

CLEAN AIR SOLUTIONS
FOR SUSTAINABLE BATTERY CELL
MANUFACTURING PROCESSES

Tailored Clean Air Solutions

The electrification of the transportation and automotive sectors is accelerating, leading to a surge in demand for Electric Vehicles (EVs) and, consequently, for Lithium-ion Batteries (LiBs).

In particular, the lithium-ion battery cell manufacturing process is characterised by a large demand for clean air in order to maintain high quality standards and to protect operators and the environment from harmful pollutants.

Camfil represents innovation and quality in air filtration. With decades of experience across various industries such as automotive, pharmaceuticals and semiconductors, we also offer tailored solutions that are specifically designed for the unique needs of the battery cell production in Europe.

The challenges in this field are diverse, but thanks to our broad portfolio, Camfil acts as a reliable partner and single-source provider for clean air solutions which ensure operational safety, energy efficiency and regulatory compliance in your facilities.

The ability to offer both, particulate and gas filtration solutions, makes Camfil an indispensable partner for companies that rely on clean and controlled production environments.

CELEBRATING **60 YEARS**
OF CLEAN AIR SOLUTIONS  1963
2023

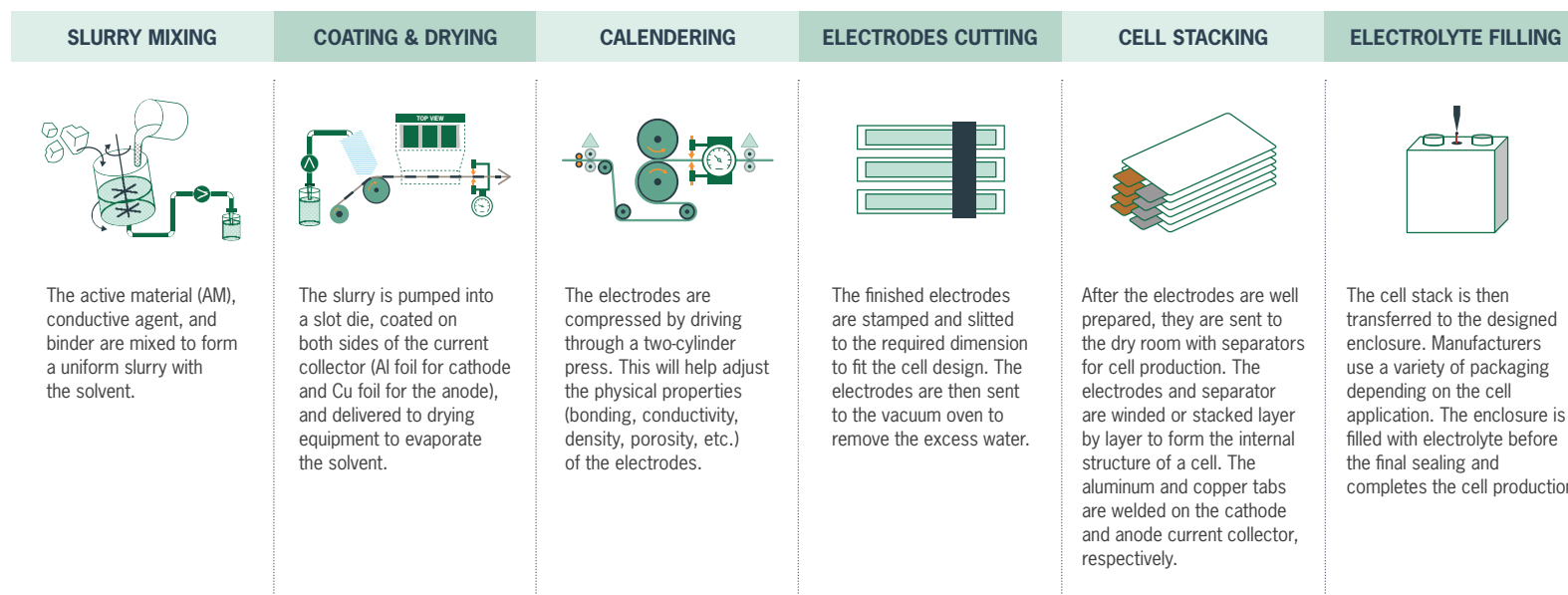


Processes & Challenges

The battery cell manufacturing process consists of multiple stages where electrodes are produced, then assembled and finally aged and validated.

