. Corrective Action		
Make recommendation to prevent this type of accident/incident from occurring again?		
Actions taken to ensure recommendations are considered and implemented		
Signature of Supervisor or Accident / Incident Investigator	Date	Time

A.3.6	Permit to work & lock-off system for maintenance	recycling & smelting

Requirement: Operational plants must have a permit to work system that stipulates plant and equipment to be isolated and locked off to allow safe repair, maintenance and cleaning.

Scope: Recycling & smelting

Background and rationale: Isolation and lock-off (also known as 'logout-tagout' or 'LOTO') is a procedure designed to provide a safe working environment during repairs, maintenance, or cleaning by ensuring that plant, equipment or associated components are not activated, set in motion or release stored energy such as an electrical charge, heat, steam or high-pressure fluids. Essentially, power or any mechanism that activates motion or releases energy is locked out of service and can only be returned to operation by the person who applied the lock. Where more than one person is working on a plant or item of equipment, multiple personal locks must be applied and only removed by the person when locking out. Only when all the locks are removed can the plant or equipment return to service.

Technical description:

Power or any mechanism that activates motion or releases energy is locked out of service and can only be returned to operation by the person who applied the lock.

The type of lockout equipment required will depend on the facility's plant or machinery.

The isolation and lock-off procedure

- Based on risk assessments, a plant's maintenance and cleaning schedule must be in writing and stipulate the items of equipment that must be isolated and locked off during maintenance or cleaning. Such requirements must also appear on any permit to work documents.
- Such procedures must also apply to an item of equipment under repair,
- Isolation locks, keys and hasps must be kept secure in a cabinet.
- Any person involved with equipment isolation and lock-off must be trained in the correct procedures and be assessed as a competent person to administer, supervise or apply the isolation and lock-off procedure.
- Any person drawing a lock, key and hasp must sign the register stating the key number, the purpose of the isolation, the date and the time.
- Likewise, when locks, keys and hasps are returned, the register must be signed and dated.
- Isolation will be from the power source, but this will not apply exclusively to an electrical supply, e.g. fuel.
- Isolation procedures should also be applied to lock off valves for services, such as steam.
- Hydraulic and pneumatic equipment or pressurised vessels must be dissipated before lock off.
- The isolation procedure should be managed in a manner that is safe and does not trigger any emergency procedures. In certain circumstances, it might be necessary to earth equipment.
- The isolation switch must be locked out of service in the "off" position by a lock.
- A sign or label must be attached to the lock to indicate that maintenance or cleaning is in progress.
- The label should list the name of the person who has isolated the equipment and a contact number.
- If more than one individual is involved in the work, each person should lock off the power with their own lock. Multi-lock hasps must be used in such circumstances.
- In those instances where it is not possible to apply an isolation lock-off, secondary measures must apply, such as removing electrical fuses or disconnecting hydraulic supply lines.
- Before work commences on any item of equipment, it is essential that the effectiveness of the isolation is verified by a suitably competent person.
- The person responsible for the lock-off must notify all affected individuals when the plant is isolated and when it is back online.
- A lock can only be removed by the person who placed it.
- Any equipment that has been isolated must be tested before it is handed back for service.

Good Practice

Lock off / tag out box. This box contains all the keys, locks and tags for effective isolation control. There is also a manual to inform engineers of the appropriate type of lock required for each item of plant and where to apply the isolation.
Further information: -

A.3.7 Fire precautions & emergency response plan

collection points | bulk transport | recycling & smelting

Requirement: Appropriate fire prevention procedures must be taken, including material and facility-specific hazard mitigation measures, emergency plans, deployment of appropriate first aid firefighting equipment, and regular drills on fire prevention, firefighting and emergency evacuation.

Scope: Collection points, bulk transport, recycling & smelting

Background and rationale: Managing and recycling of ULABs entail various fire risks, including short-circuits and overheating of batteries, the pyrometallurgical recycling process for lead components, and the storage and use of fuel and process chemicals. Additional fire risks emerge from the storage or processing of lithium-ion batteries that are sometimes falsely identified as ULABs. Lithium-ion batteries with residual charge can overheat and ignite any time after the battery has been damaged.

Technical description: Specific fire prevention measures appropriate for ULAB collection, storage, transport and recycling site must be in place and checked weekly for readiness. Any person working at the site must go through a fire prevention and response training course, including first aid firefighting. The facility must have an emergency evacuation plan and hold quarterly evacuation drills. Liaison and regular contact with the local municipal fire station is essential, and professional firefighters should be invited to visit the site to familiarise themselves with the risks and the layout of the site, including the location of all the utility isolation switches and valves.

Any facility must develop a Fire Prevention and an Emergency Evacuation Plan that includes appropriate Mitigation Measures. In addition, each facility should develop and train for an Emergency Evacuation Procedure. The following checklists shall apply:

The nine-step approach to developing a Fire Prevention and an Emergency Evacuation Plan

- Identify the fire hazards - potential sources of ignition, all combustible and explosive materials (see further notes).
- Note precautions already in place for the prevention and mitigation of each fire and explosive hazard.
- Evaluate the probability of a fire or explosion occurring due to a particular hazard or process.
- Consider the consequences of a fire or explosion and determine who might be harmed.
- Determine if any further measures are necessary to prevent, control or mitigate fire or explosion.
- Devise and publish a site Emergency Evacuation Plan or multiple site plans if there is more than one operational unit.
- Pass onto the local municipal Fire brigade the Fire prevention measures and the Evacuation plan.
- Train personnel on-site in the Fire prevention measures and hold quarterly fire and evacuation drills.
- Review and assess the Fire Prevention measures and the Emergency Evacuation Plan annually.

The plan as mentioned above should include the following **mitigation and preparatory measures**

- ✓ Manually activated Fire/Emergency alarms should be placed in all the operating and office locations.
- ✓ Display the contact details of the emergency services in all the operating areas.
- ✓ Display the Emergency Evacuation Plan in prominent positions around the site.
- ✓ Ensure that emergency assembly points are outside the operating areas where the risks are minimal.
- ✓ Locate any fuel oil in a bunded and locked enclosure complete with fire prevention equipment.
- ✓ All buildings should be constructed with a minimum of flammable components.
- ✓ Fire exits must be clearly marked, lit in an emergency and always kept free of any obstructions.
- ✓ Flammable gas cylinders must be stored in a locked cage, upright and chained to a rack.
- ✓ When flammable gas cylinders are used, they must be contained with a chain in a wheeled trolley.
- ✓ Smoking is not allowed on-site at any time.
- ✓ All electrical distribution boxes must be closed and locked to prevent dust ingress and short circuits.
- ✓ All furnace burners must be fitted with flame failure cut off devices and alarms.
- ✓ Fire alarms must be installed in all the offices and remote plant operating workstations.
- ✓ The company must deploy the correct fire extinguisher for each phase of the recycling process (see image below).

- ✓ Firefighting equipment must be accessible, and cylinders mounted 75 cm from the floor to the handle
- ✓ Combustible rotary residues or slags (see also B.2.7 and B.4.4) must be covered during cooling to minimise fire risk.
- ✓ Li-ion batteries must never be handled and recycled together with ULABs. Lithium-ion battery should be identified at collection and sorted so that they are kept separate from the ULABs. They must never be broken open.
- ✓ All Personnel must be trained and be familiar with fire and explosion prevention measures.
- ✓ Personnel in the operating areas must be trained in the correct use of first aid firefighting equipment.
- ✓ Firefighting equipment should be inspected by a professional fire prevention expert every six months.
- ✓ All personnel should participate in a fire drill and site evacuation every six months.
- ✓ The local Fire Brigade shall familiarise themselves with the layout and utility isolation switches and valves.
- ✓ Review all procedures at least once a year and update employee roll call lists every month

In addition to the Emergency Evacuation Plan, there shall be an Emergency Evacuation Procedure Check List including:

- ✓ Fire evacuation strategy, policy and procedure
- ✓ The actions personnel must take when a fire or emergency is discovered.
- ✓ The actions personnel must take when they hear the fire alarm.
- ✓ When and who calls the fire brigade and any other emergency services
- ✓ A complete plan of the site's power/utilities/process/ isolation switches and valves
- ✓ Key escape routes for emergency evacuation are clearly marked on the site plan.
- ✓ Fire wardens/marshals on-site trained to organise first aid fire fighting and evacuation.
- ✓ Safe places to assemble and take a roll call.
- ✓ Appropriate firefighting equipment on site
- ✓ All personnel trained to evacuate safely.
- ✓ A personal Emergency Evacuation Plan for anyone who might be working on their own
- ✓ Contact details to liaise with the emergency services

Unacceptable

This fire extinguisher has been left on the floor where it might be damaged or triggered if someone trips over it. The fire extinguisher should be wall mounted and if that is not possible, inside a floor stand.

Good Practice

What Fire Extinguisher should be used?

	Wood, Paper, Plastic	Flammable Liquids	Flammable Gases	Combustible Metals	Electrical Equipment	Fuel Oil	Molten Metal
Water	✓	✗	✗	✗	✗	✗	✗
Carbon Dioxide	Limited	Limited	✗	✗	✓	✗	✓
Dry Powder	Some	✓	✓	✗	✓	Some	✓
Foam	✓	✓	✗	✗	✗	Limited	✓
Wet Chemical	✓	✗	✗	✗	✗	✓	✗
Fire Blanket	Limited	Limited	✗	✗	✗	✓	✗

This chart should be displayed at every fire extinguisher station because choosing the correct extinguisher for each fire is critical. Using the wrong extinguisher will not put out the fire and may make the situation worse. Where there is more than one source of combustible material it may be necessary to install two or three extinguishers.

Unacceptable	Good Practice
	
Pathways and emergency exits are blocked with debris and battery components, making any evacuation difficult and dangerous especially in the dark if the power fails.	Fire/emergency exit path is clear of any obstruction.

Further notes:

- **NEVER** use water when trying to extinguish a fire where molten metal is present because there will be an explosion when the water hits the metal.
- When identifying substance specific fire hazards and choosing the right type of fire extinguisher, the following fire class system will be useful:
  - Class A: Solids such as paper, wood, soft furnishings, and plastic
  - Class B: Flammable liquids such as gasoline and fuel oil.
  - Class C: Flammable gases such as propane, methane, and acetylene.
  - Class F: Flammable metals such as aluminium, magnesium, sodium and lithium.
  - Electrical: Formerly Class E – Can fall into any of the above classes because it is not the electricity that burns but the surrounding materials.
- **Lithium-ion battery fires** are considered to be a Class B fire, so a standard ABC dry powder or BC dry chemical fire extinguisher should be used.

B.1.1 ULAB storage

collection points recycling & smelting

Requirement: ULABs awaiting transport or recycling must always be stored in a manner that avoids any damage to the batteries, and that effectively prevents any emissions of lead and acid.

Scope: Collection points, recycling & smelting

Background and rationale: Inappropriate handling and storage of ULABs can result in damage to the batteries and cause leakage of sulfuric acid and lead particulates to the workplace and the environment. Furthermore, unsound storage of batteries with residual charge can short circuit, in specific circumstances overheat and may even catch fire.

Technical description:

- Batteries must be stored on impermeable ground and well sheltered from rainfall, stormwater and direct sunshine.
- The battery storage area shall serve no other function than ULAB storage.
- The storage area must have a sump that effectively collects all liquids (e.g. Acid/Electrolyte from leaking batteries, effluent from facility cleaning).
- Captured liquids should be channelled to the plant's effluent treatment plant (see B.3.1). Collection centres usually do not have an effluent treatment plant. In that case, spills of electrolyte/acid shall be captured separately and sent to ULAB recyclers for treatment.
- For transferring batteries in or out of the storage area, batteries shall always be handled with acid-resistant gloves. Batteries shall never be thrown, toppled, or handled by any other means that might cause damage to them.
- Batteries shall always be stored upright.
- When stacking batteries, the risk of short circuits must be avoided by capping protruding battery terminals with plastic caps or insulation tape.
- Leave all vent caps securely in place (not relevant for sealed battery types)
- Damaged and leaking batteries shall be packed as described in B.1.2

Unacceptable		Good Practice
		
ULABs are stored in the open and on bare soil. Damaged batteries are not contained, and acid and lead particles leak and leach into the nearby environment.	ULAB are stored on sheltered and on impermeable ground, but not upright. In addition, open and damaged batteries are not packed so that sulfuric acid and dust particles are likely to spill or leak.	All the ULAB are stored and stacked neatly and in a tidy manner in UN approved leakproof containers on an impermeable resin coated floor with a central drainage sump located in the centre of the warehouse.

Further notes:

- ULAB storage may be arranged in a way such that different battery types are already sorted upon arrival (e.g. industrial ULABs, automotive ULABs…). The type of sorting should be selected to best serve the plant's capabilities.

B.1.2	Packaging for bulk transport	collection points / bulk transport

Requirement: For transportation, ULABs must be properly packaged so that the batteries are effectively protected from damage and short circuits. Appropriate and visible decals/labels must be clearly displayed on the packaging and the vehicle that indicate the type of freight and their associated hazards.

Scope: Collection points, bulk transport

Background and rationale: ULAB are classified as hazardous waste. If the ULAB are not packaged securely, lead containing materials and electrolyte (dilute sulfuric acid) may leak in transit. Therefore, appropriate packaging of whole ULAB, complete with electrolyte, is required to:

a) Minimise the risks of damage to the batteries
b) Prevent or contain leaks of hazardous materials from the ULABs.

A short circuit in a battery with a residual charge may also cause overheating so that adequate precautions are needed.

