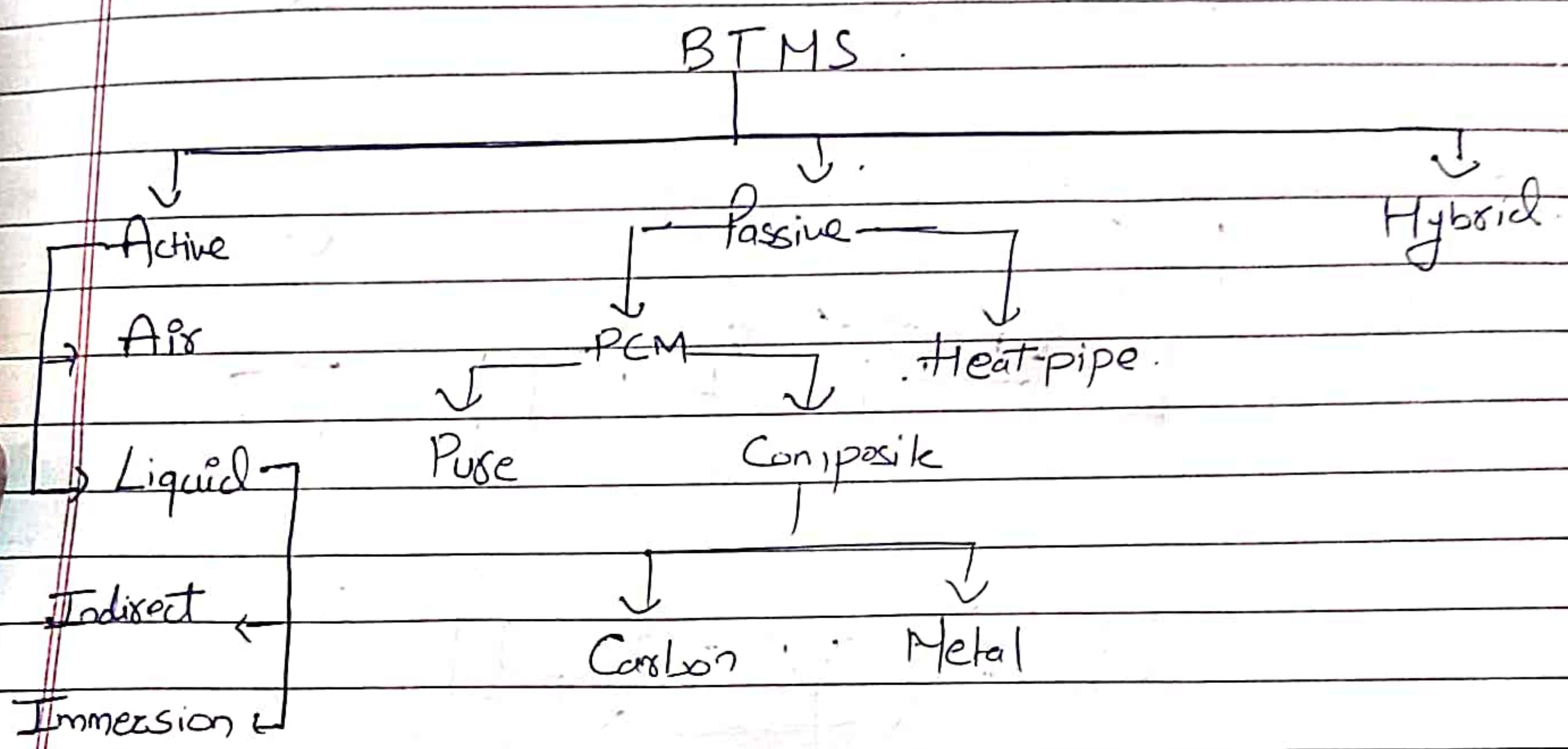
Types of BTMS.



Active BTMS

Active BTMS are based on liquid & pressure air centerd are that uses energy using equipment like pumps, Compressors & fans to push the coolant flow through the battery module

Air Cooling.

BTM air-cooled system serves the function of passively cooling of a pack by allowing the air to pass through the module.