Whatever the format (pouch, cylindrical or prismatic), the first step when manufacturing batteries is the production of the two covered layers known as electrodes. At this stage, it is vital to avoid contamination between materials, which is why gigafactories have two identical but separated production lines: one for the anode and one for the cathode.

A critical aspect is that most of these phases require special atmospheres. Dry and clean work environments are required to avoid that any humidity and airborne contaminants remain in the electrode, which can lead to increased degradation and capacity loss. At the same time these production processes generate particulate and VOC emissions and it is crucial that this airborne contaminants are captured, contained and extracted carefully in order to ensure good air quality and a safe work environment.



Air Recirculation

A clean and dry environment is critical to battery production processes. Indeed, humidity and contaminants may compromise the chemical balance of batteries compromising their charging and discharging performance. Battery cell production processes generate particles due to material handling, friction, cutting or smoke generated by largely applied laser technologies. These contaminants need to be removed by means of air filtration or dust extraction.

Costs for energy required to create the correct environment have a significant impact on the total manufacturing expenses. These costs can be reduced by an efficient air filtration system that is less energy consuming and that allows recirculation of the dry and already conditioned air. In order to obtain the required level of air quality that allows recirculation, generated dust need to be captured at the source by properly designed capture solutions. This helps to reduce the amount of extracted air which is led through the ductwork into multiple filtration layers including dust collectors, HEPA filtration and molecular filtration units.

To achieve the best results, an optimal interaction of the extraction system with the often individually developed battery production equipment is key. Camfil can help to validate your process and machinery, so that the extraction and recirculation system fulfills or even outperforms local legislation and HSE regulations.



Emissions: Particulate Contaminants & VOCs

Gases and particles are released during various stages in the battery cell production lines and to ensure the required air quality and to protect people, products and the environment, it is crucial to control these emissions.

Particulates and VOCs originate from battery cell production processes may contribute to air pollution and environmental degradation if not properly controlled. Therefore, the selection of appropriate filtration technologies such as HEPA filters, dust collectors or molecular filtration solutions is fundamental.

It is also essential to consider multiple filtration stages. Incorporate prefiltration stages to remove larger particles and prolong the lifespan of downstream fine filters. Include post-filtration stages to ensure the removal of any remaining fine particles and gases before the air is discharged.

Effective control of particulate and VOC emissions is essential for minimising environmental pollution and protecting public health. Advanced filtration technologies play a crucial role in mitigating the release of these pollutants into the atmosphere. Continuous monitoring and adherence to regulatory standards are also vital to ensure that emission control measures are both effective and sustainable.





Creating Safe Work Environments

The challenge in dry cleanrooms is around the hazards of both, particles and gases, that are released during various process stages in the cell production lines. On one hand these contaminants represent health hazards for the operators when exposed to toxic dust and VOCs, on the other hand uncontrolled emissions could create explosive atmospheres within the factory.

Mitigating Health Risks

Depending on the type, the performance level, cost and safety characteristics of a battery, manufacturers use different chemistries. Controlling toxic dust from these processes is a common, yet serious, challenge for each of them. The more hazardous the chemistries are, the lower the exposure limits set for personnel coming into contact with the materials. It is the employers' responsibility to know and understand these exposure limits for each product they are using and take the necessary steps to ensure the limits are not exceeded, in order to protect their operators and the environment.

Protect From Dust Explosions

The ATEX-directive requires that the employer is responsible to carry out a risk assessment to determine the necessary fire and explosion protection. Furthermore it is vital to ensure that the system remains compliant even after perhaps changed process conditions, to provide maximum safety for personnel and the facility. It is also necessary to carry out periodical audits for quality and process reliability as well as ATEX safety inspections.

