

**Challenges During Lithium-ion Cell Manufacturing Plant Setup – Part 1 (Understanding the Market)**

Rahul Bollini is going to present a series of articles for the next couple of months that would explain the challenges faced during Lithium-ion cell manufacturing plant setup. This pertains to any company that is newly entering into this field.

The first challenge faced while setting up a Lithium-ion cell manufacturing plant is to clearly define the target market towards which the Lithium-ion cell manufacturing output would cater.

Target market has to be further defined to a sub-category level. For example, calling the target market as EVs (electric vehicles) is not enough, it has to further narrowed down to which type of EVs such as two-wheeler, three-wheeler, four-wheeler, buses, etc. The type of EVs have to be further narrowed down to if the two-wheeler is a low speed or high speed vehicle, if the three-wheeler is a L3 (passenger e-rickshaw or e-cargo loader) or a L5 (passenger auto or heavy duty cargo loader) vehicle, if the fur-wheeler is a LCV (light commercial vehicle) or an electric car and so on.

The major factors that come into play after narrowing down the exact application is to understand the following parameters:

1. **Space/Volume:** It is a very important factor (Wh/L of the cells/battery pack) in narrowing down the suitable cell chemistry in terms of the space available for the battery in the application.
2. **Weight:** Although weight (Wh/Kg of the cells/battery pack) is a lesser important factor compared to battery space availability in an application, weight does play a vital role in designing the centre of gravity of the application, which is taken seriously in EVs.
3. **Battery Pack Capacity:** Based on the expected range per charge with respect to realistic driving pattern, the battery pack capacity (in terms of kWh) is considered. Due to the range anxiety, one feels the more range the EV has, the better it would be for them. But more range increases the battery capacity and drives up the price of the EV making them difficult to compete with ICE vehicle prices.
4. **Form Factor:** Based on the dimensions of the available space to accommodate the battery pack, form factor is chosen. For example, a low floor sedan car incorporating battery at a chassis level would either consider cylindrical cells or blade type pouch or prismatic cells. Regular prismatic cells would not be an ideal fit since it is recommended to use them in vertical position, which would make their height exceed the height of the available battery dimensions in a low floor sedan. Available form factors are cylindrical (popular models in production are 18650, 21700, 26650, 26700, 32700, 32135, 33140, 4680, 66160), pouch (regular model with both tabs on same side and blade type model with tabs on opposite sides) and prismatic (regular type, VDA module type, blade type).
5. **Cell Capacity:** Based on the form factor suitable and the available dimensions inside the battery pack, a suitable capacity of the cell is decided. Lower number of cells in parallel connection is considered better but having very big sized cells is also considered unsafe specially when it is NMC and NCA cells.
6. **Cycle Life:** Based on the life required for the application, the suitable cell chemistry is selected. In long range vehicles where space is a constraint to achieve high range, a compromise is made in the cycle life to achieve higher range using cells that have high volumetric energy density (Wh/L). This compromise leads to lower cycle life and lower safety due to the simple fact that when the battery gets smaller and lighter, its safety and life reduces. The long range of the vehicle does make up for the lower cycle life to be able to provide service life as per the expectation in the application. For example, electric car companies provide 8 years battery warranty in India.
7. **Power Density:** It is the ability of the battery to take and give power (during charging and discharging). It is essential to check the compatibility of the cell form factor and chemistry to perform at the required C rates to be able to deliver power for the required EV application. This relates to fast charging capability, maximum continuous discharge current capability, peak pulse discharge current and the amount of time peak pulse current can be delivered and ability to handle regeneration current coming from braking of the vehicle. The cell engineering structure has to be designed internally to be able to deliver such power to bring down the internal resistance of the cell. More to be discussed about this in the next part of this article next month.

There can be more than one possible solution for each application and the ideal way would be to check up the most popular combination that is suitable for the highest number of applications. Since Indian cell manufacturing plants have not yet taken off in a big way yet, below are the type of cells (imported) popularly used in India for catering to EV applications.

2.6Ah NMC cell in Cylindrical 18650

2.9Ah NMC cell in Cylindrical 18650

5Ah NMC cell in Cylindrical 26650

5Ah NCA cell in Cylindrical 21700

6Ah LFP cell in Cylindrical 32700

15Ah LFP cell in Cylindrical 33140

30Ah LFP cell in Pouch (tabs on same side)

100Ah LFP cell in Prismatic (winding type)

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**Challenges During Lithium-ion Cell Manufacturing Plant Setup – Part 2 (Product Meeting Technical Expectation of the Market)**

It is very common to hear about publications or articles about a new breakthrough technology that could change the whole market. This could be a cell technology, a major component of the cell or even a sub-component of the cell.

