TÜV Rheinland Industrial Services Limited

Solvent Management Plan

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Revision History

Version	Date	Purpose
1	28/09/2023	Issue

Approval

Version	Date	Name	Role
1	28/09/2023	Jacob Owen	Process Engineer

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1 Introduction

Envision AESC UK LTD is constructing a car battery manufacturing facility in Sunderland. The facility is due to start operation in 2024.

This Solvent Management Plan (SMP) aims to define the use of solvent for their operations, as well as solvent management and monitoring system. The SMP will be a live document. A solvent mass balance calculation in accordance with the methodology provided in guidance note PG 6/44 will be undertaken based on annual solvent purchase and disposal records. This assessment will indicate compliance with the requirements for solvent emission activities in the Industrial Emission Directive.

1.1 Site Description

The site of the facility is located in Sunderland, Tyne and Wear, situated between the Concord and Castletown areas. The site is part of the IAMP (International Advanced Manufacturing Park) designated for industrial/commercial use. It is to the west of the A19, and to the south of the River Don. Site location is shown in Figure 1

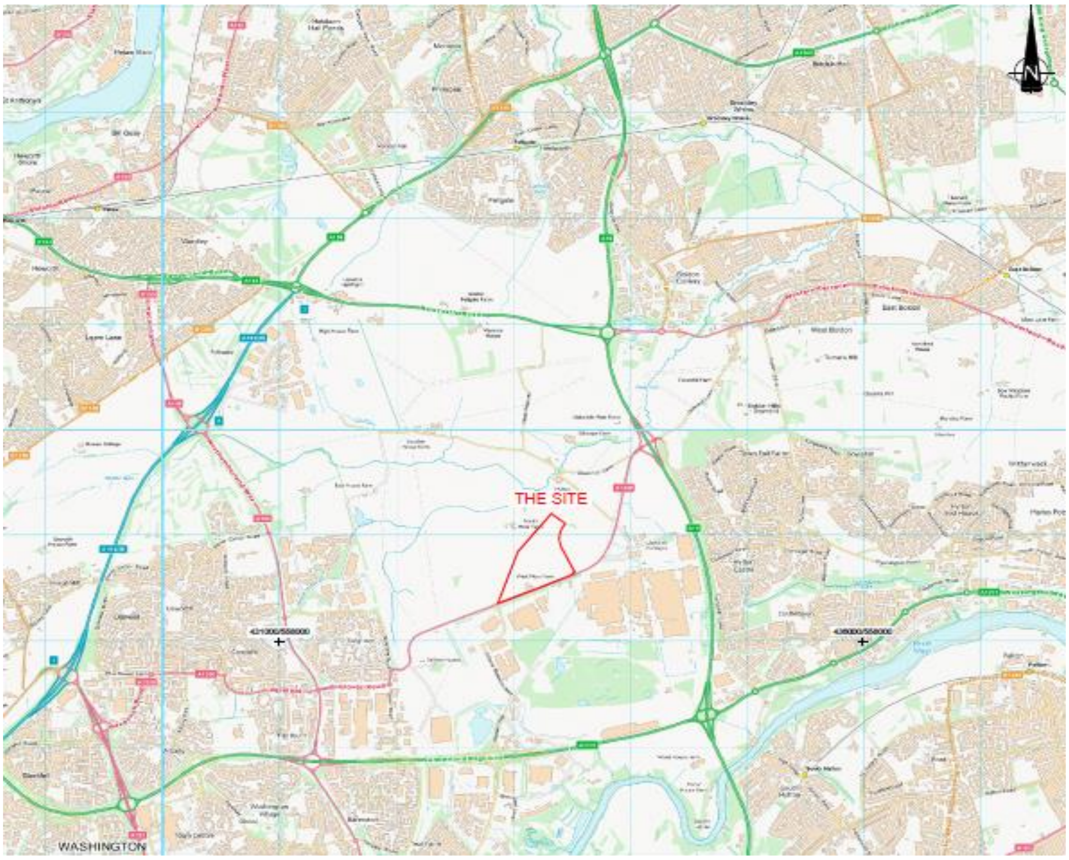

Figure 1: Site Location Plan

The site consists of a main factory building, where the bulk of the chemical processing takes place. Processes within the main factory building utilise production line type machinery and robots and are predominantly automated. Surrounding the main factory building are various storage and utility areas.

The Installation will produce electric vehicle batteries starting with the raw anode and cathode constituent parts and solvent, along with electrolyte used to fill the batteries. Most of the constituent parts are stored in powder form, while the solvent will be in a tank and electrolyte stored in refrigerated, trailer-mounted iso tanks. The process has a high level of automation with personnel only being present in hazardous areas when and where they are required for Quality Assurance and maintenance purposes Site layout is shown in Figure 2.