Supply Air Cleanroom Solutions

In the production of lithium-ion batteries, the implementation of a robust contamination control strategy is crucial. This strategy prioritises moisture control as well as the management of particles to uphold safety and quality standards.

The challenge in dry cleanrooms is to maintain an environment free from contaminants, which is compounded by the need for precise pressure control. Utilising advanced dehumidification technology and specialised cleanroom architecture is essential to ensure low humidity levels, the required air purity level and proper pressure. This is vital to ensure the integrity of the batteries and to prevent from hazardous lithium reactions.

Clean air in cleanrooms is provided by the use of Filter Fan Units (FFUs) and terminal filter housing technologies. FFUs utilise fans for active air supply while terminal filter housings are passive elements. Space, airflow and the demand of flexibility determine the choice of technology. Megalam HEPA/ULPA filter elements are central in both systems for particle removal. Proper filter selection is vital to achieve the desired air quality and to optimise energy consumption.



Terminal Filter Housing
CleanSeal



Filter Fan Unit
CamFFU



Cleanroom Panel Filter
Megalam





Supply Air General Ventilation

Dry cleanrooms and especially the process machinery in battery cell production have a very high requirement for supply air in order to ensure safe and clean operation.

Pre-Filter

Pre-filter stages are crucial for the separation of coarse and fine dust and thus for the service life of the HEPA filter stages. But they also have a significant influence on the operating costs of the ventilation systems and therefore on the economic efficiency. The selection of prefilters should always take several aspects into account. Reliable filter efficiency and dust holding capacity over the period of use are just as important as energy efficiency and ease of maintenance.

Bag filters are the most commonly used air filters in air handling units. They have a higher dust holding capacity and a longer service life than other filter types.

Compact filters, with or without a front frame, are the ideal second filter stage in the supply air, either as the last filter stage for comfort applications or as a second pre-filter stage for clean rooms. They offer excellent separation performance with a low pressure difference and require less space in ventilation systems than bag filters.

HEPA Filter

HEPA filters for high air volumes are also used directly in air conditioning and dehumidification systems. Their box-format design should be energy-efficient and not only protect downstream filter stages but can also be the final filter stage, depending on the air purity requirements. These filters can also be used in room exhaust air, separating harmful, ultra-fine particles.

Exhaust Air

Low Concentrations: Static Non-Cleanable Filters

The high requirements for supply air quality throughout the different production steps in battery cell manufacturing are ensured by numerous measures. However, dust and particles are generated within these processes themselves, must be separated for the safety of the operators, but also to protect the product and its quality.

It is essential, to prevent active material which may have CMR properties from entering the employees' breathing air or contaminating the dry cleanroom. It is also necessary to avoid cross-contamination that could negatively affect the function or even the safety of the battery cell. To extract, clean, and if possible, safely reintroduce highly pure air to the cleanroom or directly to the process, specially designed exhaust systems are required.

In situations where the particle concentration is so small that a dust extraction system is not sensible for both, investment and filtration efficiency reasons, Camfil offers a safe and efficient solution in conjunction with static, non-cleanable filters that make no compromises in efficiency and safety.

The CamSafe 2 **safety housing** with Bag-In Bag-Out system is a proven solution for safety housings, specifically adapted to the requirements of battery cell manufacturing. It offers exceptional reliability, easy and safe filter change, low maintenance, and numerous safety features for safe operation, naturally with an electrostatic certificate.

Exhaust air housings for wall installation are the ideal solution for cleaning exhaust air from cleanrooms. For reliable validation of the built-in HEPA filters, an integrated test probe is recommended. The housings must be highly reliable, robust and fully welded and should enable easy filter replacement. With these housings, it is also important to ensure that energy-efficient filter elements can be used without complications.



Exhaust Air High Concentrations: Industrial Dust Extraction

Stationary filters or dust collectors with cleanable filters? What filtration solution is best for the individual process really depends on the properties of the emissions but also the concentration of dust in the air stream. If the concentration is too high for non-cleanable filters, a dust collector should be considered and will probably be the best solution in order to reduce the Total Cost of Ownership (TCO). There's a simple rule of thumb:

"If the dust load is at or above 0.1 mg/m^3 , a dust collection system with pulse-cleaned filter elements will probably be the best option to handle the process dust as first filtration stage, providing a reasonable filter life."