Technical description:

- Always wear nitrile or neoprene acid-resistant gloves and eye protection when handling ULAB. Use further PPEs as specified in A.2.1.
- Only handle ULAB in an area where there is an eyewash basin or station in case of splashes of acid.
- When collecting, storing, or transporting ULAB, never remove the inspection caps or drain the electrolyte (battery acid).
- Check ULAB for leakage and consign any leaking ULAB to a separate leakproof plastic container.
- Store ULAB upright and away from any extreme heat or cold source.
- Prevent any battery short circuits by covering the battery terminals with an insulation cap or insulation tape.
- For transport, ULABs should ideally be stored in a UN 3794 certified leakproof container with a lid. Within such containers, ULABs may be stacked (up to 3 layers of batteries).
- ULABs can also be stacked, stored, and transported on a wooden pallet. Stacking should be limited to 3 layers of batteries. They must be strapped and shrink-wrapped to avoid any movement or toppling during transit. Strapping must be high strength polypropylene, polyester, or nylon plastic, 19 mm wide with a break strength of 1500kg.
- If ULABs are stacked one on top of another, corrugated cardboard must be placed between layers.
- Plastic containers or palletised ULABs must be chocked during transportation to prevent movement.

Unacceptable	Good Practice	
		
ULAB are packed into the back of a truck in any order. They are not upright or secured and could easily be damaged and leak during transit.	ULAB are sized and stacked upright on a solid pallet no more than 3 layers high. Thick cardboard is placed under and over each layer of ULAB, then strapped and shrink-wrapped.	ULAB are placed upright in UN approved leakproof, fork truck friendly stackable plastic containers capable of holding 750 kg of ULAB. Containers comes complete with a top cover.

Further notes:

- Smaller holes in batteries must be closed with rubber material or taped over.
- Broken and leaking batteries need to be packed separately in solid polyethylene bags or closed buckets.
- Packaging is needed for both, domestic and transboundary transportation. The latter transports additionally require notification in line with the procedures required under the Basle Convention.
- Packed batteries and transport vehicles must be marked with the following UN GHS chemical classification and labels:

UN 2794

BATTERIES, WET, FILLED WITH ACID

B.1.3 Bulk transport of ULABs

bulk transport

Requirement: Bulk transport of ULABs must be conducted so that all ULABs are secured from damage. In addition, carriers must display decals/labels to indicate the type of hazardous material, and staff must be trained and equipped for proper handling. Transports across national boundaries require notification in-line with the provisions of the Basel Convention.

Scope: Bulk transport

Note: Transport of small ULAB volumes to collection points (e.g. through users) should be exempted from this requirement.

Background and rationale: Used lead-acid batteries are classified as hazardous waste and require careful treatment and handling. Appropriate packaging and safe transport are necessary preconditions to avoid damage to batteries, leakage of electrolyte (battery acid) and emissions of lead containing materials during transport and handling. In the case of accidents appropriate warning signs and precautions must be taken and emergency services advised of the type of waste and the hazards.

Technical description: Bulk transport of ULABs shall only be conducted in well package lots as described in B.1.2. Packed ULABs should be loaded onto trucks (or other carriers such as sea containers, trains) so that the load is prevented from any movement and damage during transit. This can be achieved by bracing the containerised or palletised ULAB containers in the back of an enclosed truck, by fixing them with strong tension belts or wooden wedges, or by a combination of both.

As ULABs are heavy, attention must be paid to not overload carriers.

Carriers must be marked with the following warning signs that must be well visible from the outside:

UN 2794

BATTERIES, WET, FILLED WITH ACID

Staff operating the carrier (truck drivers) and those involved in loading and offloading must be provided with appropriate personal protective equipment (see A.2.1), which must be worn anytime when handling or in contact with (packaged) ULABs. During transport, PPEs and a battery acid spill kit must be readily available so that they can be applied or worn anytime as and when necessary (also see ‘further notes’ below).

Staff operating the carrier (truck drivers) and those involved in loading and offloading must be trained in safe handling procedures in-line with the UN Recommendations on the Transport of Dangerous Goods and other applicable health and safety legislation (see A.3.1-A.3.5).

Transports of ULABs across national boundaries requires notofication according to the prior-informed consent-procedure of the Basel Convention on the Transboundary Movement of Hazardous Wastes and their Disposal.

Unacceptable	Good Practice
	

<table>
<tr>
<td>ULAB are packed into the back of the truck in an untidy and chaotic manner such that any electrolyte might leak and batteries are likely to be broken.</td>
<td>The ULAB are palletized, shrink wrapped and braced in the back of an enclosed container. When the container is fully loaded (which is not yet the case) the ULAB are unlikely to be damaged in transit.</td>
</tr>
<tr>
<td colspan="2"><u>Further notes:</u> Bulk transports of ULABs must have a battery acid spill kit readily available. The kit serves as an easy to use equipment to clean up acid spills. A spill kit consists of

Gloves (nitrile or neoprene) → To protect the person(s) doing the clean-up
Spill pads (at least 10 pieces) → To soak-up leaking acid
Spill sock → To be used as barrier to contain acid spills
Disposable plastic bags → As safe packaging material for acid containing spill pads, spill socks and gloves

Spill kits may also contain goggles, plastic buckets, warning tape, overalls (chemical splash suit).</td>
</tr>
</table>

B.2.1	Battery breaking	recycling & smelting

Requirements: ULAB breaking must be undertaken with one of the technologies described below in a manner that effectively protects workers from the acid mist and lead particle emissions.

Scope: Recycling & smelting

Note: Battery breaking shall under no circumstance be conducted at collection points or during transport.

Background and rationale: To maximise the number of ULAB components that can be recycled efficiently, it is essential to separate the individual components and materials (the metallic lead grids, the lead paste, the plastic battery case, the plate separators, the acid electrolyte) before further processing. This must be done in a safe manner to protect the operators and by capturing the battery electrolyte and any lead containing materials so that they do not pollute the environment. For these reasons ULABs must be broken using a semi-automatic or preferably fully automated and contained mechanical breaker. Manual technologies (axes, hammers, machetes, or any other similar tool) must be avoided.

Technical description: There are two technologies commonly used for battery breaking, namely the saw method and the hammer mill breaker method: Battery saws are usually installed at small operations and still involve a lot of manual intervention compared to hammer mill breaker and as such are not the preferred option:

1. **Battery saw (also referred to as 'cutter')** → also see picture below

With this technology, the batteries must be punched and drained before breaking. Draining must be done in a safe manner to avoid acid spills and risks to workers. The ULABs must be drained of electrolyte overnight (see B.3.1) before being broken with the saw to reduce the risk of acid mist as the saw blades cuts into the ULABs.

The battery saw, or cutter removes the top section of the battery case, complete with the terminals or poles. The plates can then be removed from the bottom section of the case by turning the ULABs upside down. The horizontal saw blades can be adjusted to the size of the ULABs. The battery saw must be ventilated to capture any acid mist generated.

The battery saw casing must have a plastic acid proof curtain at the entry and exit points to prevent acid mist or droplets from being splashed into the work area.

ULABs are loaded onto the moving conveyor manually one at a time and removed at the exit once the top has been removed. The ULABs must not be allowed to drop onto the floor and contaminate the work area with acidic lead paste.

Adjustable rotating saw blades inside a fully housed and ventilated battery saw

2. **Hammer mill breaker** → also see picture below

The hammer mill breaker is designed to crush whole ULABs complete with acid electrolyte and separate the individual metallic grids, lead paste, plastic and liquid components through gravitational hydro-metallurgical separation. A hammer mill is fed with ULABs via a conveyor belt and in most cases is a fully contained process that limits opportunities for occupational and environmental exposure.

The ULABs are broken and crushed as they fall onto rows of rotating hammers or blades spinning at high speed. (Excess effluent is drained and treated – see B.3.1) The battery components are discharged separately from the breaker: metallic fractions, battery paste, washed polypropylene chips and separators.

The charge chute to the hammer mill must be in the form of a **Z** to prevent ULABs being thrown out of the charge chute on impact with the hammer mill. The crusher unit must be sound proofed to reduce noise levels. Together with the noise of all other machinery on the production floor, workers should not be expose to levels above 85 decibels (with exposure levels ideally below 80 decibels at all times). Rubber ridges should be installed on the inclined conveyor to reduce the risk of ULABs slipping down the conveyor.

Oscillating hammers inside a hammer mill that has been opened for inspection and maintenance

Unacceptable	**Good Practices**	
		
Manual breaking of ULABs is prone to cause acid splashes and emissions of lead containing materials to the workspace. While this is unacceptable, the worker in the picture is not even protected from splashes of acid by use of safety goggles.	Semi-automated battery saw with a conveyor belt for charging. The saw is housed, ventilated and protected with an acid proof curtain at the entry and exit points.	A fully automated hammer mill charged via a conveyor belt and housed to protect the working area from the acid mist, crushed objects and noise.

Further notes:

- All ULABs should be checked manually to effectively sort out and remove lithium-ion batteries before processing them through any of the breaking processes described above. Any physical impacts to Li-ion batteries (such as punching, sawing and crushing) involve a serious risk of fires and explosion.
- ULABs can weigh 50 kg or more and should be lifted with care or be a two-person or automated assisted lift.
- Irrespective of which breaker technology is used operators must wear acid resistance boots with toe protection, long-sleeved overalls, a rubber or plastic apron, nitrile gloves, dust respirator with an acid mist absorbing cartridge, safety goggles or face visor, hard hat and ear defenders (see A.2.1).
- In case workers' exposure to noise is close to or above 80 decibels (e.g. at a hammer mill breaker), noise abatement measures should be applied. In addition, workers should be provided with hearing protection (ear defenders) and hearing protection zones.
- An emergency eye wash station and/or shower must be installed close to the breaker to be used in case a worker's eyes or face are splashed with acid electrolyte. (see picture to the right).

Emergency shower and eye wash station

B.2.2	Desulfurization	recycling & smelting

Requirement: Measures must be taken to effectively avoid sulfur dioxide emissions from lead smelting operations. Best practice encompasses at least 2 sulfur removal methods described below (either 1+3, 2+3 or 1+2+3). Sulfur emissions must at least be in-line with international norms and meet national emission regulations.

Scope: Recycling & smelting

Background and rationale:

Spent lead battery paste contains a high percentage of lead sulfate at around 55%. During the reduction phase of the smelting process sulfur will be released to the atmosphere in the form of sulfur dioxide gas if not captured. It is therefore essential to remove the sulfur (1) prior to smelting, (2) during smelting or (3) after smelting. An effective sulfur removal requires a combination of these methods, either 1+3, or 2+3, or 1+2+3.

The three processes for removing sulfur are:

1. **Desulfurization prior to smelting (pre-desulfurization):**
   - ✓ Reduces the amount of slag produced in the furnace.
   - ✓ Minimises potential corrosion of the plant ventilation system and certain bag filters
   - ✓ Enables the production of a potentially saleable product or an inert non-hazardous waste
   - ✓ Produces a lead compound that decomposes at a low temperature to a form that can be smelted.
   - X Only applies to plants using a hammer mill to separate paste and metallic lead (see B.2.1).
2. **Desulfurization during smelting (in-situ desulfurization):**
   - ✓ Sulfur is removed using scrap iron, soda ash (sodium carbonate) and carbon (S combines with the iron/soda ash to form $NaFeS_2$)
   - ✓ 95% or more of the sulfur is removed from the charge material into the slag
   - ✓ Although no additional plant is required, a gas scrubbing system is recommended.
   - X The sulphide matte formed reports to the slag – increasing the slag volume
3. **Desulfurization after smelting using a Scrubbing Tower (post-desulfurization):**
   - ❖ This process should never be the primary process to remove sulfur as SO_2.
   - ❖ The scrubbing tower should be used to remove any final traces of SO_2
   - ❖ Lead smelters should have a scrubbing tower as backup equipment.

Technical description:

Desulfurization prior to smelting (method 1):

Removal of the sulphurous compounds prior to smelting is via an aqueous reaction with either sodium carbonate or sodium hydroxide. The battery paste is mixed in a reactor with either compound, although carbonate is the common method due to costs. The lead carbonate product is sent to the smelter, but the sodium sulphate (a highly soluble product) requires a separate complex crystallizer or vaporizer plant, to recover a saleable product. The soluble sodium sulphate product must not be disposed from a smelter in the water courses.

Desulfurization during smelting (method 2):

Iron and sulfur have a great affinity and will form FeS, (ferrous sulfide) in the furnace. Therefore, iron must be added to the furnace charge material along with a carbon in a metallurgical balance during smelting. The lead sulfate is reduced to lead sulfide and the iron will combine with the sulfur, along with sodium, to form sodium lead sulfide called 'Erdite' and it reports to the slag.

It is noteworthy that iron/steel drums can be used for collecting baghouse dust. The dust-filled drums can be sealed and charged to the rotary furnace, which has a dual advantage: the lead-containing baghouse dust remains enclosed throughout the handling processes (see B.4.2) and the iron of the steel drum acts as a sulfur binding/capturing agent during the smelting process. Feeding lead-containing residues such as baghouse dust back into the furnace is a crucial measure to recycle hazardous process by-product.