Although part 1 discussed about clearly defining the target market towards which the Lithium-ion cell manufacturing output would cater to, part 2 discusses about the challenges faced during meeting those expectations. I discuss about these typical technical parameters below:

1. **Market Trends:** There are trends happening with existing technologies in the international market at a Giga-scale and any company newly entering into cell manufacturing must be aware of this in order to avoid themselves to be left out from the international competition. For example:

1. NCA cells max out at 5Ah discharge capacity in 21700 cylindrical form factor presently and it is being upgraded to 5.3Ah by some manufacturers, hence it is able to provide 6% higher discharge capacity in the same volume and it has improved gravimetric energy density (Wh/Kg).
2. LFP cells in 32700 cylindrical form factor max out at 6.5Ah discharge capacity presently. But it is getting updated to 7Ah in the same 32700 and there is an addition of a 32800 model which would have 8Ah.
3. LFP cells have crossed above 400Wh/L for the first time in some models such as 33140 form factor, providing 15Ah discharge capacity. This is by far the highest volumetric energy density that LFP cells have achieved till date.
4. Large LFP cells such as pouch cells have improved from 1C max continuous discharge rate to 2C max continuous rate along with improvement in gravimetric energy density from 160Wh/Kg to above 180Wh/Kg. It is a matter of time it will reach 190Wh/Kg in the coming times.
5. Large LFP cells demand is shooting up, specially the 280Ah prismatic cells used in BESS (battery energy storage system). Traditionally they offered cycle life that wouldn’t allow it to operate beyond 10 years at 90% DoD (BESS typical operation). Newer cell models have enhanced the cycle life to comfortably function beyond 10 years.
6. **Customer Qualification Plant (CQP):** This is a term being used by the new companies that are setting up a decent size pilot scale manufacturing facility after they are sure about what they want to produce. The intention of this plant is to provide regular samples to its potential customers for testing and validating their products. The intention of this plant is to confirm that this exactly is what needs to scaled up to a Giga-scale. Challenges in this plant include optimising the recipe of the cell to the required accuracy in order to achieve the required specification. Most companies face indefinite delays in their QCP, especially the companies that have their own lab-made technology or those who collaborate with lab-level technologies. Hence, some companies choose to collaborate with experienced companies, who not only have experience dealing with such plants but also have experience scaling up to Giga-scale plants and operating them successfully for many years. Parameters that need to be maintained consistently in QCP are:
7. **Discharge Capacity:** It has to be maintained ranging between minimum capacity and rated capacity at a given C rate of charge and discharge. The consistency in the discharge capacity is very important to the battery pack assembly companies and it is their first step of QC.
8. **Internal Resistance:** ACIR and DCIR values to be within the desired range and higher values categorise the cells under Solar grade (unfit for electric vehicle application).
9. **Self-discharge:** During grading process, it needs to be within the desired range and higher values categorise the cells under lower categories such as A- or B grade. It is known as k value during grading process, it refers to the drop in the voltage in a given unit of time (millivolt/day).
10. **Energy Density:** Lower gravimetric energy density is a possibility in defined form factors such as 18650 cylindrical cells lower volumetric energy density is a possibility in flexible form factors such as pouch cells. This would mean that the cells are heavier and bulkier than expected respectively. This can be because of various reasons such as more dead-weight materials such as binder, conductive additives or electrolyte is used and this can even increase the production cost.
11. **Temperature Profile:** It is a known fact that there is a temperature rise in the cells during charge and discharge operations. It varies at various C rate of operation. A consistent cell design incorporated manufacturing process in place ensures that the temperature rise of the cells are uniform. Temperature profile is considered as a very important factor while building a battery pack because based on this, the thermal management is designed for the battery pack. Higher temperature rise compared to other similar type of cell manufacturers in the market, discourages the buyer.
12. **Efficient Design:** Lithium-ion cell making is not very difficult at a research level, you can hear about it every now and then. But achieving the required specification meeting the overall expectation as per the market standard can be tedious. Starting with the fact that the market grade specification can’t be manufactured in a laboratory, the equipment simply does not support to achieve the market standard specification. This is where a gradual increase in discharge capacity is tested out (in same form factor, without a drastic increase in IR), where laboratory level technology is taken to a Mega-scale manufacturing, then to a CQP and then to a Giga-scale. The gradual increase in the scale calls for gradual improvement in the cell design and process in order to achieve the set target.