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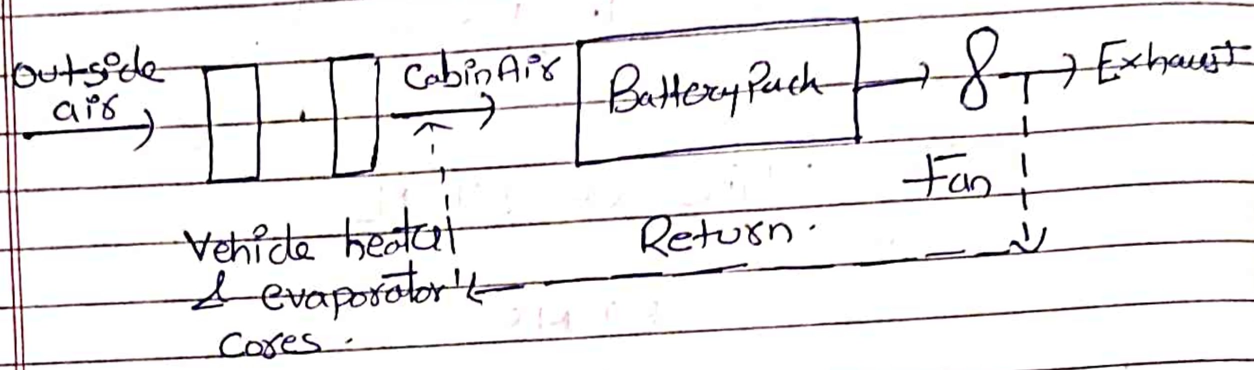
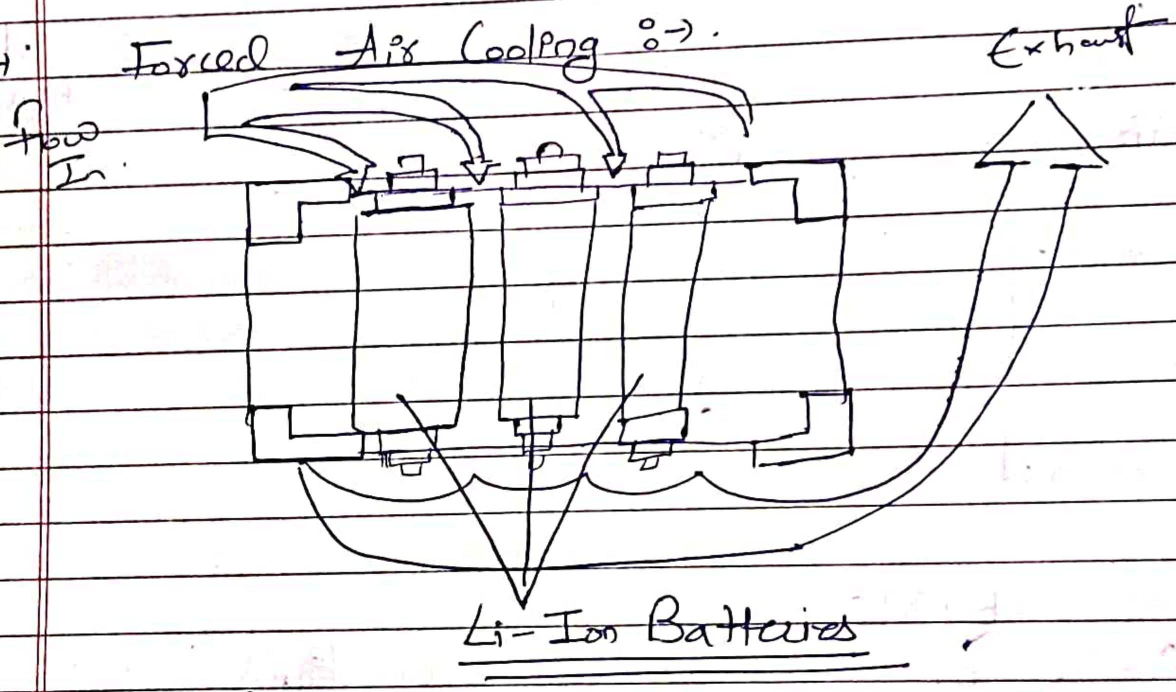
→ Natural Air cooling



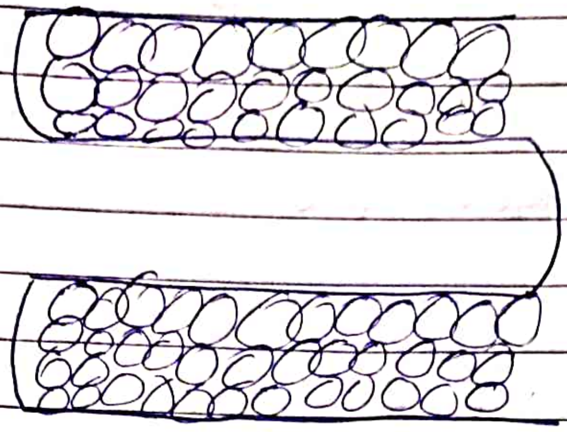
→ Forced Air Cooling :-



→ Liquid Cooling is another way of active cooling with the following advantages over cooling.

