WGP 135 (24)

Construction and operation of Electric vehicle battery manufacturing plants

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Working Group Members

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WGP135 (24) Members

- Matthew Gosling, Chair (Aviva)
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- Andy Kane (QBE), Sponsor

TOPIC

Introduction

02

Introduction to WGP135 (24)

As the demand for electric vehicles increases there is an increasing need for battery manufacturing plants.

The final working group paper will cover:

- The manufacturing processes for different EV batteries
- Unusual risk characteristics of battery plants and construction challenges
- Design, workmanship and materials risks
- Operational issues and need for specialised protections
- Underwriting information and guidelines
- Policies, special clauses & exclusions
- Case Studies and claims
- Surveys and risk management

TOPIC

03

What is an Electric Vehicle Battery?

What is an Electric Vehicle Battery

- A battery, comprised of a cell or series of cells, is an electrochemical device that produces a voltage potential when placing metals of different affinities into an acid solution (electrolyte).

- Each cell has four key components: an anode, a cathode, a separator, and an electrolyte, which is usually a liquid.

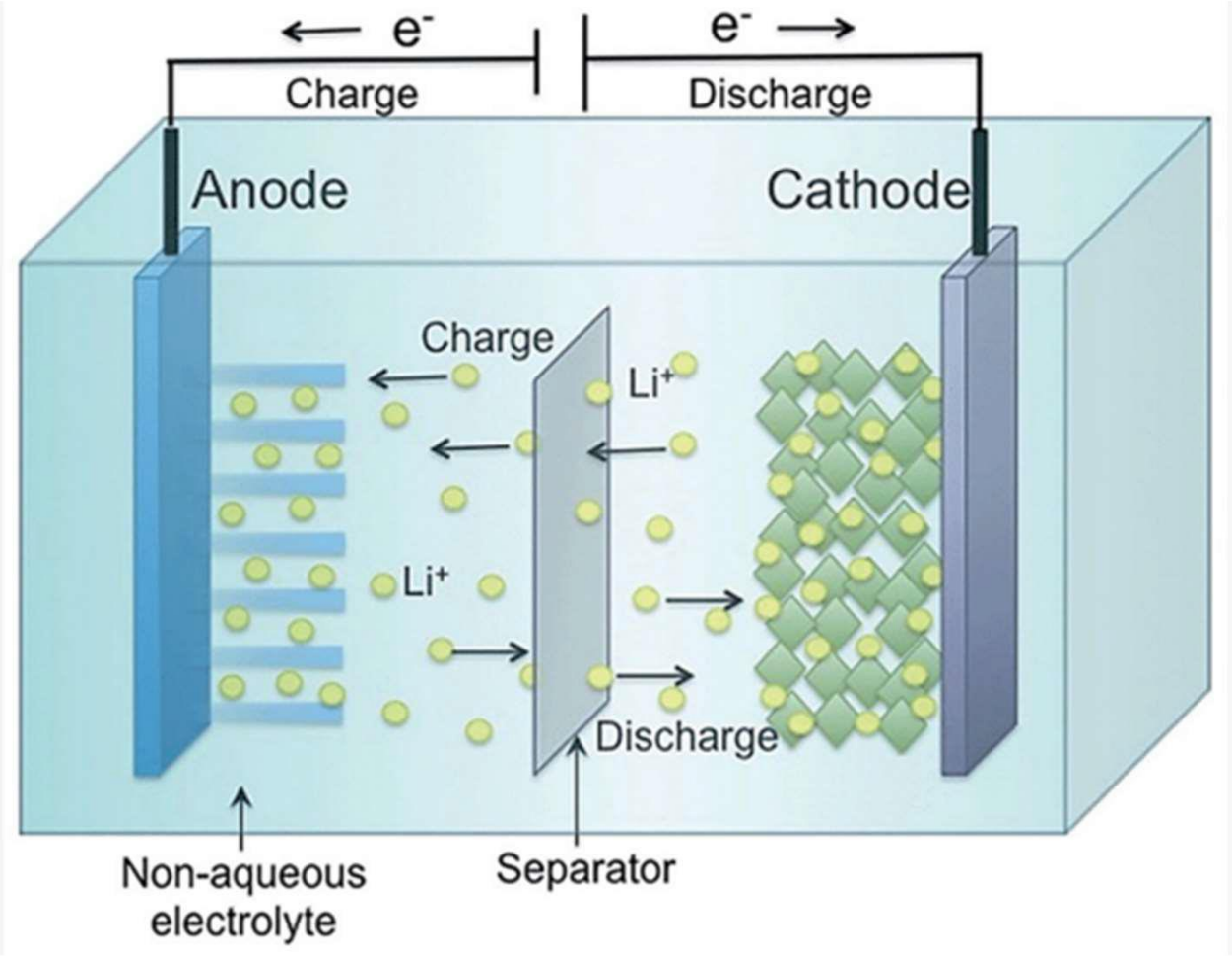
- The open circuit voltage (OCV) that develops as part of an electrochemical reaction varies with the metals and electrolyte used.