Desulfurization after smelting using a scrubbing tower (method 3):

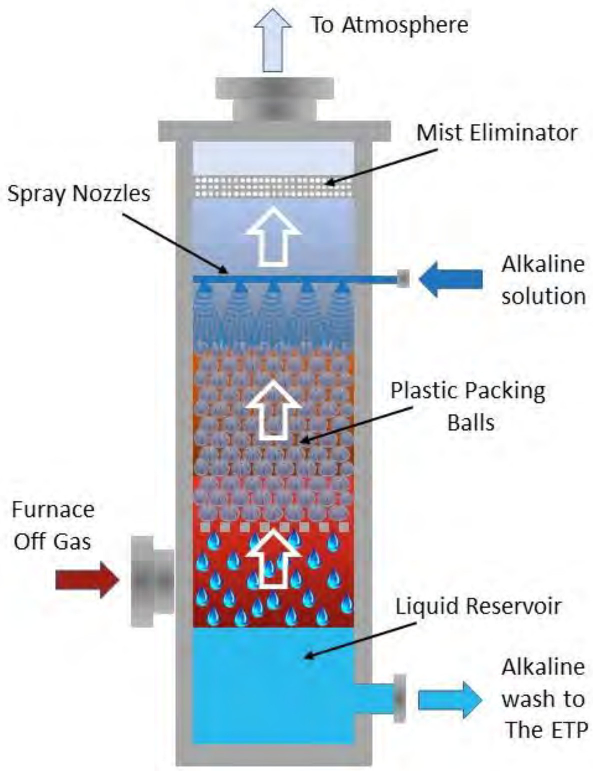
Of the many design variations of scrubbing towers, only the two most common options are considered. A well-managed scrubbing tower will remove 99% of the sulfur dioxide contained in the furnace off-gas.

The scrubbing tower must be installed after the filter plant (baghouse) and before the off-gas is released to the atmosphere via the stack (see B.6.1).

A scrubbing tower is essentially a tall steel vessel that has an alkaline solution of either sodium carbonate or calcium carbonate sprayed into the chamber from the top of the vessel. The solution passes over thousands of plastic fillers or spacers packed effectively to increase the surface area of the liquid, thereby maximising contact between the furnace off-gas entering the tower at the base and the alkaline solution.

The reactions are typically the absorption of the sulphur dioxide by either the calcium carbonate or sodium carbonate, and the liberation of carbon dioxide gas. The calcium and sodium sulfates will be suspended in solution, but the salts can be recovered and once isolated, they can be sold as a product.

It is recommended that sulfur removal using a scrubbing tower is never used as the sole process for removing sulfur, but to remove any residual sulfur and as an insurance that sulfur is removed if either methods 1 or 2 fail, for whatever reason.



scrubbing tower

Unacceptable	**Good practice**
	
Failure to either remove the sulfur present in the feed material either before, during or after smelting will result in sulfur dioxide gas emissions, typically seen as a white plume as the sulfur dioxide combines with water vapour in the air to form an acidic cloud (known as acid rain).	No visible emissions (further confirmation by emission monitoring → see B.4.3).

<table>
<tr><th>Unacceptable</th><th>Good practice</th></tr>
<tr><td></td><td></td></tr>
<tr><td>A steel corrugated roof above a smelting operation corroded from sulfureous compounds.</td><td>A scrubbing tower removes residual sulfur dioxide from the off-gas stream (sulfur removal method 3).</td></tr>
<tr><td colspan="2"><u>Further notes:</u>
Irrespective of which desulfurization process is used operators must wear acid resistance boots with toe protection, long sleeved overalls, dust respirator, safety goggles or face visor, and a hard hat. In addition, for processes 1. and 3. nitrile gloves, and for process number 2. furnace gloves (see A.2.1).
An emergency eye wash station must be installed close to processes 1 and 3 (see last picture of B.2.1)</td></tr>
</table>

B.2.3	Furnace technology	recycling & smelting

Requirements: Smelting and melting operations associated with ULAB recycling must be performed with environmentally sound furnace technologies and operated in a safe and hygienic manner.

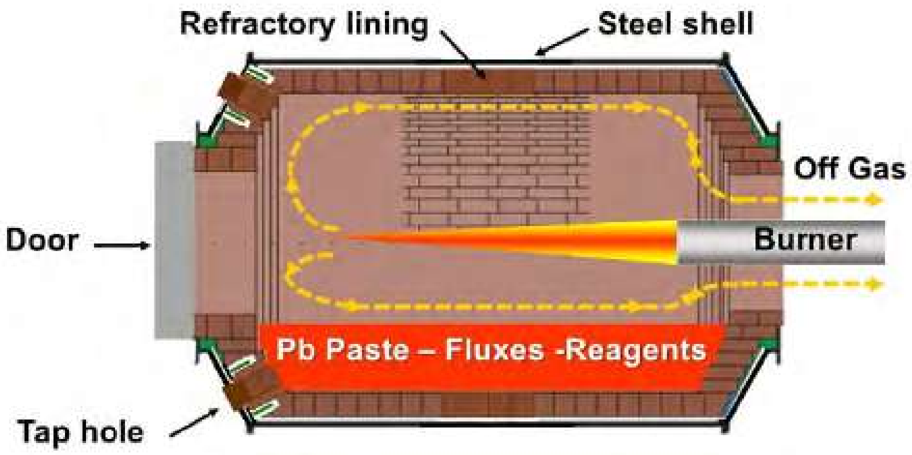
Scope: Recycling & smelting

Background and rationale: The pyrometallurgical smelting of the lead bearing components are core process phases in the recovery of metallic lead. These methods produce significant quantities of lead fume and dust as well as sulfur dioxide unless there are adequate environmental control systems in operation. Effective environmental controls will reduce the risk of occupational and population lead exposure, as well as environmental impacts. Selection of an appropriate furnace technology will ensure that all the by-products produced during the recycling process, such as the baghouse dusts and the refining drosses can be returned to the furnace to recover the valuable metallic components and to ensure that no lead containing wastes leave the facility (see B.4.2 & B.4.4).

Technical description: Selection of an appropriate furnace technology will depend on a number of key factors, such as metallurgical versatility, throughput capacity, the type of feedstock and the fuel that is readily available. Currently, in most of the world, rotary furnaces have generally replaced blast furnaces as the major smelting technology for ULAB recycling because of their versatility, particularly their ability to recycle all by-products, and in contrast to blast furnaces, it is easier to control smelting conditions and emissions.

Rotary furnace: Rotary furnaces have a steel outer shell and an inner magnesia-chrome refractory lining. The drum is on rollers and has a motor drive that can rotate the drum on a fixed or tilted axis in either direction.

There are different variants, but generally the burner is located at the rear of the furnace to maximise fuel efficiency in the case of a fixed axis, and in the front for a tilting furnace.



The furnace can operate as a melting furnace for the metallic fraction from a breaker, and as a smelting furnace for battery paste and by-products, such as the baghouse dust and refining drosses.

The furnace operates on a batch charge basis and the temperature range, depending on the charge material and whether it is in melting or smelting mode, is from 500º Celsius to 1100º Celsius.

Feed material is charged through the front of the furnace, preferably remotely controlled and automatically (see B.2.5), and the lead bullion and slag can be tapped from either the front of the drum or the centre, depending on the location of the tapping port (see B.2.7). In the case of a tilting rotary furnace the metal and the slag are tapped from the front of the drum by tipping the furnace forwards to allow the material to flow out of the door.

A single rotary furnace can process between 5,000 and 25,000 mt of battery scrap material annually and for tonnages above 25,000 mt, additional furnaces will need to be installed.

Alternative furnace technologies: There are types of rotary furnaces, such as tilting rotaries but for the purpose of this document, they are included in the above work. Whilst other furnace technologies are used in the lead smelting industry, they are more suited to complex multi-metal feeds such as concentrates. Generally, they are not as versatile as the rotary furnace.

The following furnace technologies are being phased out by many companies:

- Blast furnaces
- Cupola-type furnaces

Unacceptable		Good practice
		
Outdated blast furnace where fumes and dust are not ventilated and escape to the workplace	Rotary furnace not equipped with a fume hood so that dust and fumes inevitably escape to the workplace	Encapsulated rotary furnace with charging and tapping ports fully ventilated to a filter plant/baghouse

<u>Further notes:</u>

- It is essential that the furnace is ventilated to a filter plant/baghouse (see B.4.1 to B.4.3).
- It is vital that the furnace is either encapsulated and ventilated or equipped with extraction hoods over the charging and tapping portals such that all fugitive lead fume and dust escaping from these openings are captured and ventilated to the filter plant / baghouse.
- Ideally, workers will operate the furnace remotely from and air-conditioned control room, but if not, they must be equipped with appropriate PPE (see A.2.1).
- As smelting operations involves high temperatures, fire precautions must apply (see A.3.7).

B.2.4	Furnace charge preparation	recycling & smelting

Requirements: The charge for the smelting process must be prepared in a manner that minimises emissions of lead dust.

Scope: Recycling & smelting

Background and rationale: The material mix to be fed into a furnace (see B.2.5 on furnace charging) needs to be prepared in advance of the smelting process. The charge material will vary depending on the method of battery breaking and typically will consist of one or more items of grid metallics, lead battery paste, battery plates along with the reducing agents and fluxes such as sodium carbonate and iron (to remove sulfur → see B.2.2). Inappropriate charge preparation procedures may result in fugitive emissions of lead dust. This guidance describes appropriate charge preparation procedures that minimise the risk of occupational Lead exposure.

Technical description: Charge preparation should always apply the following principles:

- The charge preparation storage area should be in an enclosed building under negative pressure with extraction ventilation to a baghouse (see B.4.1). Negative pressure should be applied so that lead particulates do not leave the storage area.
- The various charge materials should be segregated and stored separately (e.g. lead scrap, iron scrap…)
- By-products, such as baghouse dust should be stored in self-contained hoppers or sealed charge bins (also see B.4.2)
- Charge bins or hoppers must have a maximum charge line to ensure that they are not overfilled in order to avoid spillage and overcharging the furnace
- A calculated amount of iron, soda ash and a carbon source (e.g. coke) must be added to the charge.
- Preferably, the charge should be prepared in advance under hygienic conditions and stored in either a separate bunker, charge hopper or bin, that can be delivered to the furnace by mobile equipment (e.g. adapted fork truck). Anyone working in the charge preparation area should ideally be in an enclosed vehicle equipped with a HEPA filtered air supply to the vehicle cabin (see the illustration below). However, this is not always feasible or possible, especially if the recycling operation is a small-scale recycling plant. In which case if the charges are prepared manually, the operators must be equipped with the correct PPE because furnace charge material can be very dusty.

Depending on the method of ULAB breaking and the furnace technology employed, the makeup of each charge may vary. However, it is prudent to prepare furnace charges in advance to minimise the time it takes to recharge the furnace, thereby keeping cycle times to a minimum whilst maximising production time.

The following points also need to be considered:

Charge preparation for ULAB material from a battery saw (see B.2.1):

- Terminal posts removed from the top of the battery cover and clean of lead paste and compounds, can be charged directly to a refining kettle provided there is adequate fume extraction. Battery grids, plates or paste must never be charge directly to a refining kettle.
- No attempt should be made to remove the paste from the grids
- No attempt should be made to remove plate separators (either glass-fibre or polyethylene) because manual efforts are likely to generate lead emissions, increase the risk of occupational exposure and potentially make contact with the corrosive residue from the battery electrolyte.

Charge preparation for ULAB material from a hammer mill breaker (see B.2.1):

- The metallic grids should be as clean as possible (free of as much battery paste as possible) and can be charged to a furnace operating at about 450°C for melting (instead of charging them to a smelting furnace operated at a much higher temperature). The remnant oxide dross from the grids will need to be processed by smelting at the end of the melting campaign.
- Battery paste must be dewatered as best as possible, with no free-water present, either by compression or filtration, in order to reduce the risk of explosion in the furnace.
- Smelting the battery paste separately from the grid metallics will produce unrefined lead bullion that requires a minimum of refining compared to the grid alloy lead (antimonial containing lead). The plate separators (either glass-fibre or polyethylene) can be added to the paste charge, as they basically add silica to the slag, but will not contaminate the bullion.

Unacceptable	Good Practice
	
Charge material is stored in the facility, and not in a separated room or building. Fugitive emissions of lead dust are likely to contaminate the work environment. In addition, the building is open to the outside without any extraction ventilation or dust suppression.	The sealed driver's cab in this vehicle engaged in charge preparation has a positive pressure HEPA filtered climate control system to minimise dust ingress. The charge preparation building is also under a negative pressure extraction ventilation system attached to a baghouse to prevent any dust emissions escaping from the building.

Further notes:

- Operators working in the charge preparation area must wear footwear with toe protection, long sleeved cotton drill overalls, riggers gloves, neoprene respirators with dust cartridges rated at least P2, but better P3, safety goggles, glasses or visor and a hat – a hard hat if there is an overhead crane or hoist in operation (see A.2.1).
- The leggings of the cotton drills must be worn over the boots and not tugged into them. This avoids lead particles falling into the boots and contaminating the inside of the footwear.

B.2.5 Furnace charging

Requirements: Furnace charging needs to be undertaken in a safe, hygienic and controlled manner such that any dust emissions are captured, and the furnace is not overcharged. In particular, operators need to refer to automated or semi-automated charging methods and should never manually charge a furnace by hand or with shovels.

Scope: Recycling & smelting

Background and rationale: Charging a furnace may result in lead dust emissions and therefore needs to be carefully controlled and if possible automated. Furthermore, charging and operating a furnace is associated with high temperatures such that adequate safety precautions have to be taken.