→ Indirect Liquid cooling.
It uses channel indirect contact with the cells through which a cooling fluid (commonly, a mixture of water & ethylene glycol) circulates. It is the methodology adopted by tesla & audi

* Indirect Liquid Cooling in Tesla.



* Immersion Liquid Colling

-) Phase change Material (PCM).

* Illustration of PCM in a Battery
→ Disadvantage of PCM.

⇒ Heat Pipe
for commercial & industrial purposes, heat pipe have been widely used since long ago as the device to maintain the temperature with in the permissable of limits.

* Hybrid BTMS
Hybrid cooling Method is an optimal choice in controlling the temp. uniformity & tempʳ gradient built up within the battery.

Air cooling + PCM
Liquid Colling + PCM
Heat Pipe + PCM.

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* BTMS in Indian EVs

1. BTMS is being used in the electric car & electric bus segment.
2. TATA is using Liquid cooled battery pack in TATA Nexon EV.

3. Some companies are using PCM in their battery pack for electric 2W.
4. Some companies are using Silicon Foam to fill the gaps b/w the cells to absorb the heat from the cells.

* India's First Active Liquid Cooled 2W EV Battery Pack.

→ Matter Energy 1.0

1. Integrated Intelligent Thermal management System.

2. High Voltage Energy Pack for performance E-2W.

3. Super Smart BMS for optional system safety, efficiency, relaibility.

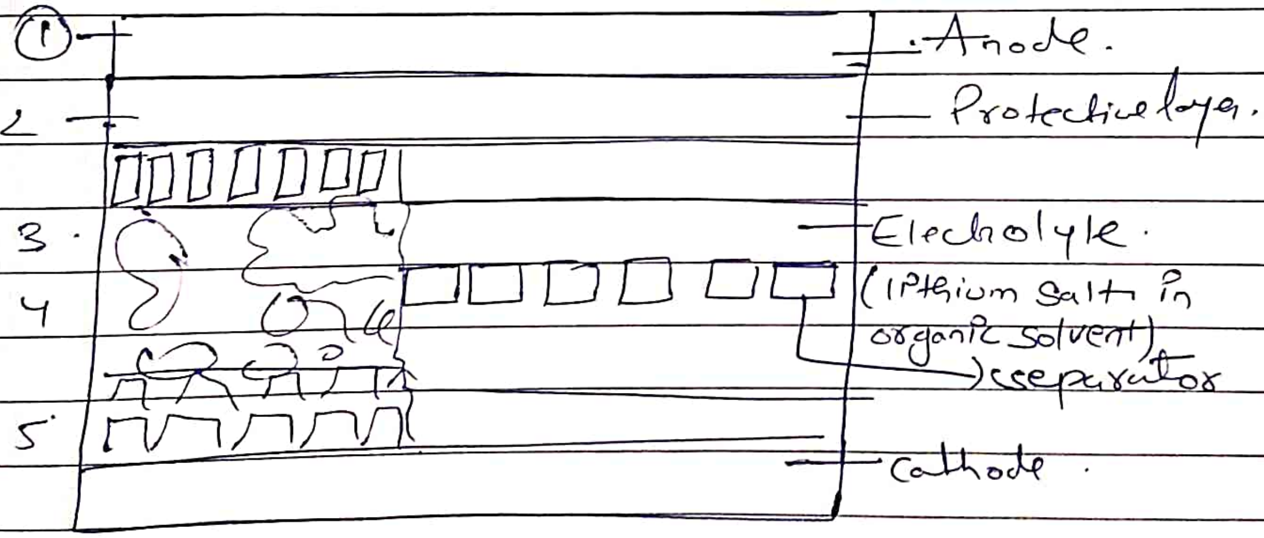
4. Battery pack with IP67 rating

5. Thermal Conductive light metal casing.

Thermal Runaway in Lithium Ion Battery

1. Heating starts.
2. Protective layers break down.
3. Electrolyte breaks down into flammable gases.
4. Separator melts, possibly causing a short circuit.
5. Cathode breaks down generating oxygen.