What is an Electric Vehicle Battery

To power a device, charged atoms or molecules called ions move from the anode to the cathode through the electrolyte, releasing their extra electrons along the way and producing electricity.

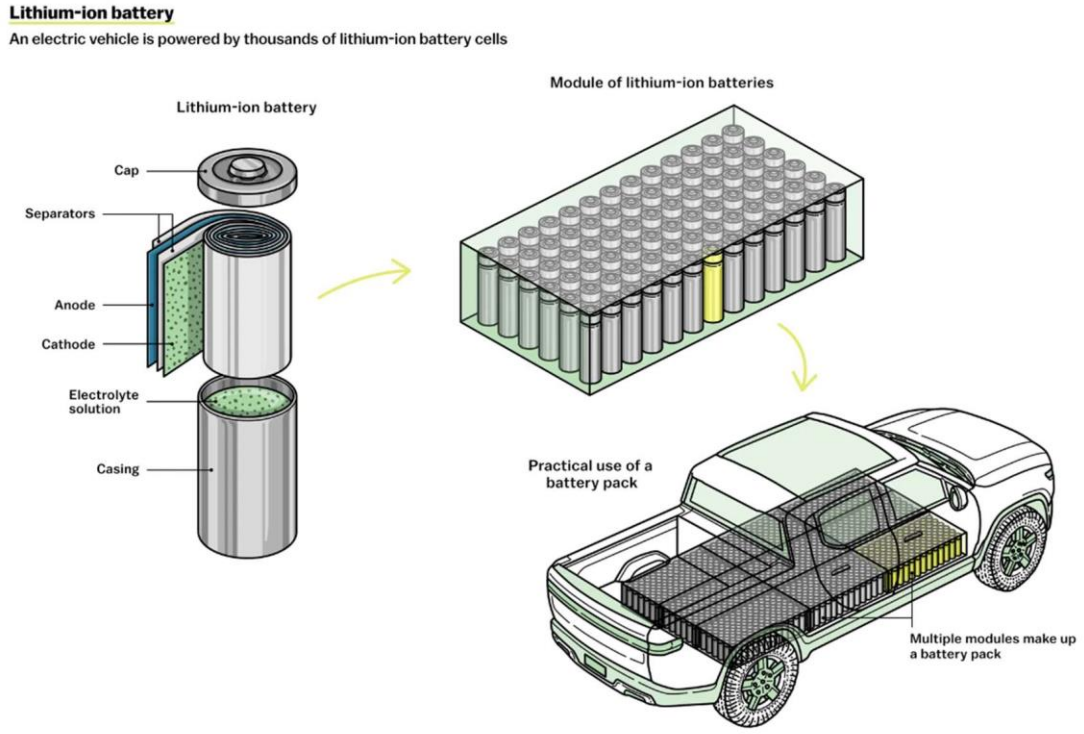
To charge a battery, the opposite happens: Electrons flow into the battery, and the ions flow back from the cathode to the anode, creating potential energy that the battery can later discharge.

Electric Vehicle batteries usually comprise a number of cells connected in series to achieve the required voltage and form a battery module. Multiples of the modules are then connected in parallel to achieve the required capacity (Ampere hours) and current carrying capability (Amps).



What is an Electric Vehicle Battery

- Vehicle batteries are predominantly based on lithium ion technology at this time and with cell voltages of between 3.6 and 3.8 volts.
- Typically, electric vehicles operate at a voltage range of 400 to 800 volts which requires each module to comprise between 100 and 250 cells in series.