Technical description:

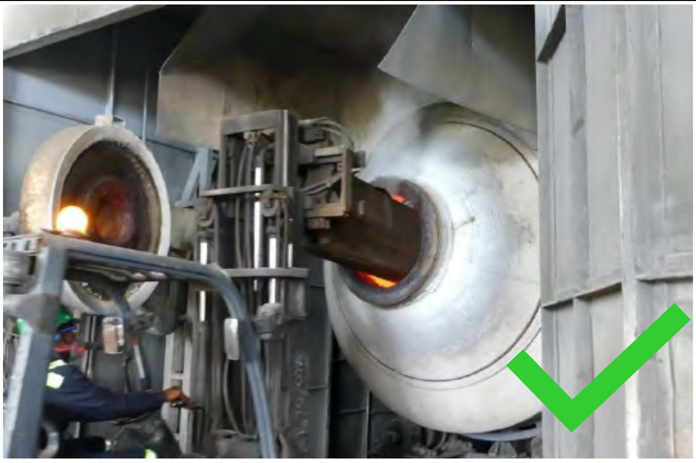
The procedures for charging the various furnace technologies will vary, but the following principles apply to all:

- Furnaces must never be charged manually by operators using shovels or buckets because exposure and explosion risks are unacceptably high.
- Charges should be prepared in advance in a self-contained area so that any spillage does not contaminate the site. Also see B.2.4 on charge preparation.
- Materials charged to a furnace must have a low moisture content and not contain free water to minimise the risk of explosion.
- The furnace extraction ventilation (including the extraction system for the charging port) must always be switched on during the entire charging and smelting process to effectively capture all dust and fumes.
- A furnace must not be overcharged.
- Mobile equipment operating around the furnace must have HEPA filtered air-conditioned enclosed cabs and the glass in the front of the vehicle must be shatterproof and heat resistant.

Rotary furnaces, which operate as a batch process require charging every cycle. Ideally, batch charging should be controlled remotely and completed in the shortest time to minimise the risk of fugitive emissions and occupational exposure to lead and minimise energy consumption. Charging machines, such as the one illustrated in the picture above, can charge a rotary furnace in under 5 minutes, thereby reducing cycle times. However, for many operations under 12,000 mt annual throughput, investing in an automated charging system is not cost effective so a semi-automated charging with a modified fork truck is the norm.

Differences in charging for melting and smelting furnaces

Most furnaces are designed and operated as smelting furnaces where lead containing materials such as battery paste are reduced to produce metallic lead. In many instances battery plates with paste are charged to a smelting furnace. However, it is more energy efficient to separate the grid metallics and the battery paste (as a hammer mill breaker will do → see B.2.1) and smelt the paste component at a high temperature to produce a soft lead bullion. The grid metallics, if clean from paste, can be “melted” at a much lower temperature to produce a lead bullion with a high level of elements derived from the grid alloys. Grid metallics should not be charged to a refining kettle in an attempt to melt them as they still contain a high proportion of lead paste and hence will generate large amounts of lead fume and dross. Therefore, such melting/smelting processes are conducted in the rotary furnace but just operating at different temperatures. The method of charging a melting batch to the furnace is similar to that of charging a smelting batch.

<table>
<tr><th>Unacceptable</th><th>Good Practice</th></tr>
<tr><td></td><td></td></tr>
<tr><td>Operators using shovels for manual furnace charging. The operators are not wearing PPE. The operators are completely exposed to lead bearing dust, fume and any hot embers discharged from the furnace. The furnace extraction ventilation system fails to capture the dust and fume generated as the charge heats up.</td><td>The furnace is being charged semi-automatically by an operator using a fork truck with a special rotating charge bucket to deliver the charge directly into the furnace. The operator is wearing a dust respirator, face visor and a hard hat. Note that the furnace burner is on to burn off any organics and any dust or fume emissions are captured by the extraction ventilation system and vented to the baghouse.</td></tr>
<tr><td colspan="2"><u>Further notes:</u>
Operators involved in charging a furnace must wear footwear with toe protection, long sleeved cotton drill overalls, riggers gloves, neoprene cartridge respirators with dust cartridges rated at least P2 or better, safety goggles, glasses or visor and a hat – a hard hat if there is an overhead crane or hoist in operation (see A.2.1).
As charging and operation of a furnace involves high temperatures, fire precautions must apply (see A.3.7)
Housekeeping in and around the charging area is most important – see A.2.5 – and collect any charge material that falls onto the floor.</td></tr>
</table>

B.2.6	Smelting	recycling & smelting

Requirement: Smelting operations need to be conducted in a safe, hygienic and controlled manner such that any fume or dust emissions are captured and that workers are protected from heat, molten metal and slag.

Scope: Recycling & smelting

Background and rationale: Irrespective of the furnace technology employed, smelting operations are a major source of lead fume and dust emissions. Environmental controls and safety precautions are essential due to the high temperatures involved.

Technical description:

Smelting is a complex metallurgical process involving the reduction of lead-bearing materials such as battery paste, refining drosses and baghouse dust into metallic lead. The various furnace technologies will pose their own safety and pollution control issues.

The following guidelines should be observed at all times during all smelting operations:

- No material containing "free water" should ever be charged to the furnace.
- All materials being added to the furnace should be in accordance with a metallurgical balance for the charge. (Smelting battery scrap is not an ad hoc operation and must follow metallurgical process rules).
- Burners and burner controls must be regularly maintained and inspected. This includes all burners, feed-lines, fuel and oxygen tanks and failsafe devices. If oxygen is being used, storage tanks and lines must be protected from damage (also see 'further notes').
- Recyclable materials, fluxes and reagents should be added to the furnace according to a standard formula, and that formula must be maintained for all charges.
- If combustible material such as separators are added to the furnace, they must be mixed well into the charge mix. They should not be added separately. During any smelting operation visual checks must be made to ensure that:
    - There are no hot spots on the outer casing of the furnace, which would indicate a refractory failure or a water jacket blockage.
    - There are no fugitive emissions being emitted to the atmosphere from either the furnace or the extraction ventilation system.
    - The baghouse dust collection system is continually cleaned, is not overloaded and any collection bins that are full are replaced.
    - Differential pressure readings across the inlet and outlet ducts of the baghouse are recorded (see B.4.3). Initiate cleaning cycle if the pressure differential exceeds the design specification.
    - There are no dust emissions from the baghouse stack (see B.4.3).
    - Walkways and emergency exits in and around the furnace are clear of any spillage or debris
    - All the required tools and PPE are in place to tap the metal and slag from the furnace when smelting is completed (see A.2.1 and A.2.2).
    - No person, other than those designated and trained to operate the furnace, are in the furnace working area.

Unacceptable	Good Practice
	
In this smelting operation there is: × No hygiene ventilation system × No combustion ventilation ducting × No ducting to a baghouse × Sulfur dioxide gas formed that will be ejected from the rear of the furnace × Debris all over the floor area – tripping hazards × Dust and fume in the working areas	This long rotary furnace has: ✓ Adequate hygiene and combustion extraction ventilation systems in operation at the front and rear of the furnace ✓ No visible fugitive dust emissions ✓ Clean floors ✓ Unobstructive working area in front of and at the rear of the furnace

Further notes:

- Only operators that are trained on furnace operations should work in the furnace area. In all cases, no operator should work alone.
- Workers operating close to a hot smelter need to be equipped with a neoprene respirator with dust cartridge, a long sleeve cotton drill with leather apron, foundry gloves, boots with steel or carbon toe protection, safety goggles, glasses or visor, and a head cover (safety helmet in case there is any overhead mobile equipment). Also see A.2.1.
- In the event of a spillage during smelting – WATER MUST NEVER BE SPRAYED ONTO THE SPILL. Use sand to contain the spillage and dry powder on any material or equipment that catches fire (see A.3.6).
- If oxygen enrichment is used for smelting, the following additional safeguards shall be applied:
    - The furnace burner flame failure device must be linked to the fuel, air and oxygen supply lines so that it shuts of the supplies to the furnace if the flame fails.
    - The flame failure sensors must be kept clean and free of any soot or residues that might "blind" the sensor.
    - The oxygen enrichment storage tanks and burner systems must be installed by a specialist company.
    - Thick furnace gloves must be worn at all times when inspecting or servicing any oxygen supply lines or valves to avoid freezer burns.
    - Smoking anywhere in the proximity of an oxygen storage facility or supply line must be strictly banned (explosion risks).
    - When working on any oxygen storage or supply line – brass tools must be used to avoid any risk of sparks from steel tools.
    - Oxygen storage tanks must be in a bunded, fenced and locked open enclosure. Bunded to contain liquid oxygen in the case of storage tank leakage.
    - The local fire brigade must be informed that oxygen storage tanks are on site so that they know what to expect in the event of an emergency

B.2.7	Furnace tapping	recycling & smelting

Requirement: Furnace tapping must be conducted in a way that effectively captures all fugitive emissions and minimizes the safety risks to operators.

Scope: Recycling & smelting

Background and rationale: Furnace tapping is a critical step in the smelter operation. It can generate considerable amounts of fume and dust that must be captured completely and ventilated to a filter plant / baghouse (see B.4.1). At the same time when tapping a furnace, the high temperature of the molten lead and slag pose significant safety risks to operators and may also cause damages to equipment and installations. Safe tapping requires measures in the following fields:

1. Safe tapping method
2. Safe capture of molten lead and slag
3. Effective extraction ventilation to a filter plant / baghouse

Technical description:

Some parts of the following description differentiate between tapping melting and smelting furnace operations: Pure melting operations can be conducted for elementary lead scrap such as sheeting, pipes, underwater cables, and the clean grid metallics from ULAB (separated by a hammer mill breaker → see B.2.1). Such melting processes can be operated between 400 and 450°C. Smelting operations are applied to materials containing lead-compounds (e.g. battery paste, mixed battery scrap, baghouse dust) and to reduce it to metallic lead. Smelting processes require temperatures between 900 and 1,100°C (also see B.2.6). Therefore, tapping smelting operations requires a higher level of precautionary measures.

1. Tapping method

Manual tapping of the furnace is still the most common practice for rotary furnaces. It is therefore essential that the correct PPE is worn by operators and special attention is paid to closing and opening the tapping port. Clay is used to close tapping ports and it is important that the tapping port can be opened easily and quickly as necessary, preferably using a rock drill supported by a steel arm attached to the furnace. A counter-balance may also help the operator to drill through the tap hole plug.

In the case of a tilting rotary furnace there is no need to plug a tapping port because the lead bullion can be poured into moulds from the door by tilting the furnace forwards (see B.2.3).

2. Capture of molten lead and slag

Metal from a smelting operation is very hot at around 900°C and should not be poured directly into cold kettles or metal moulds due to the risk of explosions from contained water or moisture (particularly critical in humid climate conditions). This practice also causes stress to the steel wall through thermal shock and that can cause a fracture in the kettles, moulds and launders, which can cause lead spillage (a severe occupational safety risk).

The furnace can be tapped through a preheated launder to either a holding kettle or 1 or 2 tonne moulds that have been preheated. The molten metal cast to moulds is allowed to solidify to produce 1 or 2 tonne blocks of lead bullion.

Before the 1 or 2 tonne blocks solidify, steel anchors should be placed in the molten metal to enable the blocks to be removed from the moulds easily by overhead crane and charged to a refining kettle. The blocks should be allowed to cool under an extraction ventilation hood connected to a baghouse, because at and above 500° Celsius, lead fume is still being generated.

Slag should be tapped to 1 or 2 tonne block moulds and allowed to cool in a manner similar to the molten metal, that is, under a ventilated extraction hood.

Due to the lower temperatures, the molten lead bullion tapped from a melting furnace can be tapped directly into an empty refining kettle or a metal mould, but extraction ventilation must be on.

3. Ventilation

Whatever tapping procedure is adopted, effective extraction ventilation to a baghouse is essential to minimise the risk of occupational lead exposure (see B.4.1). The smelting tapping process will produce high amounts of fumes and dust so that extraction ventilation should be switched to maximum force and typical a face velocity of at least 1 m/s measured at the point of exposure to the dust or fume and 7 m/s at the ventilation duct. Furthermore, for hot lead bullion and slag that are stored for cooling, extraction ventilation must be applied as well (see above and picture below).

Unacceptable	**Good Practice**
	
Hot fuming molten lead bullion is tapped from an unventilated port and poured into unventilated 25 kilo ingot moulds. Safety and occupational lead exposure risks will be high. Furthermore, operators are not equipped with effective PPE.	The operator is tapping the molten metal and slag into their respective pots with extraction ventilation hooding in place. The operator is wearing all the requisite PPE, including hard hat, face shield, respirator, overalls, and flame-resistant jacket and trousers.

Further notes:

- Unless an operator is tapping a furnace remotely, full PPE protection should be worn; respirator (at least N95/FFP2), long sleeved cotton drill with leather apron, safety helmet, foundry gloves, boots with steel or carbon fibre toe protection, safety googles, glasses or visor (see A.2.1).
- Adequate fire precautions must be in place (see A.3.7).

B.2.8	Lead refining & alloying	recycling & smelting

Requirement: Lead refining and alloying must be conducted in a set-up minimizing occupational hazards and capturing all fugitive emissions such as lead dust and fumes generated by the operation.

Scope: Recycling & smelting

Note: Not all secondary smelting operations have a refinery step in their process. In some operations, the unrefined lead bullion from the furnace is on-sold to other lead smelters as feedstock for their refineries. The bullion lead is considered as a semi-finished product and there is a strong market for the product. Thus, lead refining and alloying is not an obligatory part of a ULAB recycling plant.

Background and rationale: To be utilized back into the industrial cycle, such as in producing new lead-acid batteries, unrefined lead bullion must undergo refining to meet international and in some cases battery company standards. For example: For pure lead material battery manufacturers require purity of 99.97% or greater to produce lead oxide, a vital component of the battery.

Lead refining requires heat, addition of chemicals and elements, and a molten lead bath. Thus, refining needs to apply stringent health & safety measures, as well as off-gas capture and treatment.

Technical description: Refining kettles are produced from steel as there is no solubility of iron in lead, i.e. lead does not dissolve or alloy with iron. Refining kettles vary in size depending upon a number of factors including: throughput of the plant, alloying requirements and soften capacity. Kettles range from 20 mt to 100 mt and in the cases of very large facilities such as in the primary smelters, up to 200 mt. Ideally, the molten lead metal is tapped from the furnace directly to the refinery either to a holding or refinery kettle where the first pass dross is removed. If a holding kettle is used, once cleaned of this dross the metal is pumped to a refining kettle at around 450^{o} Celsius. Alternatively, the molten metal can be tapped from the furnace and cast into 1 to 3 ton blocks, allowed to solidify and then charged to a refining kettle (see B.2.7).