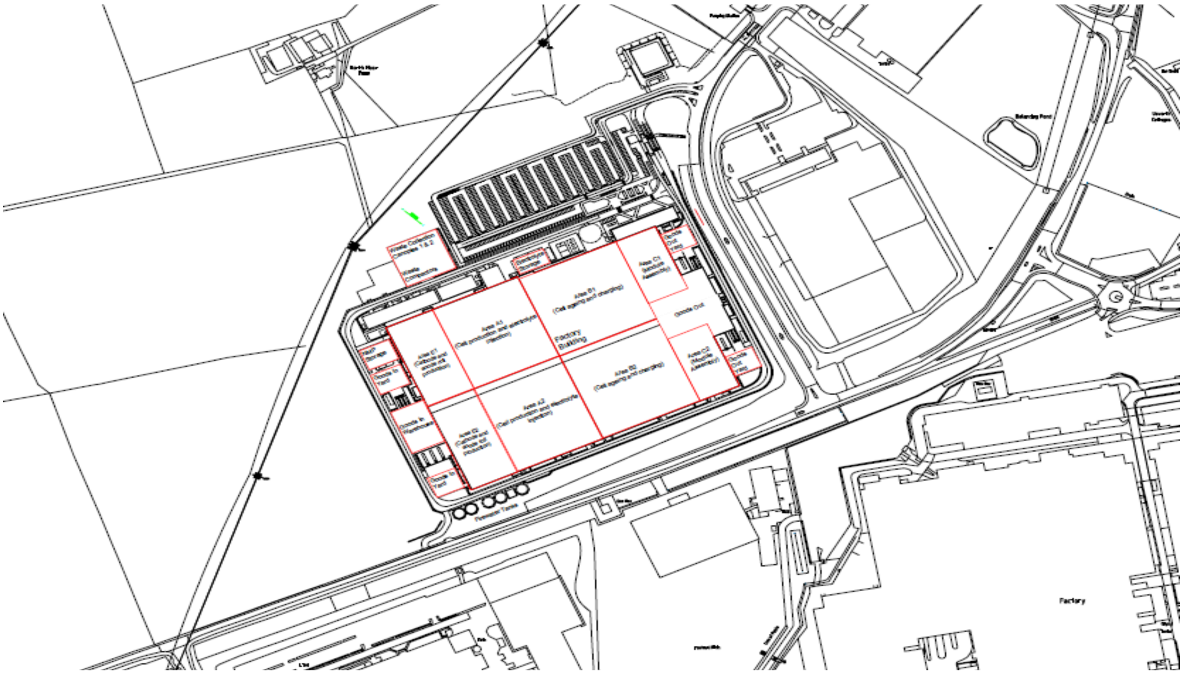

Figure 2: Site Layout Plan

2 Activity Description

Electrode Area

Various powders are used during the manufacture of cathode and anode electrodes and represent one of the main feedstocks on the establishment. Powder bags and FIBCs are stored on pallets and shipped to the Main Warehouse Area, also known as the Goods In Area, located on the west side of the site. Following shipment, the pallets are transported to the Powder Warehouse at the west side of the Factory Building and stored until they are required for processing. Transportation of the pallets is achieved via an Automated Storage and Retrieval System (ASRS). The ASRS consists of an Automated Guide System (AGS) which directs robots to materials for collection and transportation. Transportation from the Powder Warehouse to the Powder Discharge Station on the 3rd floor of the factory is achieved via a goods lift with adequate containment to prevent falls.

Once collected from the Powder Warehouse and transported to the Powder Discharge Station, the FIBC is lifted using a manually operated crane and positioned above one of four loading stations. Each loading station consists of a hopper, weighing system, and 2 mixers which are used to process the powder. The equipment items operate at or near to atmospheric pressure and ambient temperature. Smaller bags are loaded into the powder system at small bag discharge stations.

There are 4 hoppers within the Powder Discharge Station which are used to load cathode materials (NMC, Carbon Black and PVDF Grade A) and anode materials (graphite, CMC, and Carbon Black). The powders are loaded directly from FIBCs or bags via a manual crane or small bag dischargers. Once the powder is loaded into the hopper, it is discharged via gravity to the weighing system on the second floor. The second floor contains the weighing systems for each of the loading stations and is generally unmanned. Each hopper has its own weighing station, load scales are used to achieve specific weights. Once the powder is at the correct weight, it is then transferred to the central hopper.

Once the powder is loaded into the central hopper, it is discharged to the mixers on the first floor. In both cases, the powders are transferred via gravity to one of 2 mixers. Once the powder is loaded into the mixer, cathode solvent (NMP as well as CNT conductive paste) or anode solvent (deionised water) is added and mixed under vacuum. The mixers use a high shear and planetary type mixer to effectively mix the powder with the solvent. The mixing process takes approximately 4 to 5 hours per batch and the mixture emerges as a slurry and is transferred to the coating machines in preparation for coating and drying.