Efficient design also means using the best possible resources to achieve the required cell specification. NMC 532 cathode with graphite efficiently allows for 2.6Ah discharge capacity in 18650 but achieving the same discharge capacity in NMC 811 would be considered inefficient because NMC 811 cathode is expensive and has the potential to provide higher discharge capacity in 18650, say 2.9Ah. Also, NMC 811 works with an expensive formulated electrolyte, adding more cost. More to be discussed about this in part 5, which discusses about the challenges of process optimisation and skilled man power.

**Part 3 will discuss about Challenges faced during securing the Raw Materials and an outlook of what can be utilised from India.**

**Challenges During Lithium-ion Cell Manufacturing Plant Setup –** Part 3 (Possibility of Localisation and Securing Raw Materials)

In this article, I’m going to explain about the challenges faced during securing the raw materials for Lithium-ion cell manufacturing plant setup.

The first step is to understand what goes inside a cell, let me list down the components that go into manufacturing Lithium-ion cells:

1. Cathode Active Material
2. Solvent for Cathode Slurry (NMP)
3. Cathode Binder (PVDF)
4. Conductive Carbon Additive (For Cathode and Anode)
5. Anode Active Material
6. Solvent for Anode Slurry (Deionized Water)
7. Anode Binder (CMC and SBR)
8. Separator
9. Electrolyte Salt in various ratio of EC (Ethylene Carbonate) and other Carbonate based Organic Solvents along with additive(s).
10. Cathode Current Collector (Aluminium Foil)
11. Anode Current Collector (Electrodeposited Copper Foil)
12. Cathode Tab (Aluminium)
13. Anode Tab (Nickel Coated Copper)
14. Nickel Coated Stainless Steel/Aluminium Cylindrical Can Assembly Kit for Cylindrical Cell
15. Aluminium Prismatic Can Assembly Kit for Prismatic Cell
16. Aluminium Polymer Sheet for Pouch Cell

Let us discuss about the challenges of locally sourcing the above raw materials and possible supply chain related issues.