The refining of the lead bullion is a series of processes carried out in the kettles. Specific impurities are removed with the addition of certain compounds or elements at different stages and temperatures. The resultant drosses, often rich in the impurities, are removed from the kettles and returned to the smelter for reprocessing (see further notes).

Design of the refinery: For safe and energy efficient operation, the refinery should be designed as follows

- Kettles can either be above ground, as pictured, or in the floor, but in each case the burners must be able to be maintained easily.
- For the operators the working area of the refining floor should be free of any tripping hazards.
- If the refining floor is elevated, it must have handrails installed that are at least 1 metre high.
- If the refining floor is elevated, there must be two access and exit points from the refining floor to evacuate in the event of an emergency.
- The sides of the kettle must be at least 1 metre from the floor to a) minimize the risk of anyone falling to a molten lead bath and b) allow for safe and efficient drossing of the kettle.
- All the kettles must be fully enclosed at all times when in operation, except when lead blocks, reagents or alloying metals are charged to the kettle.
- Every kettle, including the combustion chamber, any dross drums and other receptacles for holding dross and other equipment should be connected to the fume extraction system (see B.4.1).
- Access doors fitted to the kettle covers allow access for sampling and reagent additions.Casting the final product is usually done by pump transfer, although with elevated kettles gravity casting is possible.

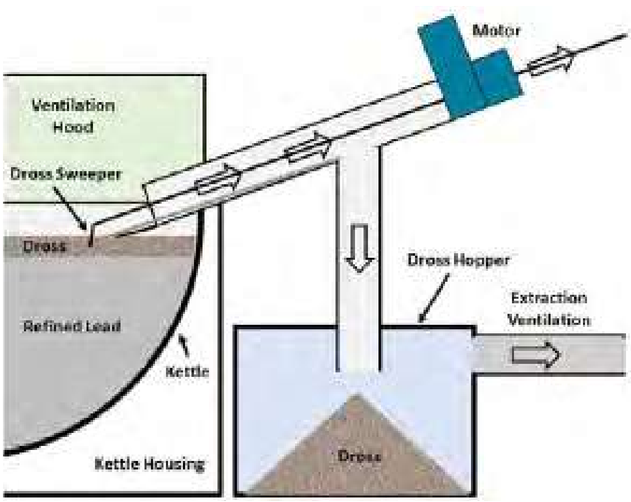
Dross Removal: In the refining process, the metal impurities are removed from the lead bullion in numerous forms including oxides, sulfides and complex compounds. These are captured in drosses that float on the surface of the molten lead bath, which are hot and dry, usually dusty, and quite dense. If the drosses are removed manually an inspection hatch has to be opened to allow access to the dross. It is recommended that manual de-drossing should use a pivot spoon method to reduce the effective weight of the dross (see picture below). All refining drosses are returned to the furnace to recover the lead content and in some cases the impurities.

One method for dross removal from a kettle which is preferred by larger operations is an automated dross removal machine. All dross bins must be attached to an extraction ventilation system to prevent lead containing compounds being released (see B.4.1).

Manual de-drossing using the pivot method to remove the refining dross to a bin connected to an extraction ventilation system. Allowing the arm of the de-drossing spoon to rest and pivot on the supporting stand reducing considerably the workload and any strain or stress to the operator's back and arm muscles. The operator needs to wear a neoprene respirator with dust cartridge or dust mask (at least P2 or N95/FFP2), a long sleeved cotton drill, a hard hat, heat resistant gloves, boots with steel or carbon fibre toe protection, safety goggles, glasses and a visor.

Schematic of an automated dross removal unit with a mechanical sweeper that transfers the dross to a ventilated collection hopper.

The dross is returned to the furnace to recover the lead content. , Some of impurities can be recovered as by-products such as tin.

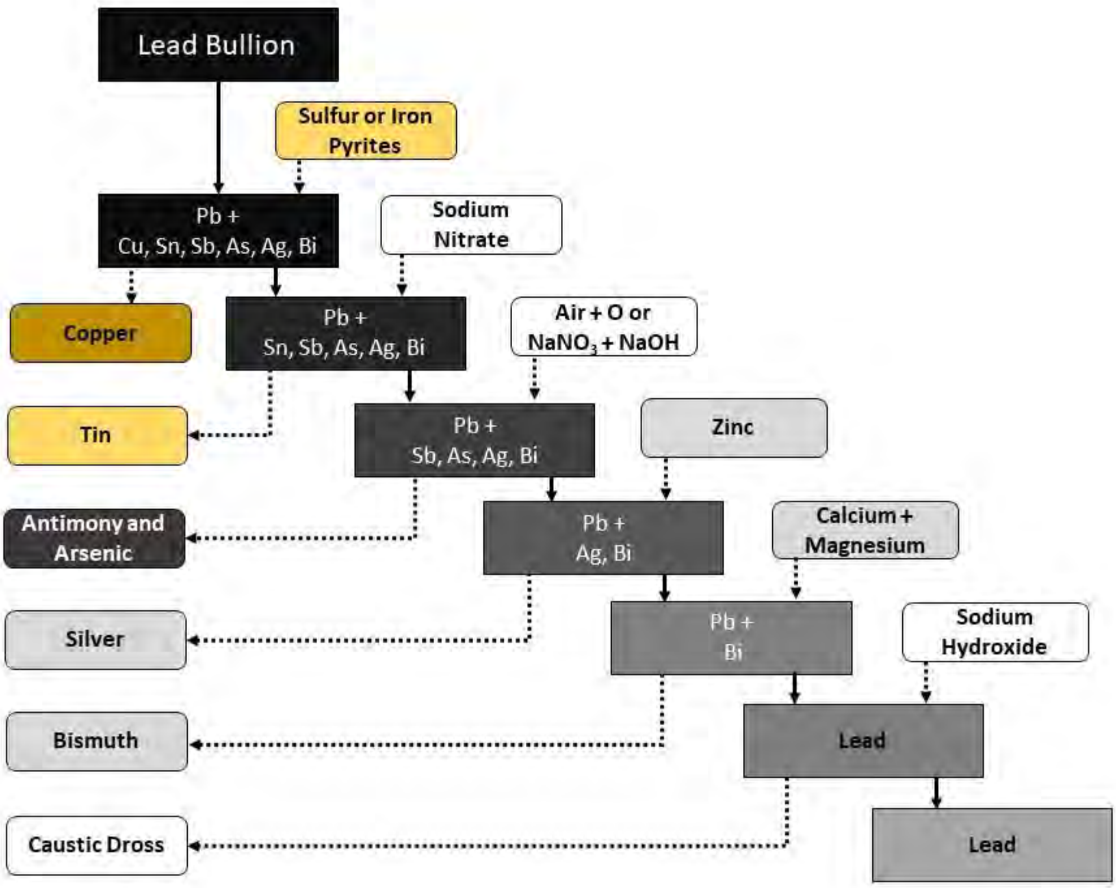


Lead Alloying: To meet customer requirements alloying metals, such as calcium, antimony, silver and arsenic can be added in specified quantities to the molten metal bath through one of the inspection hatches (see further notes).

Unacceptable	Good Practice
	
The refining kettle is set in the floor without a 1 metre skirt. This creates a hazard as the operator can fall into the molten lead bath. The kettle is not covered or attached to an extraction ventilation system.	Integrated kettle refining complete with cover, extraction ventilation system connected to a baghouse, mixer, pump, inspection hatches for charging the kettle, sampling, reagent and alloy additions. This system also comes with automated de-drossing fitted internally. Dross is removed to a ventilated bin and all drosses are recycled internally. Operation of the kettle is from a remote workstation.

Further notes:

In terms of chemical processes, the refining processes follows sequence:



- Copper (Cu) is usually the first metal removed with either elemental sulfur or a combination of sulfur and iron pyrites. There are two methods used in its removal. The first method is by adding small amounts of elemental sulfur to the stirring vortex at around 330ºC, just above the melting point of lead.

The copper is removed as a copper sulfide (CuS) dross, along with lead sulphide produced in the reaction. The second method is performed at higher temperatures of around 450ºC, where a mixture of sulphur and iron pyrites is added to the vortex of the stirring metal.

- Antimony (Sb), arsenic (As) and tin (Sn) are elements that come from the lead alloys in the battery, and although a percentage is lost to the slag, the elements are found in substantial levels in the lead bullion. In the case where the bullion is used to make alloys they are retained for their value, but in the case of soft lead, they must be removed. There are two methods employed in removing the elements, the first is the removal by oxidation with either air enriched with oxygen (O_2) or pure oxygen. The temperature of the molten lead is raised to 550ºC and a flow of O_2 needs to bubble into the molten metal. The reaction must be monitored closely because it is exothermic, and the temperature of the lead bath can easily reach 650ºC if the flow of oxygen is not controlled correctly. The second method is the addition of sodium hydroxide (NaOH) followed by sodium nitrate ($NaNO_3$) at a kettle temperature of between 450ºC and 525ºC. Sodium nitrate is a strong oxidizing agent and care must be taken in handling the product. In both processes the dross is removed and returned to the furnace for reprocessing.
- Tin (Sn) is an element that can be selectively removed from the bullion lead with the addition of ammonium chloride at around 450ºC. This process is not often used as it introduces chlorides into the smelter system, which is not desirable in many circumstances.
- Silver (Ag) can be removed next, but this stage, using zinc which is termed the Parkes Process, is normally only applied to primary lead bullion because the quantities in ULAB are too small to remove economically.
- Bismuth (Bi) can be removed with some difficulty if necessary, but like silver, falls below 99.97% based alloys and soft lead. The process is used predominately in primary lead refining, but if bismuth has to be removed, metallic calcium (Ca) and magnesium (Mg) are added to the kettle, forming a lead-calcium-magnesium-bismuthide as an intermetallic dross/compound that can be removed by skimming the surface of the molten lead bath.
- The final process is the treatment of the refined lead with sodium hydroxide (NaOH) to remove any residual impurities in preparation of casting into one-ton blocks or 25/40 kilogram ingots.

B.2.9	Casting refined lead & lead alloys	recycling & smelting

Requirement: Casting refined lead or lead alloys must be undertaken in a well ventilated and safe working environment that effectively protects operators from hot molten lead (400°C and above), and any fugitive emissions or dust is captured and ventilated to a baghouse filtration plant.

Scope: Recycling & smelting

Background and rationale: Refined pure lead has a melting point at 327.2°C, but when it is being cast correctly to moulds is at a higher temperature of between 450 and 500°C. It is hot enough to cause serious injury if an operator is not wearing the correct PPE and molten metal comes into contact with any part of an operator's anatomy. Dross forms during casting, more so if the process is turbulent and will cause occupational lead exposure. Extraction ventilation must be adequate when the dross is removed, generally by manual methods, from the surface of the lead in the mould.

Technical description: Molten refined lead and lead alloys are normally cast into either ingots of 25 or 40 kg or one tonne blocks. There are two methods of casting from a refining or alloying kettle. One method is to pump the molten lead out of the refining or alloying kettle to the casting machine. Two main variants with this method, one the direct casting of lead to a "star wheel" and the second, small holding tanks or tundishes from where the molten metal is gravity fed into the moulds. This method is safe as long as the operators are protected from the hot overhead transfer lines/pipes that contain the molten metal at 400°C+ when they pass over or across a walkway.

Elevated lead refining kettles with a gravity feed to casting machines adjacent to kettles 1 and 4

The alternative is to gravity feed the molten lead from the base of the kettle straight to the holding pot or direct to the mould. This method eliminates the use of a pump and enables all the refined lead or alloy in the kettle to drain provided the valve is located at the base of the kettle. This method also requires the refining kettles to be elevated above the casting machine. Refined lead and alloys can be cast manually, but this is not recommended due to the safety and occupational exposure risks associated with the transferring methods employed, such as the ladling molten metal into ingot moulds.

Proprietary semi and fully automated casting machines are available and are recommended.

As lead ingots are heavy it also recommended that the casting machine is ordered with an automated stamping, stacking, weighing and banding machine. This additional item of equipment will virtually eliminate the risk of fatigue and possible back injuries amongst the operating personnel. Once stacked and banded the bundles can be removed from the conveyor by fork truck.

However, automated lead casting, stacking and banding machines require operators to:

- Either heat the transfer lines and flow valves or fire the trace heating to make sure the molten lead does not freeze in the transfer lines and valves at the start of, or during casting.
- Apply heating to the empty moulds before casting to ensure that, when the hot molten lead is poured in, it does not spit and splash as it will do if the mould is cold and contain trace of water/condensation.
- Adjust the feed of the molten lead to the holding tank and check the casting temperature.

- Remove any dross formed on the top of the molten metal and place it in an enclosed bin for recycling back via the furnace. If manual skimming (de-drossing) is preferred, the operator must have the right tools for the job. Automated flame skimming is used by some companies, but most prefer to remove the dross manually.
- Inspect the quality of the finished ingot to ensure there is a smooth surface on the top of the ingot free of any inclusions and adjust the flow rates or cooling process to minimise the risk of inclusions forming. Inclusions attract and trap moisture and water and if this happens, there is the potential for an explosion if an ingot with water in an inclusion is added to a molten lead bath during subsequent industrial use (e.g. grid casting in battery production).
- Check the extraction ventilation systems are working so that any dross dust generated is removed from the working environment.
- Remove the bundles of cast lead ingots or blocks by fork truck to storage awaiting delivery.