Machinery is used to unwind a roll of aluminium foil and then a slot die is used to spread the active slurry on to the top of the foil. The coated foil then passes through an oven 60 m in length to dry the slurry and set it to the foil. The ovens have a variable temperature range between 60 and 150 °C. Once through the oven, quality inspection checks take place and then the second side of the foil roll is coated. The coated foil then passes through another 60 m oven which is located on top of the first stage oven. Further inspection checks are made once the second side of the foil roll has passed through the oven. Following the drying process, the coated rolls are then split into two smaller width rolls using slitting machines. The cycle time for one roll is approximately 60 minutes.

The rolls which leave the coating and drying process are fed through a series of press rollers, before being slit and fed into Area A (west side of the Factory Building). The purpose of this process is to remove any loose contamination, before compressing the coating and making the thickness uniform. The cathode rolls are heated to approximately 100 °C for this process, requiring additional heating and cooling rollers. However, the anode rolls do not require this. The pressing and slitting process takes an estimated 40 minutes for each cathode roll and 30 minutes for each anode roll.

Area A – Cell Assembly

Anode rolls are passed through roll to roll drying machines to remove any residual moisture before they are processed into cells. The anode rolls have a maximum diameter of 800 mm and weigh up to 600 kg. Machinery unwinds the anode material and feeds it through an electrically heated oven which operates under vacuum and an operating temperature of 300 °C. The anode material then passes through a cooling chamber before being rewound onto another roll. The process takes an estimated 40 minutes to dry one anode roll. Note cathode rolls do not require this process following roll pressing at elevated temperature. Cathode rolls have a maximum diameter of 800 mm and weigh up to 1100 kg.

The anode and cathode rolls are again unwound and fed into a laser cutting chamber where the terminal profile is cut along one edge of the material. A small 'V' shaped notch is also cut into the anode and cathode material. The machines carry out a cleaning operation to remove dust particles before feeding into the final stage which rewinds the electrode materials back onto a roll. These machines contain ATEX zones due to the potential for build-up of aluminium dust during the laser cutting process. The estimated process time is 40 minutes per roll. The material is then cut into single sheets in this process by cutting blades, then cut is performed where the notch is located. Each individual sheet has one foil terminal. The individual sheets are stacked and transferred to the next process in magazines. Separate cutting facilities exist for anode and cathode materials. Approximately 272 sheets are produced every minute.

Machinery then takes anode, cathode, and separator sheets and stacks them vertically with each stack consisting of a repeating configuration of individual anode and cathode sheets separated by separator sheets. The stacks are taped and transferred to the next process on pallets, each pallet contains 2 cell stacks. Stacks on the pallets are then transferred into the hot press machine which compresses the stacks and heats them to approximately 80 °C. Stacks are then automatically transferred from the hot press to a cooling conveyor.

The cell stack is transferred onto internal pallets and any excess terminal foil is trimmed off. Then terminal tabs, patch material, and the foils of the stack are ultrasonically welded together. This process occurs on the anode and cathode terminals, such that both terminals now have rigid tabs attached. Following welding, the welded areas of the tabs are pressed, to remove shape distortion following welding and then insulation tape is applied to the upper and lower weld regions. The stack is then placed inside a preformed laminate pouch. The laminate material is formed with a die and cut to shape. The laminate pouch is then heat sealed on three sides. The cell is then tested for short circuits that could have formed due to the processing. Following short circuit check, a unique cell ID is printed directly to the laminate pouch and the pouch is loaded into a magazine and transferred to the next process.

Each cell pouch is then weighed on an electric scale. Cell pouches are then stored in magazines which each hold 36 cell pouches. The magazines are transferred to an electrolyte injection chamber where electrolyte is injected into each of the laminate pouches using injection machines under vacuum. On completion of electrolyte injection, the cell pouches are weighed and held in a vacuum buffer. Cell pouches then progress to the temporary seal chamber. In the temporary seal chamber, the open side of the cell will be heat sealed under vacuum. On completion, the seal thickness is checked followed by a final weight check of the cell. The cell pouches are then returned to a magazine. The electrolyte injection process includes ATEX zones due to the flammability of the electrolyte.

Area B – Cell Processing

Once the cells have been assembled and transferred to magazines, they are then transferred to Area B which is to the east of Area A in the Factory Building. Area B consists of various lanes which are used to further process the cells. Transport of cell magazines within Area B is fully automated. Each of the lanes and their purpose is summarised below:

- Soak Lane – Allows the cells to soak in the electrolyte for 18 hours at room temperature.
- Formation Lane – Charges each of the cells to 100%.
- High Temperature Ageing Lane – Heats the cells to 45 °C for 60 hours.
- Charge/Discharge Lane – Charges each of the cells to 100% and then discharges the cells.
- Screening Lane – Stores the cells at room temperature for 90.5 hours.
- OCV Lanes – Open circuit voltage measurement of each cell whilst it is in the magazine.
- Inspection Lane – Automated checking and inspection process for each of the cells. Includes sealing inspection, open circuit voltage and impedance check, cell leak check, automated appearance inspection etc.