1. **Cathode Active Material:** Focus on localising Lithium Iron Phosphate (LFP) Cathode material is a beginning step because of the simple reason that it uses raw materials that are easier to source compared to other Cathode materials. LFP cathode is made with a combination of Iron Phosphate (FP) precursor and Lithium Carbonate. FP precursor is made with a combination of Iron Oxide and Phosphoric Acid. This equation seems very easy when compared to acquiring difficult materials such as Nickel and Cobalt in Sulfate form (battery grade) and converting them into precursor as per NMC or NCA ratio requirement and then adding Lithium Carbonate or Lithium Hydroxide as per the formulation. Focus is on LFP because it simply works out to be cheaper, lasts long, needs lesser thermal management and safer than the remaining cell chemistries out there (except LTO).
2. **NMP Solvent:** It is already produced by companies catering to the pharmaceuticals industry. Most (>90%) of the NMP is recovered during production through a NMP recovery system (heavy power consumption, but it is unavoidable in terms of Cathode Slurry making with present technology), so less volumes are procured in the future production cycles.
3. **PVDF Binder:** PVDF binder localisation is time taking for any country, in fact China (with many years of established Lithium-ion cell manufacturing industry) took many years to make a decent PVDF binder but still lacks the kind of performance that anybody can expect from the ones manufactured by western countries. A cell manufacturing has to pick a side when choosing a PVDF binder, whether they want to go with a suspension-based or an emulsion-based binder material. There are no obvious favourites when it comes choosing from these both. There was a shortage of binder in 2022 and the price shot up multiple times. As long as PVDF binder is used for Cathode slurry making, NMP solvent is the only way to make slurry because PVDF has a hard time to dissolve in water.
4. **Conductive Carbon:** A few companies have been focussing on conductive carbon additive for lead acid batteries in countries where there are good volumes of lead acid battery manufacturing. Although the properties vary, it shouldn’t take very long to localise this in any country. But there are top companies in the west, that kind of stand out when it comes to conductive carbon.
5. **Anode Active Material:** Graphite (Natural and Synthetic) is about achieving the purity, particle size and certain other critical parameters right. The plant setup cost is also not very expensive for localising it. But when it comes to Silicon-Graphite (Si-Gr)/Silicon-Carbon (Si-C) Anode, things become complex because it is an evolving technology with various updates expected in the coming years. Increase in the silicon content will have a drastic increase in the specific capacity of the anode material. LFP cell manufacturers are very much working with only Graphite but NMC 811 and NCA work with SiGr/SiC and have to be more careful about its procurement. Petroleum coke used to make synthetic graphite, is one of the cheapest in India and India has an edge to be a market leader in this space.
6. **Solvent for Anode Slurry (Deionized Water):** Can be made in the cell manufacturing plant. Water is processed in a deionized water filter to make it suitable for use in Anode Slurry.
7. **Anode Binder (CMC and SBR):** These materials are already locally manufactured but they need little work to match the battery grade specification and hence these can be domestically produced.
8. **Separator:** It is the only plastic-based material in the list of major components of a Lithium-ion cell. As easy as it sounds, there is a huge complexity while choosing from the available options in a separator. The most basic being dry process-based PP (polypropylene) separator is the easiest to localise, it also happens to be the least expensive and generally used in LFP cells. Things get complicated when cell manufacturers want to differentiate themselves from their competition and decide to step up to other available separator options. The other options include dry process-based PP separator with ceramic coating (one or two side), wet process-based PE (polyethylene) without any coating or with ceramic (one side or two side) coating along with or without PVDF coating. Dry PP separator with ceramic coating can be the next easiest type of separator to localise. But moving to manufacturing wet separators can mean very high CAPEX. Such a high CAPEX plant is only justified when it caters to a large number of big capacity cell manufacturing plants.
9. **Electrolyte Salt in EC and other Carbonate based Organic Solvents along with additive(s):** Localisation of Electrolyte would mean starting with a basic step by importing the electrolyte salt and formulating the electrolyte locally. This a preferred method and doesn’t involve much difficulty. Second step of localisation would mean manufacturing the Electrolyte salt domestically and this would involve dependency on Lithium Hydroxide Salt. Organic solvents are available domestically and additives localisation would be another great step, which is additives such as VC, FEC, etc. Due to risk of transportation of the complete electrolyte solution, it is highly advised to immediately start with the first basic step.
10. **Cathode Current Collector (Aluminium Foil):** Any domestic aluminium foil manufacturer that can make foils for as low as 10-micron thickness with high level consistency can be suitable to work with.
11. **Anode Current Collector (Electrodeposited Copper Foil):** The plant setup for this can be very expensive because of the electrodeposition method of manufacturing copper foil. Such a high CAPEX plant is only justified when it caters to a large number of big capacity cell manufacturing plants. Until then it has to be imported from other countries. Copper shortage is expected to come in the coming years because of its fastest growing demand in various industries, hence securing this critical raw material would be very crucial.
12. **Cathode Tab (Aluminium):** It can be made available locally. Comes in rolls. Shapes and dimensions vary for each form factor (cylindrical, pouch and prismatic).
13. **Anode Tab (Nickel Coated Copper):** It can be made available locally. Consistency of Nickel coating is very important because if the coating on the Copper comes off, there will be performance issues during the current carrying activity (during charging and discharging). Shapes and dimensions of the tab vary for each form factor (cylindrical, pouch and prismatic).
14. **Nickel Coated Stainless Steel/Aluminium Cylindrical Can Assembly Kit for Cylindrical Cell:** Nickel coated Stainless steel cylindrical cans were the standard for cylindrical cells so far but there is an emerging market for aluminium cans for cylindrical cells. There is a difference in their tabs and according to the preference of welding, the type of metal for cylindrical can is selected. For example, an aluminium can can’t be grooved like a nickel coated stainless steel can and hence its cap is different and moreover it comes with a laser welding friendly tabs on both ends. But aluminium cans tend to experience dents. On the other hand, nickel coated stainless steel cans are friendly for spot welding (a method favoured by many in the industry due to its ease of operation).
15. **Aluminium Prismatic Can Assembly Kit for Prismatic Cell:** Prismatic cans are made up of aluminium with high strength to be able to withstand any kind of bulging that tends to happen with aging. But the bulging does show up eventually. The cap of the prismatic can has a flat type tab, which is generally made for laser welding purpose. But with special orders, it is also made to be threaded. Localisation for this needs careful validation before mass deployment.
16. **Aluminium Polymer Sheet for Pouch Cell:** Easiest of the three casing to manufacture, it has multilayer of materials combined together. It is made in sheet and sold in square meters. It is customised as per the requirement.