TOPIC

04

The Rise of Battery Manufacturing Plants

The Rise of Battery Manufacturing Plants

- In the early 2020s the world suffered a supply chain crisis associated with integrated circuit or microchip supplies.
- The crisis was the result of weather and the global pandemic and highlighted the issues of placing significant reliance on essentially one region for sole supply of components.
- China has long been the go to manufacturer of lithium ion batteries and with the massive growth in electric vehicle demand, the world's car manufacturers could see potential for a repeat of the chip crisis in this sector.

The Rise of Battery Manufacturing Plants

- Various tax advantages have also been put into place in various regions of the world including the US, UK and Europe making it more attractive for to invest in manufacturing facilities for domestic consumption in these regions. That said the current US Inflation Reduction Act is challenging development in Europe and pricing means that the Chinese producers remain attractive options.

- In light of the above, the world has seen a huge increase in the development of lithium ion battery manufacturing facilities.

- In the US and Canada, in 2019 there were only two operational battery manufacturing plants. As of now there are about 30 either planned, under construction or in operation.

TOPIC 05

Economics / Supply Chain

Economics / Supply Chain

Green Subsidies play a crucial role in supporting Li-Ion battery production and the broader adoption of clean energy technologies. Some of the key subsidies are:

1. US Inflation Reduction Act (IRA):
    1. United States has committed USD 400 billion in investments and subsidies through the IRA to reduce greenhouse gas emissions and accelerate the adoption of renewable technologies. European Union's Green Deal Investment Plan
2. In response to IRA, the EU has proposed a EUR 250 billion green subsidies package called the Green Deal Investment Plan to boost private sector renewable investments within the EU. The main elements in the plan are:-
    1. A predictable, coherent and simplified regulatory environment, which supports the quick deployment of net-zero manufacturing capacities;
    2. Faster access to sufficient funding, by boosting investments while avoiding the fragmentation of the Single Market;
    3. Skills, by ensuring that the European workforce is skilled in the technologies required by the green transition; and
    4. Open trade for resilient supply chains, based on cooperation with the EU's partners to ensure diversified and reliable supplies and fair international competition

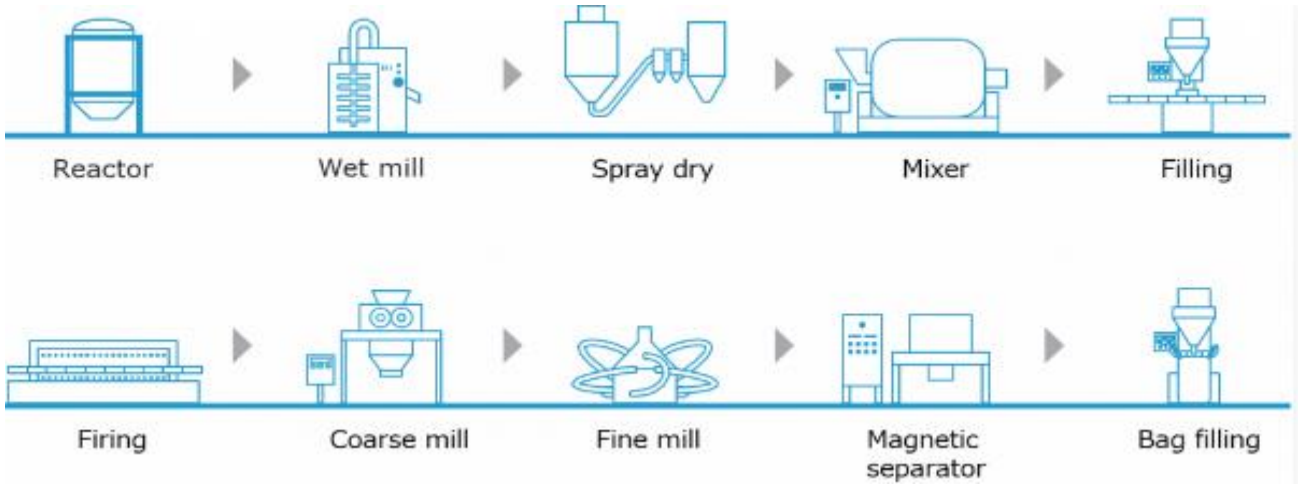
TOPIC 06

Technology / Process

Technology / Process

- Both battery and manufacturing technology is moving quickly in this field. With only a handful of facilities were operating outside of China, virtually all of the processing equipment has also been developed in that region, much of which will have to be imported initially. This may bring compatibility issues, language barriers etc.
- As experience is gained, process techniques will also likely be enhanced as lessons are learned.
- Product technology is also changing with much research underway for the next more powerful, longer lasting and smaller devices.
- Some of the in-development technology is already making its way to market and we should be alive to the prospect of other advancements in the future.