Once the cells have been processed and have passed their inspection, they are then transferred to Area C.

Area C – Module Production

Area C is to the east of Area B in the Factory Building and is used for creating cell modules from cell magazines. Cell magazines are handled by personnel within the Factory Building at this stage. Cells are removed from the cell magazines and individually inspected by personnel. Once inspected, machines are used to flatten the tabs around the edges of each cell. The tabs are then trimmed, and any dust is vented to a dust extraction system.

Following the tab tramming, protection tape is applied to the laminate edge. The tab shape is then checked, and each cell is cleaned by an air blower. Compression glue is then applied to each cell and cells are stacked on top of each other. Pressure is then applied to the cell stack to make the cells paste together. Welding of a module container then takes place on site. The module container is used to contain stacked cells. Once the stacked cells are suitably stored within the module container, the module passes through a series of checks and inspections to ensure the module meet product requirements. A process flow block diagram is shown in Figure 3 to demonstrate a basic overview of the process.

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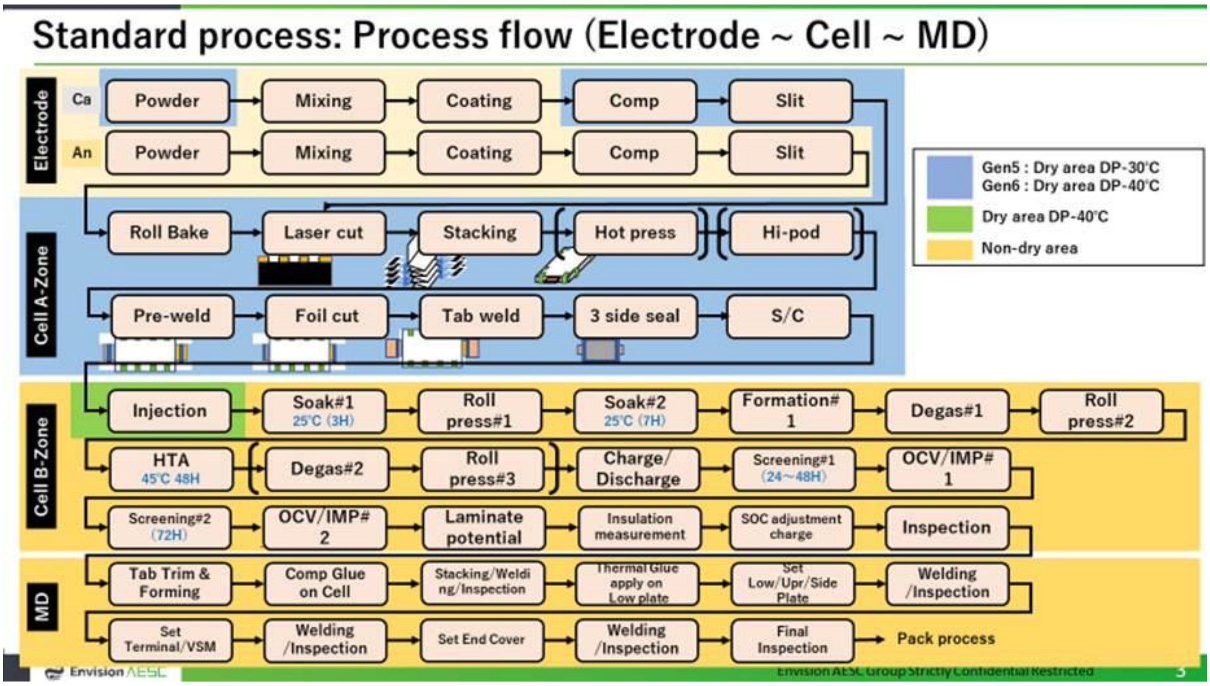

Standard process: Process flow (Electrode ~ Cell ~ MD)

Electrode
Ca: Powder → Mixing → Coating → Comp → Slit
An: Powder → Mixing → Coating → Comp → Slit

Cell A-Zone
Roll Bake → Laser cut → Stacking → Hot press → Hi-pod
Pre-weld → Foil cut → Tab weld → 3 side seal → S/C

Cell B-Zone
Injection → Soak#1 25℃ (3H) → Roll press#1 → Soak#2 25℃ (7H) → Formation# 1 → Degas#1 → Roll press#2
HTA 45℃ 48H → Degas#2 → Roll press#3 → Charge/ Discharge → Screening#1 (24~48H) → OCV/IMP# 1
Screening#2 (72H) → OCV/IMP# 2 → Laminate potential → Insulation measurement → SOC adjustment charge → Inspection