**Note:** All metal-based products from number 10 to 16 can be localised with number 11 facing difficulty finding commercial viability because of very high CAPEX.

**Challenges During Lithium-ion Cell Manufacturing Plant Setup –** Part 4 (Plant Setup Planning)

In this article, I’m going to explain about the challenges faced during the Lithium-ion cell manufacturing plant setup.

Any company entering into Lithium-ion cell manufacturing aims for a laboratory setup to get its team acquainted with the complexity of the Lithium-ion cell manufacturing process. This laboratory also helps to analyse the critical raw materials at a deeper level.

First step towards understanding the characteristics of critical raw materials such as Cathode is to make a half cell, which is made using a Lithium metal anode. Characteristics such as specific capacity during discharge is studied at a low C rate (0.1C or 0.2C rate). Along with it, the first discharge efficiency and other performance related parameters are studied to understand the electrochemical nature of the material. The particle size of the Cathode is also studied at a very high magnification scale to understand the physical nature of the material. Similarly, each raw material needs to be studied and finalised to take it up for regular production. Generally, two or three vendor for each type of raw materials are finalised so as to ensure regular supply and competitive pricing.

The laboratory scale is scaled up to a pilot scale (usually in MWh scale) to test the cells at a mass scale and provide the cells to the potential clients for qualification and take orders in a big way, which then paves the way for Giga-scale production.

There are various parallel tasks to be performed for the plant setup planning. Below are the details of the tasks:

**Equipment Planning:** It is the most intensive planning for the plant setup in which there is a meticulous discussion with the company handling the sourcing of all the equipment and takes care of installation and commissioning. This kind of company is called as a system integrator. Sometimes the scope of the plant equipment is split and sourcing is done directly from the equipment manufacturer. The latter version tends to save money but can be hectic at times during the commissioning (trial run as per the desired output) of the plant. At times, there can be blame game between the equipment suppliers when the production output doesn’t as desired. Any new company is advised to work with a system integrator who can take the complete responsibility of the plant functioning and can guarantee the desired output. Either way, the production process and the cell design are to be shared with the equipment company to help them understand the type of cell(s) to be manufactured. If planning with a multiple type of cell production in the same line, it is advised to take the less automation route to have flexibility. Finetuning the production plant takes up a few months usually and more details will be discussed about in part 5 of my series, where I’ll discuss about the challenges faced during the process optimisation at a Giga-scale plant.

**Infrastructure Planning:** Although the discharge in Lithium-ion cell manufacturing is minimal due to solvent recovery process during electrode manufacturing (cathode uses NMP solvent and anode uses deionized water). Lithium-ion cell manufacturing is allowed to setup in high to very high polluting areas only. Land acquired in these zones are generally far away from the city and poses a challenge for skilled man power. More details about challenges for skilled man power to be discussed in part 5.

Generally, Giga-factories are planned in multi-storeyed to have better monitoring and so that each team involved during various processes can work very well together. Usually, a two storeyed building is preferred. In this case, the bottom floor handles the incoming raw materials and feeds it to the mixer, feeds to the coating, followed by a long drying process usually starting from 40m length.

Dry room infrastructure planning is also very crucial since it needs to be up and running most of the time and any down time in its functionality can temporarily stop the production. Selecting the relative humidity and dewpoint temperature can vary for each process area, it will be less strict in the coating room and stricter in the electrolyte filling room. It can also vary depending on the type of cathode being used, for example NMC handling conditions are stricter than LFP handling conditions. Dry room power consumption tends to be more when the conditions are stricter (lower relative humidity and lower dewpoint temperature). These conditions are also set based on the number of people working inside the dry room and based on the number of times the dry room door is opened in a given time.

**Utility Planning:** Lithium-ion cell manufacturing at a Giga-scale needs very high power. One GWh/year plant capacity needs to have an approximate connected load of close to 10MW and it can vary depending on the automation.

Uninterrupted power supply is a must in Lithium-ion cell manufacturing and hence there are many MVA sized diesel generators to ensure there is no interruption in the cell manufacturing process and most importantly to ensure non-stop functioning of dry room.