Technology / Process



Above is an active electrode material preparation plant.

This process may be at the battery manufacturing facility or may be located at a different site and / or the site of a sub supplier.

Materials to form the active electrode in the battery are carried on thin metallic foils. In order to place the materials onto the foil they are first made into a paste and in order to do this, the materials need to be ground to a powder / fine dust as part of the preparation process.

The process includes various stages of milling, grinding mixing, cleaning and drying to produce a fine powdered form of the desired material.

On completion the powdered material may be bagged or held in silos for use in the process depending on the location of the preparation plant.

Technology / Process

At the cell manufacturing plant, the various component parts are assembled and there are three key stages in the overall process being electrode manufacturing, cell assembly and cell finishing.

Electrode manufacture starts with mixing of the powdered active electrode materials to form a paste. The paste is applied to a thin metallic foil by a process known as slurry casting – essentially the paste is poured onto the surface of the carrier foil at a uniform thickness.

The coated foil then passes through drying ovens and a calendar rolling process to compact the materials and ensure a uniform structure prior to final drying by vacuum and slitting to provide materials of the correct dimensions.

Solvent extraction systems are provided for both recovery and environmental control. It should be noted that the solvent for anode materials is typically water but that for the cathode is NMP - N Methyl Pyrrolidone, a flammable liquid.

Technology / Process

Cell Assembly is where the various component parts are brought together. The electrodes are wound together with separators, electrical tabs are welded and the whole assembly is inserted into a casing, filled with electrolyte and capped.

Cell Assembly takes place in a clean and extremely dry environment to ensure against contamination which could lead to product failure / life issues.

Cell finishing includes formation – the process of charging and discharging the cells to form a solid electrolyte interface between the electrodes and electrolyte – plus aging and final testing / quality assurance.

Finished cells are then subject to packaging, storage and shipment.

Though not always the case, it is likely that a battery manufacturing plant will make battery cells for a number of vehicle manufacturers with cells arrange into modules and modules packaged into battery packs at other facilities elsewhere.

TOPIC

Fire Risk / Fire Safety

07

Fire Risk / Fire Safety

In this chapter of the paper the focus is on the typical fire hazard risks that would be associated with the cell and battery manufacturing processes at different stages.

The intention is to give reader a broad view and insight in the processes from the underwriting and risk hazard point of view.

Fire Risk / Fire Safety

Thermal Runaway

- Thermal runaway of lithium-ion batteries generally refers to the phenomenon of exothermic chain reactions inside batteries due to many electrochemical side reactions, causing a sharp temperature rise.

- The main cause of a thermal runaway event is the internal short circuit fault, which can cause the temperature of lithium-ion batteries to go beyond control in a few minutes.

- The failure of a single cell can generate sufficient heat to trigger the surrounding cells into thermal runaway, leading to propagation and continue to damage surrounding fully functional battery cells.

Fire Risk / Fire Safety

- The fast pace of development in lithium-ion cells and battery packs brings new challenges from the perspective of fire protection.
- The challenges arise due to the material hazards owing to intrinsic nature of the lithium ion cells and process hazards due to variety of steps followed in the production of cells and battery packs. As with other manufacturing processes, the fire hazard potential varies in each step of the manufacturing process.
- Depending on the type of cell (cylindrical, prismatic, pouch) some of the manufacturing steps may differ and hence the related fire hazards. However, the battery chemistry in combination with charge level is key fire risk associated with any type of cell.