MD
Tab Trim & Forming → Comp Glue on Cell → Stacking/Welding/Inspection → Thermal Glue apply on Low plate → Set Low/Upr/Side Plate → Welding /Inspection
Set Terminal/VSM → Welding /Inspection → Set End Cover → Welding /Inspection → Final Inspection → Pack process

🟦 Gen5 : Dry area DP-30℃
Gen6 : Dry area DP-40℃
🟩 Dry area DP-40℃
🟨 Non-dry area

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Figure 3: Process Flow Diagram

3 Solvent Use

The following solvents will be stored and used on site for the activity including cleaning (Table 1) –

Solvent	Estimated Annual Usage (Kg)
NMP (CNT)	3,667,500
Electrolyte	6,207,390
Diethyl Carbonate (DEC)	6,000
Fermapor K31	26,598
Bergquist TGF2200	259,766
NMP	1,327,040
IPA (70-30)	9,337
Acetone	4,368

Table 1: List of solvent used on site.

NMP

NMP is the liquid material utilised within the manufacture of the Cathode electrode. The purpose of NMP is to dissolve the PVdF (Polyvinylidene difluoride) and act as the binding agent of the active materials to the metallic foil.

NMP *CAS NO (872-50-4)* is listed within REACH and was placed on the candidate list as a SVHC. GHS records the material with a Hazard Phrase of H360D (May cause damage to the unborn child) therefore significant Health, Safety and Environmental restrictions have been placed on suppliers and downstream users.

Article 5 of the Solvents Emissions Directive identifies substances with the Hazard Phrase of H360D (formally R61) with a mass flow of greater or equal to 10g/h, an emission limit value of 2mg/Nm^3 is to be complied with. Based on the calculations provided by the abatement supplier, the mass flow for the UKBIC chosen abatement system will be 2.8g/h.

There are currently no alternatives or substitutes that are commercially available. The report associated with the supporting document; ‘Report on the state of art for N-Methyl-2-pyrrolidone in the production of Lithium-ion battery cells’, addresses the elimination & substitution options by academic research and has been commissioned by UKBIC to Aachen University, Germany. A leading research university establishment on Lithium-ion batteries and their main competencies are in the manufacturing production environment. Aachen university is involved in the Giga-factory technical development within Europe. Aachen specifically are the lead institute for the German battery facility equivalent to that of UKBIC.

The report summary concludes that elimination or substitution of the substance NMP currently is not technically feasible. This is in essence due to a) the solvent alternative(s) are not commercially viable and only being utilised at research levels and b) any change from known technologies require compliance with strict certification and approval routes.

NMP RECOVERY

There are 4 fresh NMP storage tanks each with a maximum capacity of 25 m^3. The tanks are located within the NMP canopy within a shared bunded area with the Waste NMP tanks. NMP is discharged into the Fresh NMP tanks from road tankers at a flowrate of 480 lpm and a maximum temperature of 30 °C

As part of the cathode electrode manufacture, fresh NMP is introduced to the process in the wet mixing tanks where it is mixed with NMC, SP and PVDF Grade A. In addition to cathode manufacture, the NMP is used as part of the insulation layer process, where it is mixed with Boehmite and PVDF Grade B in a mixing tank. These two slurries are applied to an aluminium foil which is then passed through a hot air-drying oven where the NMP is evaporated and removed.

Vapours (NMP for cathode, steam for anode) from the drying process are exhausted from the dryers at 100 to 130 °C and are sent to a heat exchanger. The vapours are cooled to approximately 60 °C using air at room temperature. The air is heated to temperatures of 70 °C or higher and is recirculated back to the ovens. Once cooled, the vapour exhaust from the ovens is sent to the condensers which utilise room temperature cooling water. The NMP/deionised water is cooled to 30 to 40 °C and a large amount of condensed NMP/deionised water is produced. Any uncondensed vapour flows to a cryocooler where it is condensed further until the NMP vapour content is less than 250 ppm.

Any condensed NMP/deionised water is transported through pipework to Waste NMP/deionised water tanks. A specifically designed VOC zeolite purification unit is then utilised to separate the residual NMP vapour from the air. Approximately 90% of the treated gas is passed through a heat exchanger and then returned to the dryers to supply air for the drying process, while the other 10% passes through the VOC zeolite purification unit and is discharged to the atmosphere.

Electrolyte Storage and Supply

Electrolyte is a key component within the battery cells and is responsible for transporting positively charged ions between the cathode and anode sheets. The electrolyte is delivered to site in 25 m^3 isotankers which are stored at the Storage Bay. The ground beneath the Electrolyte Isotanker is sloped such that electrolyte would flow to a sump located at the back of the Storage Bay canopy, preventing electrolyte from pooling directly under the Electrolyte Isotanker. There are 4 electrolyte isotankers on site at any one time, 2 duty and 2 standby, with swap over and subsequent removal of empty isotankers occurring approximately every 1 to 2 days (depending on site production). The isotankers are cleaned by the supplier following each delivery to Envision using diethyl carbonate solvent to remove any traces of contamination prior to refilling with electrolyte.