Deionized Water is actively used as Graphite based Anode Solvent and its requirement can be close to 1.5 Million Litres for one GWh.

**Challenges During Lithium-ion Cell Manufacturing Plant Setup –** Part 5 (Process Optimisation and Skilled Man Power)

In this article, I’m going to explain about the challenges faced during the Lithium-ion cell manufacturing plant with respect to process optimisation and skill training man power.

As discussed earlier, any company entering into Lithium-ion cell manufacturing sets up a laboratory setup to get its team acquainted with the complexity of the Lithium-ion cell manufacturing process. This laboratory setup is scaled up to pilot scale (usually MWh size) and again scaled all the way to Giga scale. One fully automated end-to-end equipment line can cater up to a few GWh.

At each of these stages, there are a few hiccups relating to process optimisation. What exactly does process optimisation mean? Well, it simply means tuning the production process with respect to the equipment to get the desired output. It also means dealing with accuracy problems every now and then with the right troubleshooting steps. It really takes an expert to handle these process optimisation tasks. Let us talk about process optimisation in various aspects of the cell manufacturing process.

**Man Power**

Man Power challenges can be divided into two categories: Upskilling them and strict QC (quality control) practices to be followed in cell manufacturing. This challenge is alike for every advanced technology field that is newly emerging.

**Upskilling:** It simply means to acquire the skills (basic, intermediate and advanced) required for a particular job. This can involve a mix of theoretical and practical training sessions. It is really a challenge to find institutions (educational or industrial) that can provide skill development for a newly emerging technical field such as cell manufacturing. Hence, cell manufacturing companies consider sending their first set of employees (from chemical, electrochemical, mechanical, mechatronics, electronics and electrical field) to their technology partner company (usually outside India) for hands on training. Due to high training cost involved for specialisation training, these companies try their best to retain such employees for as long as possible. Maintenance personnel can be hired from a different field such as Pharma, where the operations for the equipment, dry room and total plant maintenance are similar.

**QC Practices:** It is by far the most important aspect in cell manufacturing. Any overlooking of quality practices during the cell manufacturing process can cause a serious damage to the production output, including serious rejection rate during cell grading. There can also be long term issues on the field such as cell failures and it can lead to dangerous incidents and even catch fire in certain cell chemistries. Adhering to strict QC process must come from personnel that are certified in six sigma and other similar QC certifications.

QC is very important from incoming raw material inspection, process control and monitoring parameters during production, grading and pre-dispatch inspection. It is also relevant to maintain the right ambient working conditions in raw material storage and cell production area in terms of relative humidity, dew point temperature and cleanliness (any foreign particle can disturb the production).

**QC and Process Optimisation**

They both are related because QC not only involves keep the environment client but also involves getting the process right. Below are the processes where strict standard operating procedure must be adhered.

* Studying the incoming raw material such as analysing active material in SEM and XRD. There are other processes to be followed for other raw materials. Also looking for their moisture content.
* Composition of electrode (cathode & anode) slurry mix consisting of active material, binder, additive and solvent. Binder really needs to blend well in the solvent and additive needs to disperse well on the active material.
* Consistency of the slurry material while prepping for coating in terms of viscosity, etc.
* Consistency of the slurry thickness while coating, after drying and calendaring.
* Maintaining a consistent measurement and looking for burr (a rough edge left on a metal after cutting) in daughter coils after slitting from the mother coil.
* Static removal in separator to ensure that it is not carrying any charge.
* Uniform winding (cylindrical and prismatic) or stacking (pouch) to ensure proper alignment of the electrodes with respect to separator.
* High accuracy electrolyte filling (less filling can’t ensure proper wettability).
* Strict protocols of cell formation (important aspect for first time cell activation).
* Having a regular cleaning system until the cell is closed to ensure there is no contamination in the manufacturing process.
* Strictly maintained conditions for dry room (cell production) area, cell aging area and cell storage area.

If any of the above procedures are neglected, the output can be compromised and there can be more lower grade cells in the output which can only be sold at lower than market prices. The results are usually evident while studying the self-discharge (voltage drop) of the cells after activating them and putting them for aging under high temperature and normal temperature room for a defined period of time.

A newly setup plant has low output of high-quality cells initially. Regular process optimisation and finetuning over certain months ensures that the output of high-quality cells steadily goes up to an acceptable level. Quality control plays a vital role in this whole process.