Unacceptable	**Good Practice**
	
Molten lead is being cast manually to 25 kg ingots using a 3 kg ladle with a long handle. The lead is being poured close to the operator removing the dross rendering him directly in the line of fire should the molten lead spit or splash. In addition, the operators are not wearing appropriate PPE with insufficient footwear and eyes and skin exposed. Also removed dross is dropped onto the floor and a source of occupational lead exposure. Cooled lead ingots must be removed from the moulds, stacked and banded manually, which is likely to cause ergonomic problems.	Casting with an automated casting machine. The operator is wearing appropriate PPE and is carrying out a quality inspection from a stable purpose-built standing platform.

Further notes:

- The operator of an automated casting machine needs to be at a certain height above the ingots to carry out a proper inspection and a stable purpose-built standing platform might be required.
- Operators must wear appropriate PPE, including neoprene respirator with dust cartridge, long-sleeved cotton drill (the leggings must go over the outside of the boots), leather apron, safety helmet with a full-face visor, heat resistant gloves, boots with toe protection and a high ankle, spats on the lower leg and welding sleeves on the forearms, and in certain circumstances, ear defenders (also see B.2.1).

B.3.1	Management of battery electrolyte	collection points · bulk transport · recycling & smelting

Requirement: Appropriate control procedures must be in place to prevent leakage of the battery electrolyte (commonly referred to as 'battery acid') at any stage of the collection and recycling process. During the recycling process the battery electrolyte must be collected and treated, rendered inert or converted to a non-hazardous product. Neither untreated nor neutralised electrolyte shall be discharged to freshwater sources.

Scope: Collection points, bulk transport, recycling & smelting

Background and rationale: Lead-acid battery electrolyte is dilute sulfuric acid with a pH of less than 2. It must not be allowed to come into contact with incompatible materials such as oxidizing agents, reducing agents, combustible materials, organic materials, metals, other acids, strong bases, alkalis and alcohol. The electrolyte will, over time, also dissolve concrete. Furthermore, because it is a very corrosive chemical, it can cause skin burns and permanently damage the eyes if contact is made. Released into the environment it is harmful to aquatic life, fauna and flora and significantly contributes to soil acidification. Further, it often contains other hazardous substances that have been solubilised from the reactions in the battery.

Technical description:

Release of battery electrolyte to the workplace or environment must be avoided during all stages of ULAB management, including collection, transport and recycling. All actors in the reverse supply chain shall aim to channel complete wet batteries (including the electrolyte) to ULAB recycling where the electrolyte can be safely collected and recycled.

All areas where ULABs are stored and handled must be equipped with impermeable floor and a drainage system that effectively captures and collects all potential electrolyte spills. Exemptions are possible for ULABs stored and transported in leakproof containers (see B.1.1 and B.1.2).

Battery electrolyte shall only be removed from the batteries in the recycling process (during breaking process) in a controlled manner (see B.2.1):

- When using a battery saw to break ULAB the electrolyte must be drained to the effluent treatment plant (ETP) prior to breaking.
- Automated hammer mill breakers must be connected to the ETP to capture and treat the electrolyte.
- Every effort should be made to remove as much electrolyte as possible to minimise the sulfur content of the furnace charge and subsequently the sulfur dioxide burden in the furnace off-gas (see B.2.2).
- Treatment of electrolyte in the ETP mainly encompasses 2 steps:
    1. Filtering of electrolyte through a filter press (see picture below) to remove any suspended lead particles (recovered lead particles must be recycled through the furnace → see B.2.4).
    2. Adding a chemical to convert the sulfuric acid into a non-hazardous product.

Filter press removes suspended particulates from the electrolyte

- The recommended, and most commonly adopted treatment of clean battery electrolyte is the production of calcium sulfate (gypsum) by neutralizing the effluent with lime (calcium oxide/hydroxide). Gypsum produced to construction industry standards has applications in the building and cement industries, but in the event that a local market is unavailable, it can be disposed as an inert non-hazardous waste.

Unacceptable	Good Practice
	
Batteries are drained manually at a collection point, and the electrolyte is drained to the public sewer. Acid and lead particles (dark colour) are severe environmental contaminants. Furthermore, the corrosive nature of the acid is a safety risk to the unprotected worker.	An Effluent Treatment Plant (ETP) will capture any process effluent, including any battery electrolyte arising from battery breaking and either neutralises the effluent for a controlled and legal release or converts the effluent into a saleable product or non-hazardous waste. Any residual liquid is used to either cool the lead ingots during casting or for damping down dusty work areas.

Further notes:

- Workers that maybe in contact with battery electrolyte must be equipped with long sleeved cotton drill with plastic apron, nitrile or neoprene acid resistant gloves, eye protection and waterproof boots (also see A.2.1).
- An eyewash basin or station must be placed in areas where battery electrolyte spills or splashes may occur.
- In monsoon or hurricane (typhoon) prone regions the effluent treatment plant vessels must be elevated above the flood plain.

B.3.2 Recycling of plastic cases

recycling & smelting

Requirement: ULAB plastic cases must be processed and recycled so that all residual lead, lead-oxide and lead sulfate are effectively removed.

Scope: Recycling & smelting

Background and rationale: While the plastic cases from ULABs are – due to their typical material composition – attractive for recycling, residual lead and lead oxide may contaminate other products if not removed. Therefore, effective cleaning of plastic is required.

Technical description: The cases of most ULABs are either made from polypropylene (PP), or acrylonitrile butadiene styrene (ABS). Both polymer types can be recycled, but it is essential that all plastic for recycling is effectively cleaned to remove all remaining lead, lead oxide and lead sulfate by rinsing with an alkali solution prior to the final rinse.

Depending on the type of battery breaking (see B.2.1), plastic recycling requires different steps:

- Facilities using a hammer mill for battery breaking produce cleaned plastic chips, but a wash in an alkaline solution is still recommended, followed by a clean water rinse.
- If a battery saw is used, the cases and covers must first be washed to remove acid residues and all non-plastic material. Washing shall apply a first cycle with water, followed by a rinse in alkaline solution to remove remaining traces of lead-oxide, and a final rinse with clean water.

Independent of the breaking and washing process, strict quality assurance must be applied to ensure that produced chips are free from any lead, lead oxide and lead sulfate. In case the chips are not entirely clean, further washing in alkaline solution is required.

The process water from the washing cycles can be reused, but the water for the last cleaning cycle shall always be fresh. All cleaning effluent and alkaline solutions must be treated in the effluent treatment plant (see B.4.5).

Most plate separators in the interior of the batteries are made from plastic (polyester). Automatic hammer mill breakers will separate the polyester separators and they should be charged to the furnace without attempting to recycle them (also see B.2.4).

Polypropylene plastic chips can either be further processed (e.g. extruded to produce pellets) or sold to other plastic recyclers. An ideal application of recycled plastic from ULAB is the production of new lead-acid battery cases or moulded plastic forms.

Unacceptable	**Good Practice**
	
Plastic cases are washed in a rotating drum but the rinse water spills over and carries much of the lead- and acid-containing residues to the surrounding area. Furthermore, the process is not sheltered from rainfall and is not situated on smooth and impermeable floor as required by A.2.5.	The plastic cases obtained from the battery saw breaking process are washed in an alkaline solution and water so that they are free of residual acid and battery paste before being fed into the case shedding machine to produce plastic chips that are sold to a plastics recycler.

Further notes:

- The operation of a shredder for producing plastic chips is often associated with high noise levels, rotating blades or hammers, as well as risks of flying shards. Workers operating such a shredder (or persons working in areas where such a shredder is used) must wear appropriate PPE including ear defenders and safety goggles (see A.2.1) and be trained in the safe use of such equipment.
- For recycling of plastic cases, the polymer types (mostly PP and ABS) must be effectively separated. This can be done on the basis of the ULAB types (most automotive LABs have a PP case, while most LABs from uninterruptible power supplies have an ABS case) and the physical properties of the polymers: ABS is stiffer and harder than PP and – in contrast to PP – sinks in water. Further value addition is possibly by colour sorting.

B.4.1 Filter plant / baghouse & off gas treatment

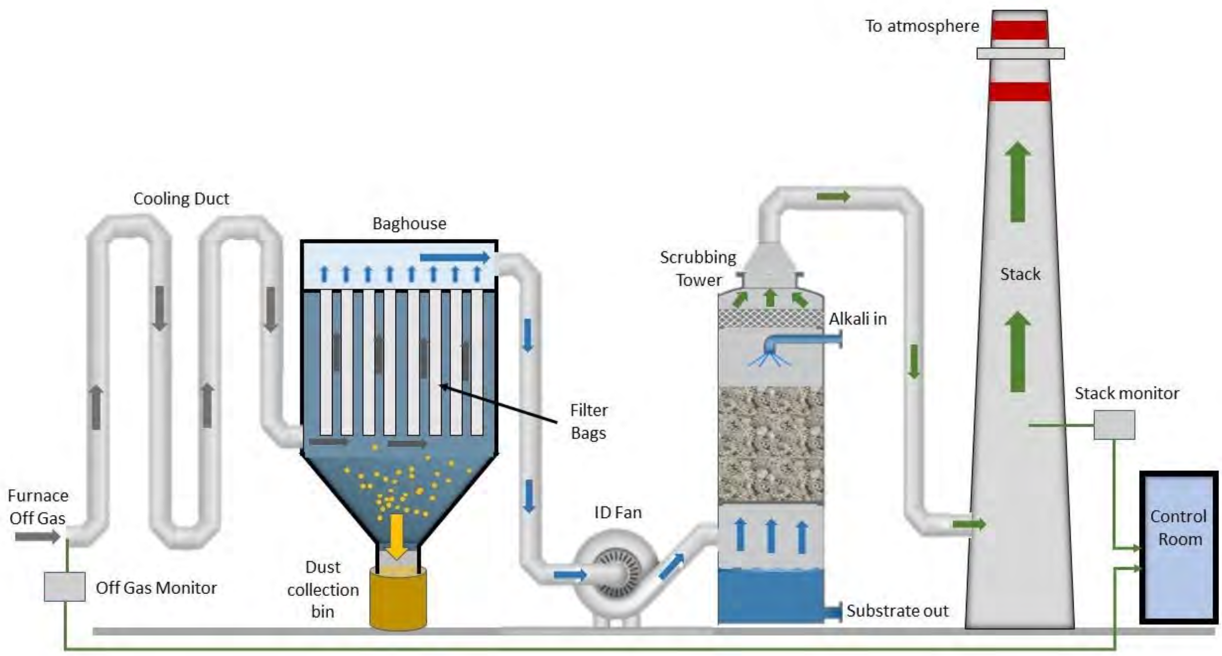
recycling & smelting

Requirement: All off gases from lead smelting, melting and refining operations need to be ventilated to a filter plant that effectively captures all emissions.

Scope: Recycling & smelting

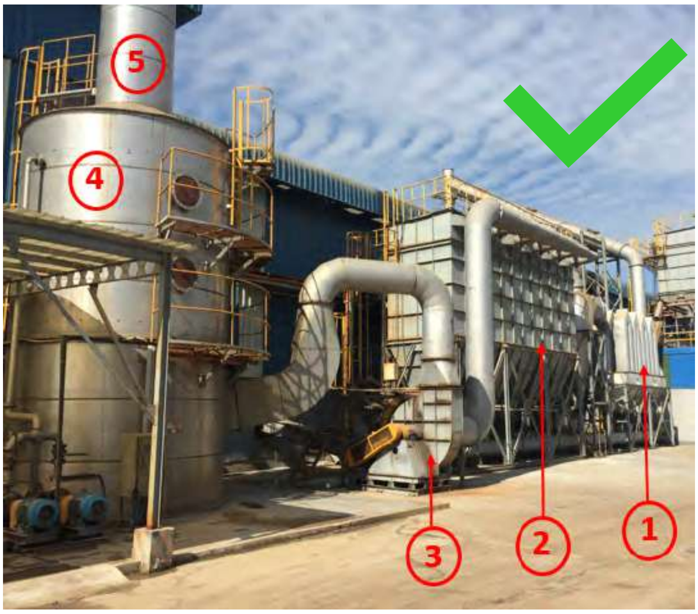
Background and rationale: The lead fumes and dust particles generated during lead smelting, melting and refining are hazardous. It is therefore essential to capture any fume and dust particles generated by passing the furnace off-gases through a filter plant, also known as a 'baghouse'.

Technical description: The filtration medium can be ceramic or fabric but the principles are the same.



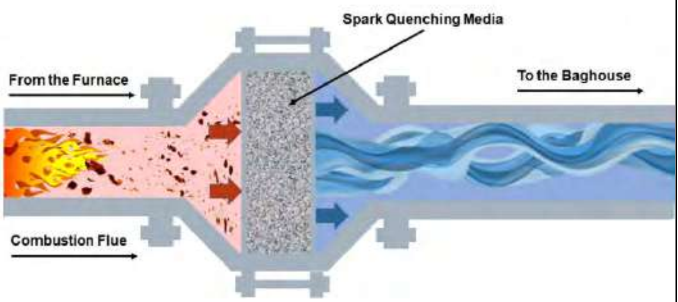
Essentially, an ID (Induced Draft) fan (or fans if there is more than one filter plant) with a high extraction rate will draw the off gasses from the furnace or refining combustion chambers and, albeit separately, the hygiene ducting, through a combustion flue (cooling duct) that is long enough to allow the fume particles to cool and coagulate into dust particles of a size that can be captured by the filter medium (also see 'further notes'). The gasses pass through the filter medium, but the dust is captured and ejected into enclosed collection bins below the filter bags. The baghouse dust collected must be returned to the furnace to recover the lead content (see B.4.2) as it is also a valuable feed. The off gases that pass through the filter medium should be dust free and will then pass through a scrubbing tower to remove any residual sulfur dioxide and dust particles prior to discharge to through a chimney stack.