The electrolyte is transferred from the isotankers by nitrogen at 3 barg through a discharge hose and stainless-steel pipework rated for 10 barg. The electrolyte then passes through a heat exchanger and multiple filters (PTFE and PP) before filling the electrolyte day tanks in the injection machine rooms. To maintain raw material quality, by reducing the precipitation of lithium salts, the electrolyte isotankers operate at a temperature of 0 °C using an onboard cooling system and a pressure of 3 barg. The electrolyte day tanks are kept in injection machine rooms within the main clean room. Within the main clean room there are four electrolyte injection machines with their own individual rooms. The main clean room and injection rooms are Class 10000 with a ventilation rate of 30 ACH, the ventilation system is in the main clean room. Each injection machine room contains 4 electrolyte day tanks each capable of storing 20 L of electrolyte. The filling rate for the electrolyte day tanks is 20 lpm at 3 barg transfer pressure. Each electrolyte day tank has its own 750 x 880 x 30 mm bunded area.

Waste electrolyte is collected from intermittent venting and purging activities in the injection machines and is pumped to the 10 te electrolyte waste tank. This is periodically collected, typically six monthly during normal operation and more frequently during maintenance/inspection, by road tanker for disposal offsite.

Diethyl carbonate

Diethyl carbonate (DEC) is the main carrier solvent in electrolyte. It is also used separately to clean the electrolyte system.

Waste DEC used for cleaning the electrolyte system and pumped into the electrolyte waste tank.

IPA (70-30) and Acetone

IPA (70-30) and Acetone are used on site for cleaning. These are sprayed over machinery etc and wiped off with a cloth.

4 Solvent Management

Solvent Policy

Envision AESC UK LTD is ISO14001 certified. The environmental management system will incorporate solvent monitoring and management requirements with the objective to comply with the regulation.

Records of purchases of solvent and solvent containing materials will be maintained, to inform the total input of solvent. A solvent monitoring system will be put in place to inform the solvent outputs of the facility from the activities.

Spill Response/Training

Envision AESC UK LTD has a written procedure for emergency preparedness and spill response (UK-ENV-MP-0002).

Staff on site are trained in accordance standard operation for spillage response for a major spill (UK-MFG-IO-B110). Training drills are carried out monthly and the standard operation is reviewed annually. All of the documents mentioned can be provided upon request.

Regular training will be undertaken for staff responsible for solvent management which will include:

- how to handle, store, use and clean up solvents and solvent-based materials and wastes
- how to use solvent-related equipment
- solvent waste management.

5 Mass Balance Calculations

5.1 Methodology

The solvent management plan is based on the British Coatings Federations (BCF) guidance ("The VOC Workbook – Guidance for coatings manufacturing installations: demonstrating compliance with PG6/44 VOC emission limits and preparing solvent management plans") as recommended in PG 6/44(11).

The basis of the method is to determine solvent input to the process and solvent output in terms of releases. The VOC Workbook defines general input and output streams for coating processes. Those considered applicable to the site are summarised in the table below.

As the site is currently under construction and operations have yet to begin, not all information about the solvent emissions is known.

The current estimated annual solvent input and output are presented in the tables below:

Input	Description	Estimated annual input (Kg)
I1	The quantity of organic solvents, or their quantity in mixtures purchased which are used as input into the process/activity (including cleaning solvents).	11,507,999
I2	The quantity of organic solvents or their quantity in mixtures recovered and reused as solvent input into the process/activity. (the recycled solvent is counted every time it is used to carry out the activity.)	4,994,540

Table 2: Solvent Input

Output	Description	Estimated annual output (Kg)
O1	Emissions in waste gases	16,118
O3	The quantity of organic solvents which remains as contamination or residue in products output from the process/activity.	To be determined
O4	Uncaptured emissions of organic solvents to air. This includes the general ventilation of rooms, where air is released to the outside environment via windows, doors, vents and similar openings.	To be determined
O5	Organic solvents and/or organic compounds lost due to chemical or physical reactions. (Including for example those which are destroyed, e.g. by thermal oxidation or other waste gas or waste water treatments, or captured, e.g. by adsorption, as long as they are not counted under O6, O7 or O8).	To be determined
O6	Organic solvents contained in collected waste.	19,105
O7	Organic solvents, or organic solvents contained in mixtures, which are sold or are intended to be sold as a commercially valuable product.	6,478,236
O8	Organic solvents contained in mixtures 'recovered for reuse but not as input into the process/activity, as long as not counted under O7.	To be determined
O9	Organic solvents released in other ways.	To be determined

Table 3: Solvent Output

Envision AESC UK LTD will monitor the outputs from their activity annually over the course of their operation, the monitoring plan to inform the gaps in information.

Solvent mass balance calculation will then be carried out to inform compliance with the requirements for solvent emission activities in the Industrial Emission Directive.