**Challenges During Lithium-ion Cell Manufacturing Plant Setup –** Part 6 (Expansion and Diversification of Portfolio)

In this article, I’m going to explain about the challenges faced by the Lithium-ion cell manufacturing company while planning for expansion and diversification.

Expansion for the same type of cell manufacturing is generally done in a modular way, meaning multiple lines of the same type of equipment is added if the plant is already fully automated. In case of the plant not being fully automated, automation is deployed to increase the output of the existing equipment.

Less automation allows for more flexibility in the desired output but with some limitations. For example, 15Ah (higher cycle life model) and 16Ah capacity of LFP in 33140 cylindrical form factors can be produced with the same equipment and further lower height with similar diameter such as 6Ah of LFP in 32700 cylindrical form factor can also be produced from the same equipment (some minor changes and tuning required). Additionally, higher and lower gravimetric energy density (Wh) cells can be produced by modifying the inner cell design. LFP cells can reach very close to 200Wh/Kg by simply using thinner current collectors and utilising more active material in the cathode and anode slurry composition. But this affects the cycle life, internal resistance, charging speed and will higher temperature rise during operations.

Already well automated plant running in full capacity utilisation factor does not have much scope to increase the production capacity. Hence similar size line is added in more numbers to increase production capacity. One might ask what’s the difference in the equipment in the semi-automatic and fully automatic plant? To start with, mixer capacity would be smaller and their quantities would be higher in a semi-automatic plant to allow for various formulations, various mixing speed to produce various type of cells. On the other hand, fully automatic plant would use a larger capacity to ensure higher homogeneity in the production and it would focus towards making fewer models of cells.

If the system integrator for the plant expansion is different from the previous one, especially during increasing automation levels, it can pose a challenge in bringing the plant to work as per desired output. There could be certain delays and higher wastage of raw material and higher wastage in the production output. With changing style of automation, there are changes in the production style and the man power needs additional training to handle these changes.

Diversification in the type of cells produced is very important for a cell manufacturing company in order to cater to a higher variety of applications. With growing popularity of Lithium-ion batteries because of their higher energy density (gravimetric and volumetric), voltage, power and cycle life, there are many applications that are shifting towards Lithium-ion batteries. But these applications demand for different type of Lithium-ion cells. For example, Lithium-ion cell used in a cell phone will have a form factor, capacity and chemistry different compared to that of a Lithium-ion cell used in an electric bus. It will difficult for a cell manufacturer to cater to these two products but choosing applications which use more similar parameters of Lithium-ion cells are easy to cater to.

**Types of Diversification:**

**Same form factor, different capacities / power ratings:** Ever heard of EV cell and ESS cell? Let’s take an example of a LFP prismatic cell, a manufacturer can produce EV cells that can deliver higher power (C rate) and have higher energy density (gravimetric and volumetric) but lower cycle life. Compare this with ESS cells of the same LFP prismatic type, which would have lower power and lower energy density but provide higher cycle life. The changes happen in the cell design and in the type of materials (similar but different specification) used.

This parameter is looked upon as a development plan. Companies plan in their future roadmap to improve the discharge capacity for the same type of form factor and dimension to offer higher gravimetric and volumetric energy density.

**Same form factor and different chemistries:** This can be explained very well by taking example of 5Ah capacity cells in 21700 cylindrical form factors. The same cell can be manufactured with NMC 811 + Silicon Graphite and NCA + Silicon Graphite combinations. Choice of cathode materials offer different advantages and disadvantages relating to maximum continuous current (charge and discharge), peak discharge current, cycle life and safety,

**Same capacity and different form factors:** This can be explained very well by again taking example of 5Ah capacity cells. This capacity can be manufactured in 21700 cylindrical form factor and 26650 cylindrical form factor. 21700 uses NMC 811 or NCA cathode + Silicon Graphite while 26650 uses NMC 532/622 + Graphite. Advantages of 21700 cell in this case includes higher energy gravimetric and volumetric energy density. Advantages of 26650 cell in this case includes higher safety and cycle life and lower cost.

All the diversification plans require the R&D team of a company to make tried and tested products and study them for a good period of time before bringing the product in the mass production. There are many tests related to aging that tells how good the newly developed product will be. These tests can be cycle life at various charge and discharge C rate combinations at various temperatures, end-of-life study, calendar aging, rise in IR with aging, thermal profiling with aging, Wh and Ah efficiency of cell with aging, etc.