Operating Essentials: It is important to maintain the internal temperature of the baghouse above the dew point of water vapour (typically above 50°C) to ensure the filter medium does not become blocked or "blinded" with condensation. If sulfur dioxide gas is present in the off-gas (which is the case for all operations not using any desulfurization prior to smelting – see B.2.2) it must not be allowed to condense because if it combines with water vapour to form sulfuric acid it will cause corrosion of any susceptible materials, such as polyester bags and any ferrous metal components. As the dew point of sulfur dioxide is more than that for water vapour the internal temperature of the baghouse needs to be in the range 120 – 150°C, depending on the concentration of sulfur dioxide.

Unacceptable	Good Practice
	
Lead smelter without any off gas treatment	Complete filter plant with cooling duct (1), baghouse (2), ID fan (3), scrubbing tower (4) and stack (5).

<u>Further notes:</u>

- The temperature of the furnace off gases entering the baghouse must be below the softening point of the bags (Polyester 150°C and PTFE 260°C). As the furnace off gas needs to be at a temperature ranging between range 120 – 150°C to avoid condensation of SO_2 and the formation of sulfuric acid (see technology description), polyester is not the most suitable filtration material for the bags.
- The appropriate length of the cooling duct depends on ambient temperatures and must be calculated by specialised engineers in a plant specific manner.
- Filter plants also need constant and thorough maintenance (see B.4.3)
- It is also important to install at least one spark arrestor in the flue between the furnace and the baghouse to prevent furnace embers reaching the filter bags.
- The spark arrestor can also take the form of a large drop-out chamber that effectively slows down the velocity of the off-gas momentarily, but long enough for any embers to fall to the bottom of the chamber. A baffle restriction can also prevent the flow of embers.
- Some countries have mandatory requirements for stack heights. While compliance with national regulations is important, high stacks are not an effective means of emission reduction and only serve to transport emissions outside of the plant.



Typical Spark Arrestor

B.4.2 Management of baghouse dust and fume

recycling & smelting

Requirement: All the dust/fume captured by a baghouse need to be contained and returned the furnace to recover the lead content. The system must be designed so that the operators never come into direct contact with either the fume or the dust.

Scope: Recycling & smelting

Background and rationale: Baghouse dust (also known as fume) is actually a condensed fume created by the oxidation of elements due to either changing vapour pressure, boiling/sublimation points or oxidation of elements. Lead dust captured by the filter media (see chapter B.4.1) has a lead content between 50% and 70% and with a colloidal particle size, it is extremely hazardous, particularly when inhaled. Accordingly, when the dust is ejected from the filter plant through a non-return valve it must be collected, contained securely and returned back to the furnace as quickly as possible. Baghouse dust must not be stockpiled.

Technical description: The dust must be returned to the furnace to recover the lead content, either using an enclosed conveyor system (see photo below) or by using sealable new or used steel collection drums or bags securely attached to the discharge chutes. Other methods involve the pelletizing of the dust, which conglomerates the fume to one-centimetre round particles. It is important that pelletizer machine must be well-maintained and working when the baghouse is operation. Pelletized fume must be charged to the furnace as soon as possible because it can have a short shelf life and soon disintegrates to dust.

Ideally, the collection drums or bags should be of a size that can be charged directly to the furnace without removing the dust from the drum of bag. If new or used steel drums are not easily available, then woven polypropylene bags of an appropriate size can be used provided the connection between the baghouse discharge chute and the polypropylene bag is secure. No attempt should be made to remove the baghouse dust from the collection bin or bag and mix it with the furnace charge material prior to charging to the furnace, because such mixing generates hazardous dust in the work area.

Unacceptable		Good practices	
			
The dust collection bag is not secured to the discharge chute and therefore when dust is ejected from the baghouse it could easily be blown away into the plant or the local environment and communities.	Lead dust released to open collection bays will be subject to dispersion wind or a light breeze, thereby spreading a toxic dust around the workplace and possibly outside the plant into the environment and communities	Baghouse dust is discharged into an enclosed conveyor system that feeds the material back to furnace charge preparation, thereby avoiding contact between operators and the dust.	Baghouse dust is discharged into sealed drums. The drums are charged directly to the furnace when full to recover the lead in the dust, thereby avoiding contact between operators and the dust.

Further notes:

- Operators working in or around a baghouse filter plant must wear the appropriate PPE, including overalls, boots, gloves, hat, safety glasses and not less than an N95/FFP2 dust mask or equivalent neoprene cartridge filter. When operators are engaged in clearing up a dust spillage it may be necessary to wear full-face respirators.
- The dust collection and handling procedures described above do not apply to Wet or Dry Electrostatic Precipitators (WESP/ESP) because the dust is removed from the collecting electrode by flushing with water.

B.4.3 Monitoring & maintenance of baghouse filter plants

recycling & smelting

Requirement: The filter plant / baghouse requires constant monitoring and maintenance to ensure that all lead fumes and dust particles are captured during operations.

Scope: Recycling & smelting

Background and rationale: Monitoring needs to be based on a combination of methods, including the measures in the table below. In case this monitoring indicates any shortcomings (red sections in the table below), the filter plant needs to be serviced to achieve full functionality. An obscuration meter should be in place to measure the dust levels of the baghouse system at all times.

Technical description: Generally, filter plants / baghouses have twin sections so that when one section is operating and removing fume and dust, the other section can be cleaned. When the cleaning cycle is completed, the twin sections switch roles.

Method	Indicator	Interpretation
1) Observation of stack emissions and obscuration meter*	+ No visible plumes of dust during plant operation (*Photo 2 below*); No signal from the obscuration meter	Indication that off gas system is functioning
	- Visible smoke & dust; Obscuration meter alarm initiated. (*Photo 1 below*)	The off-gas system is dysfunctional: The filter bags may have holes in them or been dislodged during cleaning, thereby allowing dust to pass directly to the stack
2) Monitoring the amount of dust collected per day	+ Collection rate similar to usual collection rates	Indication that off gas system is functioning
	- Little or no dust is collected	Either poor extraction at the source of the fume or dust, a blocked flue or the cleaning cycle is not synchronised
3) Checking the exhaust ventilation face velocities at the furnaces and refining kettles.**	+ Positive reading / measurable ventilation (*Photo 4 below*)	Ventilation off-gas system is functioning
	- No reading / no measurable ventilation (*Photo 3 below*)	Ventilation of the off-gas system is dysfunctional
4) Observing compressed air usage**	+ Normal use rate	Filters are most likely functioning normally.
	- Use rate above normal	Ceramic filters or the filter bags might be blinded, indicating a fault with the cleaning mechanism or that the filter medium needs replacing
5) Observing the electricity consumption of the ID fan	+ Normal consumption	Filters are most likely functioning normally.
	- Increased consumption	The filter medium may be blinded and need cleaning or replacing, or it could be a sign that the charge material was too wet and the bags are coated with damp dust
6) Measuring the differential pressure across the input and output sections of the baghouse****	+ Differential pressure between 0.00-0.18 psig (0.0-12.4 kbar)	Filter bags are ok (0.00-0.07 psig → still new, 0.07-0.18 psig → filter bags are already used but still ok)
	- Differential pressure > 0.22 psig (> 15.2 kbar)	Filter bags reached their end-of-life and need replacement

* 1): The data from the obscuration meter should be permanently recorded and made available to inspectors.

** 3): Auditors should always carry and use a handheld anemometer to measure extraction face velocities.

*** 4): Pulse pressure should be between 90 – 100 psi. Any reading < 30 psi will not clean the filter

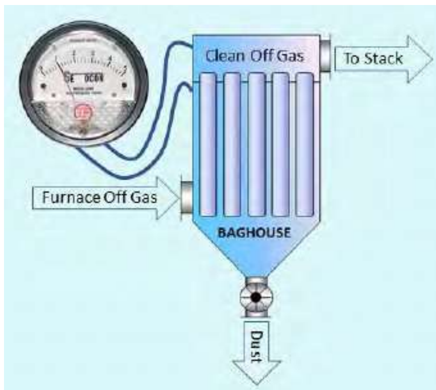
**** 6): Measuring the differential pressure across the input and output sections of the baghouse provides the best indication of the health of the filter medium. More details are presented under 'further notes' below.

Unacceptable	**Good Practice**	**Unacceptable**	**Good Practice**
			
Photo 1 Visible smoke or dust from the stack is a clear indication that the filter plant / baghouse is not functioning correctly, and lead dust or sulfur dioxide is being ejected into the atmosphere.	*Photo 2* No visible smoke or dust from the stack (or anywhere else from the system). Note: Some vapour may be visible in some cases in some distance over the stack. Such vapour indicates that furnace charge was partly too wet but is no indication of lead dust or sulfur dioxide emissions.	*Photo 3* No suction indicated by a zero reading on the anemometer, then the extraction ventilation system is dysfunctional. Possible causes could be: underpowered ID fan, the ducting to the baghouse is blocked, but whatever the reason, an investigation is required.	*Photo 4* Extraction face velocities should be measured at the point source of the fume or dust, the operator's workstation or the outside of any hooding or housing designed to contain emissions. Readings on the anemometer need to show there is suction. In the example the Extraction Suction's face velocity is 2.1 m/s.

Further notes:

On monitoring method 1:

- An obscuration meter must be installed on the outlet stack to monitor emissions to atmosphere from the plant after filtration. Calibration of such an instrument with simultaneous gravimetric sampling is required to confirm quantification of the emissions. A digital readout can be installed in the plant control room together with an audible alarm that is set to a pre-determined limit. Data must be recorded and held for at least two years.



Measuring principle of a differential pressure gauge required for monitoring

On monitoring method 3:

- In the absence of an anemometer smoke can be used to ensure the extraction is active, but it will not indicate the face velocity only the direction of the extraction.

On monitoring method 5:

- It is advisable to keep a record of the daily amp-draw of the ID fan. If the amp-draw rises above or falls below the manufacturers specified levels, this is a clear indication that the system is not functioning correctly.

On monitoring method 6:

- Modern filter plant and baghouse installations will provide a digital read out in the control room or on the side of the baghouse. In general, all baghouse filter plants should be equipped with such differential pressure gauges to allow monitoring according to method 6 above. The differential measurement is based on the fact that the off gas passing through the filter medium loses momentum and this change in velocity can be measured by connecting the measuring device (analogue or digital) to the off-gas and clean gas sections of a baghouse. When the filter bags are new the resistance to the gas flow through the bags is low, but as dust builds up on the bags through use, the resistance to the flow of gas through the bags increases and the volumetric velocity of the off-gas decreases, and the differential pressure measurements will increase. New bags will typically exhibit a differential pressure drop of between 0” and 2” water gauge (0.00 – 0.07 psig). Seasoned bags with good cleaning cycles, will measure 2” to 5” w.g. (0.07 - 0.18 psig) and when the filter bags are at the end of their working life the readings will be more than 6” w.g. (> 0.22 psig).

B.4.4	Management of furnace residues (slags)	recycling & smelting

Requirement: Furnace residues (slags) must be treated as hazardous waste and disposed of in a safe and environmentally sound manner.

Scope: Recycling & smelting

Background and rationale: Irrespective of the furnace technology, lead furnace residues are typically classified as a hazardous waste because they invariably contain entrained lead prills (tiny beads of lead metal) and traces of lead compounds such as lead sulphide. Certain slags are soluble in water, and some will also appear to be combustible under certain conditions when disposed. For these reasons, smelting batches must be optimised, and slag composition monitored to reduce the residual lead content. Interim or temporary storage of furnace slags must be under cover in a well-ventilated area or shed on impermeable concrete, and sheltered from the wind, rainfall and flooding. Furnace slag is as hazardous waste and must be disposed of at a secure licensed hazardous waste disposal facility. Untreated slag must never be dumped into the environment or disposed of in a non-hazardous landfill designed for municipal waste.

Technical description: Depending on whether the furnace feedstock has been desulfurized or not (see B.2.2), furnace slags can have an iron content up to 35%, as the slag is the medium for capturing the residual sulfur in addition to any other unwanted impurities. Rotary furnace slags will break down as they absorb moisture and carbon dioxide from the atmosphere, leaving iron, sodium and other possibly toxic compounds behind as fine powder or sludge.

- Before, during and after this decomposition process, the slags must always be sheltered from the wind, rainfall and flooding to prevent particulate emissions to the environment or being washed away.
- Hot slags must cool under an extraction ventilation hood to ensure any lead fume is captured.
- Rotary furnace slags, under certain disposal conditions appear to be combustible, when still hot and mixed with carbonaceous material. As such, slags should never leave the site still hot (greater than 40°C) and preferably broken apart and not in big blocks. Slags should also not be mixed with any other products, such as plastics or wood (broken pallets). This includes when being transported to the disposal site.
- During the cooling process entrapped lead can descend to the bottom of the slag pot and form a lead heel that, on cooling, must be removed and returned to the process or added to a refining kettle.
- The lead content of slags must be monitored. Slags with a lead content of more than 10% indicate that the smelting processes are not optimised and will need urgent modifying as it is not sustainable (see further notes). Material that has greater than 20% contained lead should be returned back to the furnace.
- Manual sieving of decomposed slag to recover lead prills must be avoided because the dust generated is corrosive and a significant risk to human health.
- Furnace slags must be disposed of in a licensed hazardous waste disposal facility.

Aspects on tapping slags from a furnace are entailed in B.2.7.

Unacceptable	Good Practice
	

The furnace slag has been dumped on open ground without containment or cover. The slag can be seen to have degraded and weathered, and any water soluble lead compounds will leach out and result in pollution and lead contamination.	In this licensed hazardous waste facility, the wastes are held in a double skin secure landfill complete with leachate collection and treatment systems to prevent the seepage of leachate to the surrounding soil. Any leachate from the holding tank is channelled to an effluent wastewater treatment plant for the removal of contaminants to ensure safe and acceptable discharge levels.