Furthermore the employer has to consider if the process contains the handling of hazardous substances which could pose health risks for the operators. If so, the dust collector system design has to include containment options like the Bag-In Bag-Out safe-change system for filters and dust discharge in order to prevent operator exposure and the collected material from escaping when performing filter change-outs.

The Gold Series dust collector family with its modular and tested airtight design, BIBO options and ATEX-certified explosion protection devices, represent a range of proven solutions specifically adapted to the requirements of battery cell manufacturing. They guarantee lower cost of operation, easy and safe filter change, low maintenance, and provide the required safety for your facility.



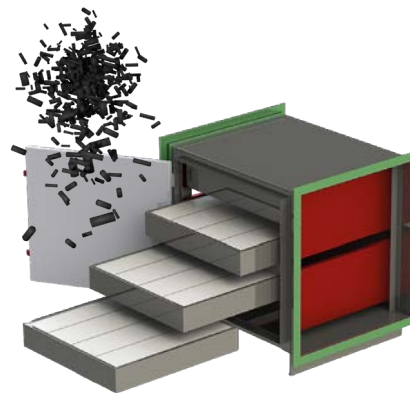
Exhaust Air Molecular Filtration

All along the battery production process, there are numerous molecular contaminants (i.e. gas or vapours) that will be emitted and that will affect the people, the process or the environment such as:

- **N-Methyl Pyrrolidone**, a.k.a NMP, is a solvent, widely used for the production of the cathode material, which has adverse effects on human health.
- **Alkyl carbonate solvents**, such as DMC, DEC, EMC and others, are found in the electrolyte formulations and can negatively impact the environment.
- **Ozone and Nitrogen Oxide(s)**, often formed during welding processes, can affect both the health of the operators as well as the integrity of the production assets (corrosion).

Molecular filtration solutions, based on adsorption techniques such as physisorption or chemisorption, have been widely used to address molecular contamination issues in industrial air streams for decades. It has flexibility in terms of filtration media, filter size, filter design, that allows its deployment in battery laboratories, in pilot plants or in gigafactories.

Adsorption of molecular contaminants by activated carbon, impregnated carbon or other types of molecular filtration media, is recognised by industrial players and by authorities as a way to efficiently clean air streams in the more stringent applications, such as nuclear environments (iodine traps) or toxic gases handling (war gases), etc. High levels of performance delivered by properly designed molecular filtration solutions, together with ability to regularly monitor the performances, make them a solution to be considered for dry air recirculation. The possibility to re-use very dry air, after “cleaning” it with a molecular filter, is a pathway for the overall battery production process to be less expensive by decreasing the amount of dry air that has to be produced.



Clean Air Solutions For Your Industry

For more than sixty years, Camfil has been helping people breathe cleaner air. As a leading manufacturer of premium clean air solutions, we provide commercial and industrial systems for air filtration and air pollution control that improve worker and equipment productivity, minimise energy use, and benefit human health and the environment.

Camfil is focused on research and development as well as state-of-the-art manufacturing. We don't just market our products, we supply clean air solutions and services on a global basis. Many of our clients have multiple facilities located around the world. Camfil is viewed by many of the largest industrial manufacturers as a partner as we are well positioned to support their clean air requirements on a local and global basis. It is common for us to 'partner' with our customers and their consultants or contractors to meet and often exceed their most demanding air filtration requirements.

Business Areas:



Filtration Solutions (HVAC)

- Comfort
- Cleanrooms
- Industrial
- Containment



Air Pollution Control

- Dust
- Fume
- Mist



Power Systems

- Power generation
- Oil & gas
- Process



Molecular Contamination Control

- Gases
- Odours
- Corrosion control

The logo features the word "camfil" in a white, lowercase serif font, with a stylized wing graphic to its left. Below it, the words "CLEAN AIR SOLUTIONS" are written in a smaller, white, uppercase sans-serif font.

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