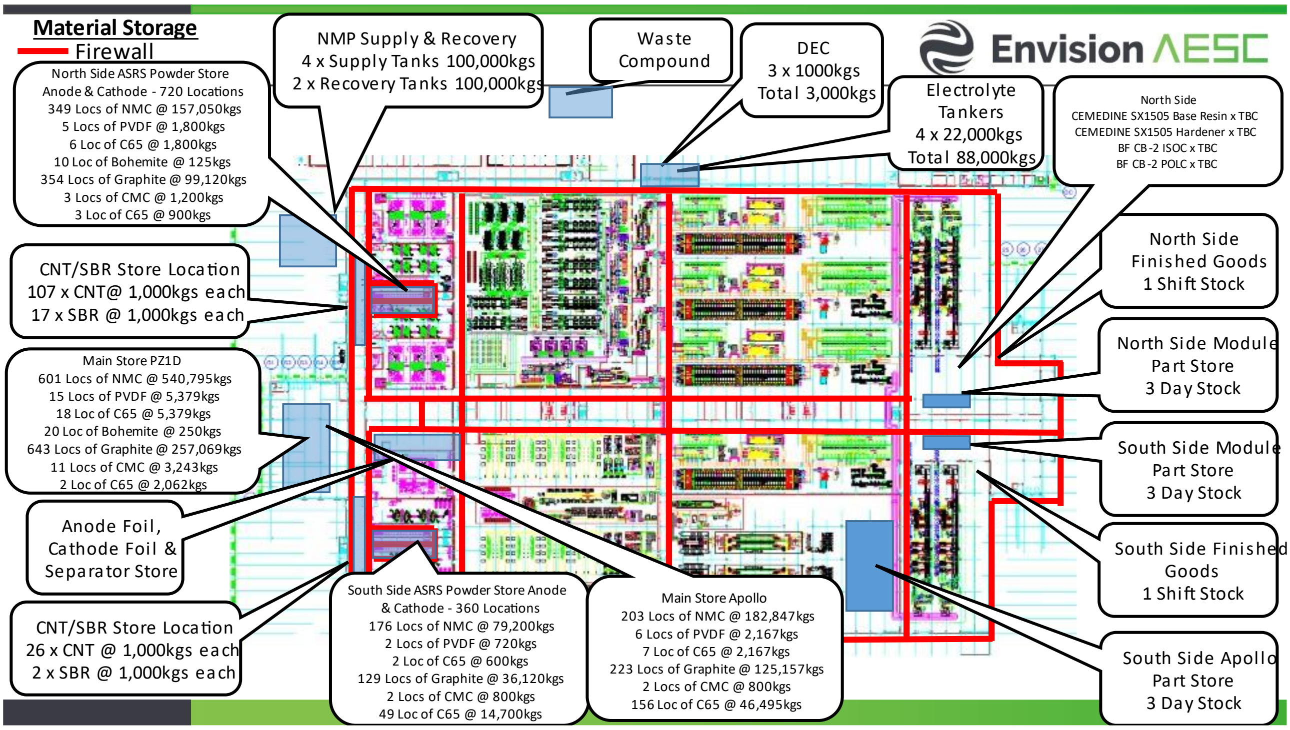
6 References

Sector Guidance Note SG6 (11) Secretary of State’s Guidance for Surface Treatment Using Solvents

Process Guidance Note 6/44(11) Statutory Guidance for Manufacture of Coating Materials.

Appendix A -

Material Storage Location



Material Storage

Firewall

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North Side ASRS Powder Store
Anode & Cathode - 720 Locations
349 Locs of NMC @ 157,050kgs
5 Locs of PVDF @ 1,800kgs
6 Loc of C65 @ 1,800kgs
10 Loc of Bohemite @ 125kgs
354 Locs of Graphite @ 99,120kgs
3 Locs of CMC @ 1,200kgs
3 Loc of C65 @ 900kgs

NMP Supply & Recovery
4 x Supply Tanks 100,000kgs
2 x Recovery Tanks 100,000kgs

Waste
Compound

DEC
3 x 1000kgs
Total 3,000kgs

Electrolyte
Tankers
4 x 22,000kgs
Total 88,000kgs

North Side
CEMEDINE SX1505 Base Resin x TBC
CEMEDINE SX1505 Hardener x TBC
BF CB-2 ISOC x TBC
BF CB-2 POLC x TBC

CNT/SBR Store Location
107 x CNT@ 1,000kgs each
17 x SBR @ 1,000kgs each

North Side
Finished Goods
1 Shift Stock

Main Store PZ1D
601 Locs of NMC @ 540,795kgs
15 Locs of PVDF @ 5,379kgs
18 Loc of C65 @ 5,379kgs
20 Loc of Bohemite @ 250kgs
643 Locs of Graphite @ 257,069kgs
11 Locs of CMC @ 3,243kgs
2 Loc of C65 @ 2,062kgs