Fire Risk / Fire Safety

Fire class definition for Lithium batteries

- There are six classes of fire and there are extinguishants to match the classes each class is described below:-
  - Class A—fires involving solid materials such as textiles, wood or paper.
  - Class B—fires involving flammable liquids such as oils, petrol, or diesel.
  - Class C—fires involving combustible gases.
  - Class D—fires involving metals.
  - Class E—fires involving energized electrical devices.
  - Class F—fires involving combustible cooking oils such as in deep-fat fryers

- The fire class of Lithium Batteries in its finished form consists of several components that cover different fire classes:-
  - Separator material, electrodes – Class A
  - Flammable liquid electrolyte – Class B
  - Energized electrical apparatus – Class E

- The fire suppression method should suppress the any Lithium Battery fire and control rise in temperature in order to avoid/stop thermal runaway that would re-ignite the battery fire. Heat propagation to adjacent batteries must also be avoided to mitigate the risk of having them entering thermal runaway.
- Underwriting Laboratories UL 2580 Electric Vehicle Battery Testing and Certification considers the fire and safety aspects of the battery when in use.

Fire Risk / Fire Safety

Applicable fire suppression standards

- There have been several studies made on fires in produced Lithium batteries – however there are fewer studies that cover fires in lithium battery factories where the batteries are still incomplete and without the final BMS-controls system installed.
- A study made by TUV Sud and Siemens concluded that since there are currently no sufficient regulations in national standards in Europe or the USA for fire protection in Lithium battery factories, international standards must also be taken into account, even though they are not drafted with Lithium Battery factories in mind:
  - EN 13501 – Fire classification of construction products and building elements
  - NFPA 855 – Standard for the Installation of Stationary Energy Storage Systems
  - FM Global Property Loss Prevention Data Sheets 5-33 – Electrical Energy Storage Systems
- Regarding the technical fire protection, the following German and European codes and standards should be applied:
  - DIN VDE 0833-2 – Alarm systems for fire, intrusion and hold up – Part 2: Requirements for fire alarm systems
  - ISO 7240 – Fire detection and alarm systems
  - CEA 4001 – Sprinkler Systems – Planning and Installation
  - NFPA 13 – Standard for the Installation of Sprinkler Systems
  - NFPA 36 – Standard for Solvent Extraction Plants

TOPIC

08

Insurance / Underwriting Considerations

Insurance / Underwriting Considerations

- Electric Vehicle battery manufacturing facilities are typically large, steel panel on steel frame buildings with a significant number of relatively small items of manufacturing equipment and centralised utilities, process solvent and electrolyte supply systems.

- During construction, they will exhibit many of the typical hazards associated with a typical manufacturing facility. This includes those relating to ground conditions, erection of steel framed buildings, lifting of equipment, weather, fire, water ingress and equipment failure.

- Typically, none of the equipment is particularly large / heavy so ground loads will not likely require significant piling. Some of the milling plant may prove an exception but loads are not anywhere near what would be expected in a power plant.

- Equipment generally comprises several smaller items with many of the same type of equipment being installed to meet production capacity. Loads are not that large so lifting hazards are somewhat reduced though there may be areas where extended reach is required to lift lighter loads over already installed facilities. A potential exception is the electrical power intake yard – battery manufacturing sites need a lot of electricity for both the process and battery charging.

Insurance / Underwriting Considerations

- Weather and other natural hazard exposures are generally location specific so can easily be identified and assessed at the outset.
- Fire loads as a result of materials of construction are likely low though there will certainly be a high level of packaging waste from equipment.
- Water ingress as a result of failed weather protection and process fluid or utilities leakage is a significant exposure, particularly if this occurs towards the end of the construction period.
- And finally, as with any construction project there is the risk of installed equipment failure.

Insurance / Underwriting Considerations

- As in most cases, the biggest exposure is that of fire during the testing and commissioning phase. Solvents are used in the manufacture of the electrodes and the electrolyte itself is a solution of lithium salt in an organic carbonate.
- The cathode solvent is NMP a combustible liquid with a flashpoint of 90C and all of the organic carbonate electrolyte solvents are low flash point flammable liquids.
- Both solvent and electrolytes are supplied to the process from centralised systems with large volumes in storage and extensive supply / distribution systems.
- During the electrode material preparation process there is risk of dust explosion. Explosion relief, inerting and static control systems should be installed and these areas should be of appropriate construction with properly rated electrical equipment.
- During the electrode manufacturing process, the solvent is vapourised in drying ovens at over 100C and collected for recycling via recovery systems with increased risk of fire.