Thermal runaway begins when the heat generated within a battery exceeds the amount of heat that is dissipated to its surroundings.



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* State of Charge (SoC) $\Rightarrow Z(t)$.

1. when cell is 100% charged $\rightarrow OCV_{max} \rightarrow$ max voltage.
2. when cell is 0% charged $\rightarrow OCV_{min} \rightarrow$ min voltage.

State of charge $Z(t)$ of a cell $\rightarrow$.

$Z = 100\%$ fully charged

$Z = 0\%$ fully discharged.

Total capacity (Q).

$Q \rightarrow$ total charge withdrawn from $Z \rightarrow 100\% \rightarrow 0\%$.

SoC can be modulated using eqn $\rightarrow$

$$Z(t) = -\frac{i(t)}{Q}.$$

$$\boxed{\frac{dz}{dt} = \frac{-i(t)}{Q}}$$

$$Z(t) = Z(t_0) - \frac{1}{Q}\int_{t_0}^{t} i(t)\,dt$$

$i(t) \rightarrow$ +ve for discharging.

~~t~~ $i(t) \rightarrow$ −ve for charging.

Discret the eqn.

$$Z[k+1] = Z[k] - \frac{i[k]\,\Delta t}{Q}.$$

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efficiency factor → $n(t)$

Efficiency & discharge rate or current drawn.

$$\boxed{CSOC = \frac{\text{Current drawn} \times \text{efficiency}}{\text{Total Charge}}}$$

+ Linear Polarization :→

$$V(t) = OCV(Zt) - i(t)R_0$$

For charging $i(t) > 0$

For discharging $V(t) < 0$

+ Polarization :→

Departure of cells terminal voltage from OCV due to current passage.

$$\frac{d}{d(t)}\left(i_{R_1}(t)\right) = \frac{-1}{R_1C_1} i_{R_1}(t) + \frac{1}{R_1C_1} i(t)$$

Current with diffusion voltage.

$$V(t) = OCV(Z(t)) - i(t)R_0 - iR_1(t)R_t$$

ΔV_0 → Immediate Jump in voltage as cell is unloaded.

$\Delta V_0 = R_0 \Delta i$ $\quad R_0 = \frac{\Delta V_0}{\Delta i}$

ΔV_{∞} = Steady state voltage change.

$\Delta V_{\infty} = (R_0 + R_1)\Delta i$.

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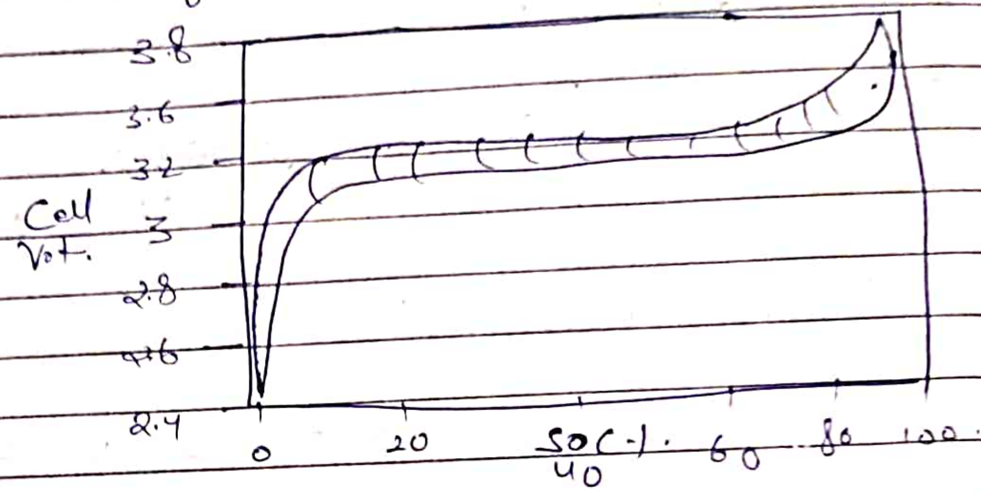
$$\boxed{R_1 = \frac{\Delta V_{oo}}{\Delta i} - R_0}$$

+ Hyselersis Voltage.



For a cell allowed to rest → .
for long enough time.

~~Diffusion~~ voltage → 0V.

$$\boxed{v(t) = OCV(z(t))}$$

Realistic Condition.
for a SOC → range of OCV.

discharge rate → C/30 (approx equlibrium state)

$$\boxed{i(t) = Q/30}$$