North Side Module
Part Store
3 Day Stock

South Side Module
Part Store
3 Day Stock

Anode Foil,
Cathode Foil &
Separator Store

South Side Finished
Goods
1 Shift Stock

CNT/SBR Store Location
26 x CNT @ 1,000kgs each
2 x SBR @ 1,000kgs each

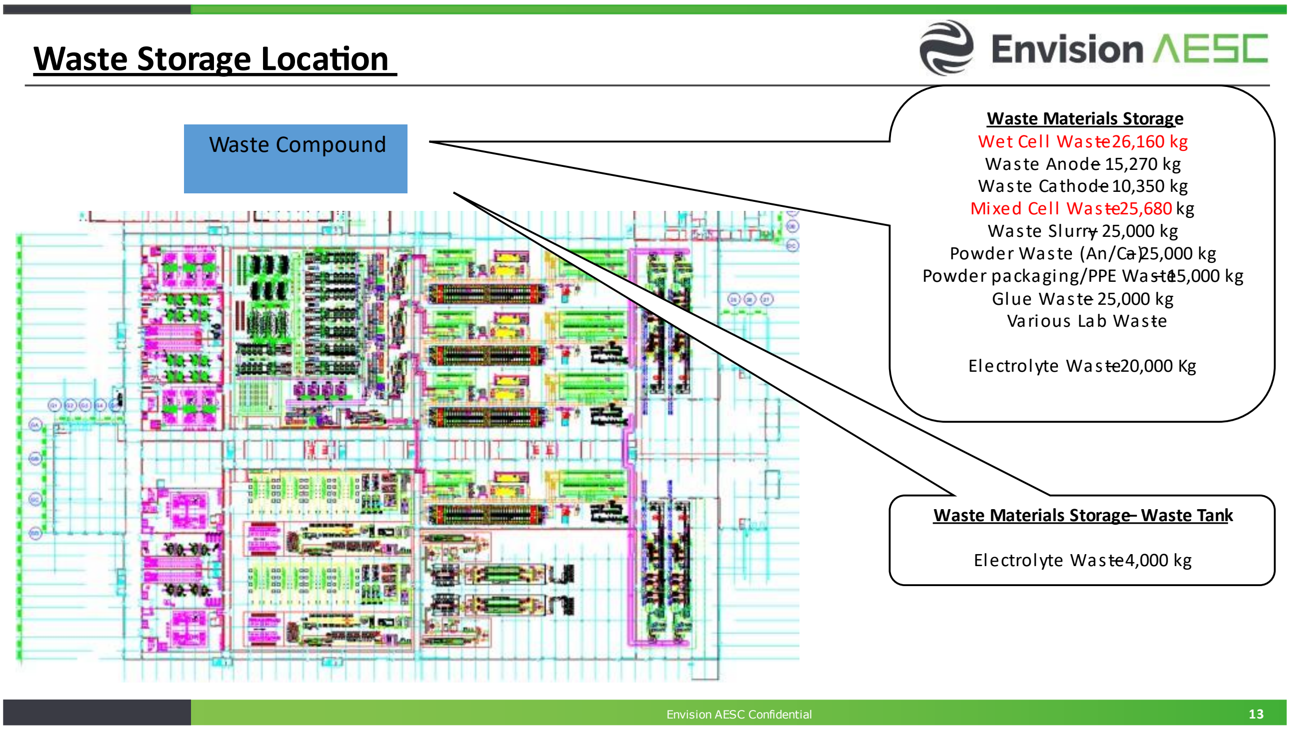
South Side ASRS Powder Store Anode
& Cathode - 360 Locations
176 Locs of NMC @ 79,200kgs
2 Locs of PVDF @ 720kgs
2 Loc of C65 @ 600kgs
129 Locs of Graphite @ 36,120kgs
2 Locs of CMC @ 800kgs
49 Loc of C65 @ 14,700kgs

Main Store Apollo
203 Locs of NMC @ 182,847kgs
6 Locs of PVDF @ 2,167kgs
7 Loc of C65 @ 2,167kgs
223 Locs of Graphite @ 125,157kgs
2 Locs of CMC @ 800kgs
156 Loc of C65 @ 46,495kgs

South Side Apollo
Part Store
3 Day Stock

Appendix B -

Waste Storage Location



Waste Storage Location

Waste Compound

Waste Materials Storage

Wet Cell Waste - 26,160 kg
Waste Anode - 15,270 kg
Waste Cathode - 10,350 kg
Mixed Cell Waste - 25,680 kg
Waste Slurry - 25,000 kg
Powder Waste (An/Ca) - 25,000 kg
Powder packaging/PPE Waste - 15,000 kg
Glue Waste - 25,000 kg
Various Lab Waste

Electrolyte Waste - 20,000 Kg

Waste Materials Storage - Waste Tank

Electrolyte Waste - 4,000 kg

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