Further Notes:

Secondary lead smelting is a metallurgical operation and the reactions that take place are well documented. The amount and composition of any furnace slag depends on the composition of the furnace charge and chemical reagents and fluxes (also see B.2.4). It is critical to an operation to optimise the charge composition according to the reactions that occur in the furnace, such that:

- The amount of iron and soda ash (sodium carbonate) added to a charge is sufficient to remove the sulfur to the slag.
- The amount of soda ash is also sufficient to ensure a fluid slag.
- That there is excess carbon to reduce the lead compounds throughout the whole batch cycle time.

B.4.5	Management of effluents	recycling & smelting

Requirement: No acidic or lead containing effluents shall be released from the plant

Scope: Recycling & smelting

Background and rationale: Next to the emission of fumes and dust, release of acidic and/or lead containing effluents and wastewater can be a major pathway for environmental contamination of ULAB recycling. Therefore, all process effluents must be captured and treated. Rainwater should be collected and tested, and if free of lead, furnace residues and battery electrolyte, can be discharged. Any effluent discharges must meet national environmental standards.

Technical description: There are various types of liquids and effluents that must be captured and managed through separate systems:

1. Battery electrolyte, process water and water used for cleaning or damping down (including wastewater from the laundry)
2. Rainwater
3. Water used in sanitary facilities

Effluent type 1: All battery electrolyte, process- and cleaning-water must be captured and processed in the effluent treatment plant (ETP). The topic is covered in depth in B.3.1. Also, effluents from cleaning and dust control (see A.2.5) and the recycling of plastic cases (B.3.2) must be managed in the same way. No such effluents shall be released from the plant without prior treatment and testing of parameters such as metal content (e.g. lead, arsenic), pH, biological and chemical oxygen demand etc.

Effluent type 2: While rainwater itself is not problematic, it can transport lead into the surrounding environment. Therefore, rainwater and runoff must be collected in basins or sinks where particles can settle at the bottom and be recovered (to be recycled through the furnace if lead-containing → see B.2.4). After testing the pH and analysing for the metal content of the effluent to ensure compliance with applicable standards and benchmarks, it may be released. Typically, pH range of effluent type 2 should be between 7 and 9.

Effluent type 3: Wastewater from the sanitary facilities should be managed through the municipal sewage treatment plant, or alternatively through a septic tank that is well-manged and in accordance with existing regulations.

Unacceptable	Good Practice
	
Effluent from a ULAB recycling plant is discharged to the environment without prior treatment rendering the soil infertile and polluting a nearby water course.	Contaminated process effluent is transferred to the effluent treatment plant. Suspended solids are removed via a three-stage filtration system. The effluent then undergoes a neutralisation process and then treated with a chemical flocculent to aid the removal of any remaining suspended solids. The suspended solids are returned to the smelter to recover the lead. The effluent is then either processed to produce a saleable product or neutralised for a controlled discharge. Residual liquid is used to cool the lead ingots during casting or for damping down dusty work areas.

Further notes: -

B.4.6	Management of other wastes	collection points · bulk transport · recycling & smelting

Requirement: All generated waste must be managed in a way such that no lead contaminated material enters a non-hazardous municipal waste management system.

Scope: Collection points, bulk transport, recycling & smelting

Background and rationale: In addition to filter plant dust, furnace residues (slags) and effluents, ULAB management and recycling can generate various other waste streams, including packaging material, waste personal protective equipment (e.g. dust masks) and filters (from baghouse operation). While much of these wastes can be managed together with municipal solid waste, the waste management regime must ensure that all lead contaminated materials are treated accordingly and do not enter any conventional non-hazardous waste management pathway.

Waste material contaminated with lead is best be managed by a secondary lead smelter (either a ULAB recycling facility or smelter receiving other lead containing materials) through charging the contaminated waste to the furnace.

Technical description: All waste that contains or is covered by or with lead (e.g. used filter bags from the baghouse filter plant) must be collected separately and are best disposed of by charging the waste to the furnace, mixed with lead paste and other feeds. It cannot be added on its own (see B.2.4 – B.2.6).

Any other waste, not contaminated with lead, can be managed together with other non-hazardous municipal solid waste. Ideally recyclable waste is sorted into main fractions (e.g. wood, cardboard, LDPE-films, packaging strips) and given (sold) to recyclers of such materials.

Some wastes may also be utilized within the ULAB handling and recycling process (e.g. use of pallets and cardboard for battery packaging → see B.1.2).

Unacceptable	Good Practice
	
Discarded N95 dust mask, possibly contaminated with lead dust.	Separate collection of non-hazardous waste for recycling at other facilities.

Further notes: -

Picture index

No		Description	Source / reference
A.1.1	a	Unacceptable picture: Satellite image	Google Earth Pro (2021) Version 7.3.3.7786
	b	Good practice picture: Satellite image	Google Earth Pro (2021) Version 7.3.3.7786
A.1.2	a	Good practice picture: Auditor	Sustainable Recycling Industries
A.1.3	a	Good practice picture: Community interaction	Brian Wilson
A.2.1	a	Unacceptable picture: Unprotected worker	Oeko-Institut
	b	Good practice picture: Protected worker	Oeko-Institut
	c	Good practice picture: Full body protection	Huntstock / Getty Images
A.2.2	a	Unacceptable picture: Worker without respirator	Pure Earth
	b	Good practice picture: Worker with FFP2 mask	Sustainable Recycling Industries
	c	Good practice picture: Worker with neoprene respirator	Clarios Recycling GmbH
A.2.3	a	Graphic: Amenities layout	Brian Wilson
	b	Unacceptable picture: Inappropriate change room	Oeko-Institut
	c	Good practice picture: Locker room	Brian Wilson
	d	Good practice picture: Shower section / change room	Brian Wilson
A.2.4	a	Unacceptable picture: Drying works clothing	Oeko-Institut
	b	Good practice picture: Hand washing	Oeko-Institut
	c	Good practice picture: Worker in works clothing	Oeko-Institut
	d	Good practice picture: Worker in private clothing	Oeko-Institut
A.2.5	b	Ride on sweeper	Luminous
	c	Unacceptable picture: Dusty working environment	Oeko-Institut
	d	Unacceptable picture: Uneven factory floor	Oeko-Institut
	e	Good practice picture: Smooth and clean factory floor	Brian Wilson
A.2.6	a	Good practice graphic: 3 focus areas	Brian Wilson
	b	Good practice graphic: Occupational health cycle	Brian Wilson

A.2.7	a	Good practice picture: Portable test kit	Brian Wilson
	b	Good practice picture: Rapid testing	Brian Wilson
A.3.1	a	Unacceptable picture: General safety sign	Brian Wilson
	b	Good practice picture: Notice board	Brian Wilson
	c	Unacceptable picture: Banana peel sign	Oeko-Institut
	d	Good practice picture: Workplace safety rules	Oeko-Institut
A.3.2	a	Good practice picture: Plant safety inspection	Brian Wilson
	b	Good practice graphic: Audit cycle	Brian Wilson
A.3.3	a	Good practice picture: Safety and hygiene induction	Luminous
	b	Good practice graphic: Safety and hygiene induction cycle	Brian Wilson
A.3.4	a	Good practice graphic: Risk Assessment Matrix	Brian Wilson
	b	Good practice graphic: Hazards and risk assessment	Brian Wilson
A.3.5	a	Good practice graphic: fishbone diagram	Brian Wilson
	b	Good practice graphic: Open ended questions	Oeko-Institut
A.3.6	a	Good practice picture: Lockout station	Clarios Recycling GmbH
A.3.7	a	Unacceptable picture: Fire extinguisher on the floor	Brian Wilson
	b	Good practice graphic: Fire extinguisher matrix	Brian Wilson
	c	Unacceptable picture: Blocked emergency exit	PureEarth
	d	Good practice picture: Accessible emergency exit	Clarios Recycling GmbH
B.1.1	a	Unacceptable picture: ULAB storage on bare soil	Oeko-Institut
	b	Good practice picture: Piled batteries	Oeko-Institut
	c	Good practice picture: Storage in leakproof containers	Brian Wilson
B.1.2	a	Unacceptable picture: Chaotic ULAB load in truck	Agenda Tanzania
	b	Good practice picture: Stacking of ULAB	Oeko-Institut
	c	Good practice picture: Leakproof containers	Clarios Recycling GmbH
	d	Warning sign “corrosive”	Public Domain
	e	Label “UN 2794”	Public Domain
B.1.3	a	Warning sign “corrosive”	Public Domain
	b	Label “UN 2794”	Public Domain

	c	Unacceptable picture: Chaotic ULAB load in truck	Agenda Tanzania
	d	Good practice picture: Palletized ULAB in truck	Oeko-Institut
	e	Battery acid spill kid	Oeko-Institut
B.2.1	a	Adjustable rotating saw blades	Brian Wilson
	b	Oscillating hammers inside a hammer mill	Brian Wilson
	c	Unacceptable picture: Manual battery breaking	Oeko-Institut
	d	Good practice picture: Semi-automated battery saw	Brian Wilson
	e	Good practice picture: Automated hammer mill	Brian Wilson
	f	Emergency shower and eye wash station	Brian Wilson
B.2.2	a	Graphic: Scrubbing tower	Brian Wilson
	b	Unacceptable picture: Acid clouds	BICANSKI (https://pixnio.com/au-thor/bicanski)
	c	Good practice picture: No visible emissions	Brian Wilson
	d	Unacceptable picture: Dissolved roof	Brian Wilson
	e	Good practice picture: Scrubbing tower	Oeko-Institut
B.2.3	a	Graphic: Rotary Furnace	Brian Wilson
	b	Graphic: Submersed Lance Furnace	Brian Wilson
	c	Graphic: Bottom Blown Furnace	Brian Wilson
	d	Unacceptable picture: Outdated blast furnace	Oeko-Institut
	e	Unacceptable picture: Rotary furnace not equipped with a fume hood	Oeko-Institut
	f	Good practice picture: Encapsulated Rotary furnace	Brian Wilson
B.2.4	a	Unacceptable picture: Manual charge preparation	Oeko-Institut
	b	Good practice picture: Charge preparation with truck	Clarios Recycling GmbH
B.2.5	a	Automated charger to a rotary furnace	STC, Italy
	b	Unacceptable picture: Manual charging 1	PureEarth
	c	Good practice picture: Semi-automated charging	Gravita Ghana
B.2.6	a	Unacceptable picture: Unsoundly operated furnace	Oeko-Institut
	b	Good practice picture: Soundly operated furnace	Oeko-Institut

B.2.7	a	Unacceptable picture: Unventilated manual tapping	PureEarth
	b	Good practice picture: Controlled tapping	Clarios Recycling GmbH
B.2.8	a	Picture: Manual de-drossing using the pivot method	Brian Wilson
	b	Graphic: Automated mechanical screw conveyor de-drossing unit	Brian Wilson
	c	Unacceptable picture: Unsafe refining kettle	Oeko-Institut
	d	Good practice picture: Integrated refining kettle	Battery Recycling Systems - www.wirtzusa.com
	e	Refining flow-chart	Brian Wilson
B.2.9	a	Refining kettles with a gravity feed to casting machines	Brian Wilson
	b	Unacceptable picture: Inappropriate casting	Larry C. Price/Pulitzer Center on Crisis Reporting
	c	Good practice picture: Appropriate casting	Brian Wilson
B.3.1	a	Filter press	Brian Wilson
	b	Unacceptable picture: Uncontrolled acid drainage	Oeko-Institut
	c	Good practice picture: Effluent treatment plant	Battery Recycling Systems - www.wirtzusa.com
B.3.2	a	Unacceptable picture: Crude plastic washing	Oeko-Institut
	b	Good practice picture: Controlled plastic recycling	Brian Wilson
B.4.1	a	Graphic: Filter plant	Brian Wilson
	b	Unacceptable picture: Smelter without off gas treatment	Oeko-Institut
	c	Good practice picture: Complete filter plant	Oeko-Institut
	d	Graphic: Typical Spark Arrestor	Brian Wilson
B.4.2	a	Unacceptable picture: Unsecured dust collection bag	Oeko-Institut
	b	Unacceptable picture: Open collection bays	Oeko-Institut
	c	Good practice picture: Enclosed conveyor system	Oeko-Institut
	d	Good practice picture: Sealed collection drums	Brian Wilson
B.4.3	a	Unacceptable picture: Visible smoke	Centre de Recherche et d'Education pour le Dévelopment (CREPD)
	b	Good practice picture: No visible smoke	https://www.piqsels.com

	c	Unacceptable picture: Anemometer with zero reading	Brian Wilson
	d	Good practice picture: Anemometer with 2.1 reading	Brian Wilson
	e	Measuring principle of a differential pressure gauge	Brian Wilson
B.4.4	a	Unacceptable picture: Dumped furnace slag	Oeko-Institut
	b	Good practice picture: Hazardous waste disposal	Wikimedia commons (2020): Hazardous waste landfill Raindorf (Veits-bronn). Areal picture. https://commons.wiki-media.org/wiki/File:Sonderm%C3%BCllde-ponie_Raindorf_(Veits-bronn)_Luftauf-nahme_(2020).jpg, last accessed 21.10.2021.
B.4.5	a	Unacceptable picture: Effluent discharge	SRADev Nigeria
	b	Good practice picture: Effluent treatment plant	Clarios Recycling GmbH
B.4.6	a	Unacceptable picture: Discarded dust mask	Oeko-Institut
	b	Good practice picture: Separate collection	Clarios Recycling GmbH