Project	Sunny Jim
Report	Battery Cooling – Thermal Liquids Approach
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1 Introduction

- The use of dielectric thermal liquids pumped through the battery cells is considered for maintaining battery temperature within allowed limits.

2 Research and Results

2.1 Products and Suppliers

- 3M manufacture a range of dielectric thermally conductive fluids that might be suitable for flooding battery cells and circulating to remove heat. There are two types of 3M fluid: Novec and Flourinert. The latter has more fluorine – but overall the two types don't seem all that different. 3M provides a brochure that outlines the different fluid properties in some detail.
- Solvents Australia is a supplier of these liquids. Colin Spencer is an employee with knowledge of these products. Some are stocked however at the moment no stock is on hand and delivery is approx. 16 weeks (Ex USA). Most commonly supplied fluids are FC40, FC3283, FC770, Novec-7120, Novec-7200. Cost is around AUD 1642 / L (excl GST) and does not vary much between the different fluids in the catalogue.

2.2 Theoretical Prototype for Consideration

For the purposes of this report, and modular battery comprising 8 series connected rectangular LiFePO4 cells is considered. In particular, the LiitoKala 3.2v 60AH cell which has the following properties:

LiitoKala 3.2v 60AH cell specifications	
Dimensions	155 * 115 * 36
Mass	1.2kg
Resistance	<2 mohm
Continuous / Max discharge current	180 / 300A
Discharging temp	-20 - +60C

Continuous power dissipation (ie: at 180A) is 180 ^ 2 * 2*10-3 * 8 = 518W.

The physical arrangement of the cells is 4 sets of cell pairs. Each cell in a pair is stacked with its neighbor along the narrow (36mm) face and with the 155mm dimension vertical, making a unit of 155 * 230 * 36mm. The four pairs are stacked along the 230mm face with a separation of 2mm to allow for fluid flow around the pairs.

The volume of the fluid within the module is thus 5 * 230mm * 155mm * 2mm = 356ml. Allowing for manufacturing irregularities and piping between modules, we could round this up to 500ml. A battery with 14 modules (358v nom) would therefore require 7L of coolant.

With the battery having a max operating temp of +60C, we require that the fluid has a boiling point in excess of this. For example, the FC770 could be suitable (b.p. + +95C).

FC770 Fluorinert Specs	
Boiling point	95 C
Density	1793 kg/m3
Kinematic Viscosity	0.79 cSt
Thermal Conductivity	0.063 W / m-K
Dielectric strength	> 40kV over 0.1 inch

Of consideration is the pressure differential required to pump the coolant through the gap between the cells. This can be modelled as viscous flow through a rectangular pipe as described in [1], however this analysis has not been carried out during this research. Suffice it to say that if the required pressure is too high, then the gap between the cells must be increased, leading to a larger coolant volume requirement. However, it should be noted that the viscosity is not too different from that of water.

The weight of the coolant would be 1.793 * 7 = 12.6 kg. This is significant, but probably manageable.

3 Conclusion

- While thermal fluids like those outlined above may have significant merit in that the entire cell can be safely flooded, the cost is probably prohibitive. At least 7L of fluid would be required and the cost for this would be around $11,500 + GST.

4 Recommended Next Steps

- Find alternative cooling solutions
- Find ways of reducing coolant volume
- Find sources of cheaper fluid (China direct??)

5 References

- [1] Solution of Viscous Flow Problems: https://www.pearsonhighered.com/assets/samplechapter/0/1/3/7/0137398972.pdf
- [2] Solvents Australia website: http://www.solvents.net.au/3m.htm