Insurance / Underwriting Considerations

- Battery charging brings with it a high level of risk. If batteries have any defects they are likely to overheat or experience internal short circuit leading to fire and / or explosion. Likewise if the charging process is not adequately managed this too can lead to fire / explosion
- Maintenance of clean and extremely dry conditions during battery assembly is critical and any failure to maintain appropriate conditions in this area of the plant would essentially cease production.
- ISO 8 or ISO 7 clean rooms and less than 1% relative humidity are typically required. At 1% RH water is drawn from your skin and creates wet puddles in a dry room.
- Correct specification / use of appropriate materials of construction in this part of the plant are essential as many sealants, lubricants etc degrade in extremely low relative humidity conditions.
- And finally, something that is often overlooked, where will the workforce be sourced for these new technology facilities and how will they be trained.

TOPIC

Claim Examples

09

Claim Examples

This section examines some of the claims experience of the battery manufacturing plants.

- The main manufacturers of EV car batteries are in China. CATL (Contemporary Amperex Technology Ltd) is by far the world's largest producer of EV Car Batteries with a 36% market share of EV car batteries with a capacity of 259.7 GWH (Global capacity 705.5 GWH) (source *CATL website)
- In terms of market share for EV cars, China tops the world’s market with a circa 60% market share
- There are numerous other manufacturers scattered in Korea (LG) and North America (e.g. Tesla, GM)

Claims Experience

- Based on the research of this study group, there were numerous losses which had occurred in EV Battery Manufacturing plants globally.
- The team had research reported cases and some examples of the losses that have occurred in the EV Battery plants are listed hereunder:

Claim Examples

- **Tesla Megabattery Fire – Victoria Australia: August 2021**
  - 300-Megawatt Tesla Megapack Battery Project in Moorabool Victoria Australia
  - It took firefighters 76 hours to get it under control
  - Firefighters had to allow the fire to burn out due to the combustible nature of Lithium-Ion batteries
  - Whilst this is not an EV Battery plant, the Tesla Megapack represents the renewable energy storage solutions – the risks are like the EV battery plant
  - The cause of the fire was reportedly attributable to coolant leak
  - Thermal runaway occurred causing extensive damage

Claim Examples

Fire at GM Factory EV Zero Plant – Detroit USA: December 2023

- Fire occurred at the GM Factory plant in Detroit USA
- Forklift accidentally punctured container containing battery materials causing it to catch fire
- No published photos of loss

Vistra Energy Battery Storage Facility – Moss Landing California USA: Sept 2022

- One of the world's largest battery storage facilities for storage solar and wind renewable energy generation
- Overheating battery packs melted and triggered the fire suppression system.
- 7,000 batteries were soaked by the suppressant and damaged in the process

Claim Examples

- **Aricell Battery Factory – Hwaseong South Korea: June 2024**

  - 23 deaths – one of the deadliest fires in a battery factory which happened in June 2024 in Korea

  - Factory contained 35,000 lithium-ion batteries

  - Unconfirmed reports on social media revealed that the fire started from a small cell and quickly developed into a thermal runaway spreading to the whole factory

Claim Examples

Causes

- As the main risks of fire losses is well known for EV Batteries (majority of them being Lithium Ion), based on loss experience, the main causes of EV Battery fire is summarised as follows:
  - **Internal short circuit**: When damaged/defective, an internal short circuit triggers a chain reaction called thermal runaway, causing the battery pack to generate more heat than it can dissipate and catch fire.
  - **Battery design defects**: Faults or defects in the battery design can lead to fires.
  - **Abuse of battery cells**: Overheating, crushing, penetration, or overcharging can cause battery fires
  - **Human Errors**: Impact damage
  - **Water damage**: Fire suppressant systems
  - **Losses during Testing and Commissioning**: thermal runaway risks

Conclusion

- The loss experience for EV Battery plants is ever escalating globally and the resulting fires have proven to be fatal in some cases.
- There is an urgent need to address risk management and fire safety controls. In 2024, QBE Europe, the European arm of the Australian insurance group, urged companies to put in place appropriate risk management and fire safety controls to tackle lithium-ion battery fire and health risks that have “crept up” and become a “big issue”.
- Due to the unique challenges present in Li-ion EV battery manufacturing plants, standard smoke-detection and fire-suppression equipment is often not sufficient to address the risk of fire. Instead, advanced, performance-based, industrial-grade designs and systems are often required to minimize thermal runaway, accommodate different ceiling levels and the difficulties inherent in the various production stages of EV batteries.

Thank You

- Thank you to Andy Kane for sponsoring the working group and to all the team members for participating.

- Thank you all for your attention and participation.