Cooling of Urban Railways

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Agenda

Reasons for cooling urban railways

Sources of heat

Methods of cooling

Reasons for Cooling – Stations

Cooling provided for thermal comfort of passengers.

Differs from building applications due to transient conditions.

Passengers are more accepting of warmer conditions

- The goal is to provide a continually improving comfort sensation along the journey.

Transient thermal comfort indices:

- Relative Warmth Index.
- Transient Predicted Mean Vote.
- Both adopt changing metabolic rate and time delays because of clothing insulation.

Exemplar metros maintain platforms at or around 28℃.

Reasons for Cooling – Tunnels

Cooling provided for thermal comfort and safety.

Normal operations:

- Allow the air conditioning to provide comfort with a reasonable capacity unit.
- Allow ventilated trains to provide acceptable conditions.
- Allow safe and effective maintenance.

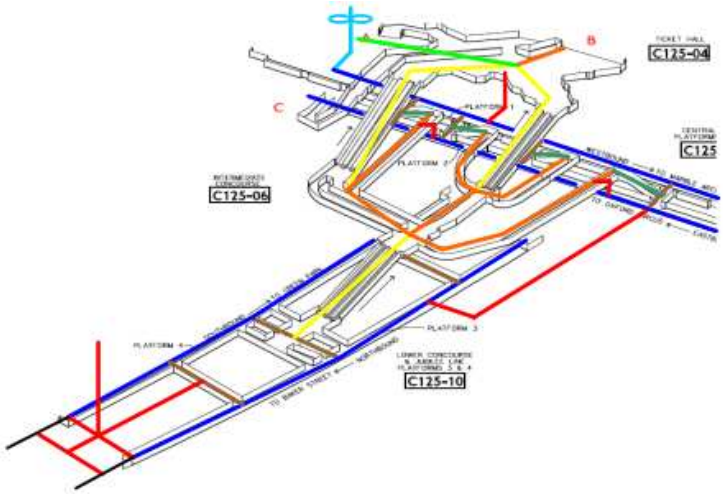
Congested operations:

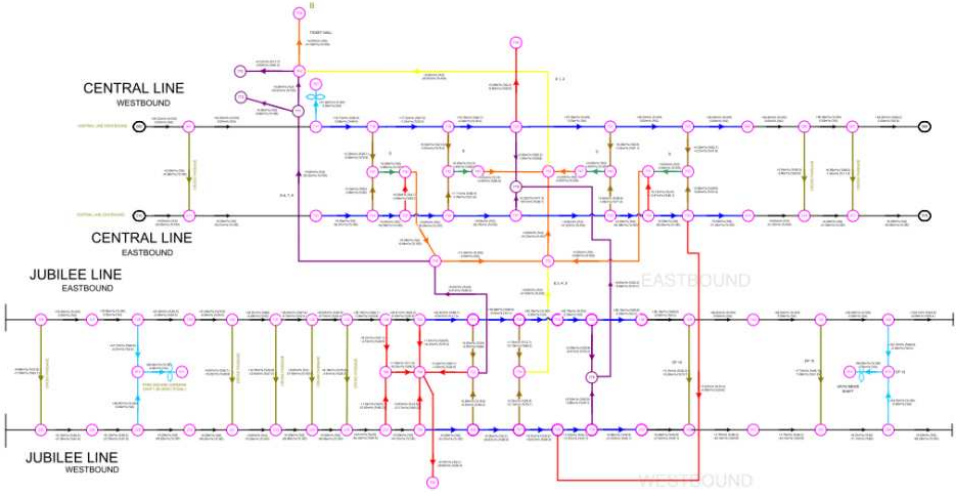
- The air conditioning can fail if the air intake is too hot.
- Ventilated trains can become too warm for thermal safety.

The above typically results in a criterion of about 30℃ for a railway without in-car air conditioning and 35℃ for a railway with .

Heat Sources - Analysis Methods

- 1D modelling.
- Typically use Subway Environment Simulation (SES) software.
- Ideal for complex flow networks with transients.
- Analyse temperature and airflow rates.
- Ideal for longitudinal ventilation problems.





Methods of Cooling – Reducing Heat

Heat strongly affected by braking action.

Hump track profiles reduce heat (uphill into the station and downhill out).

Braking kinetic energy proportional to train speed squared:

- reduce speed before braking using coasting;
- adopt more coasting as part of recovery time management.

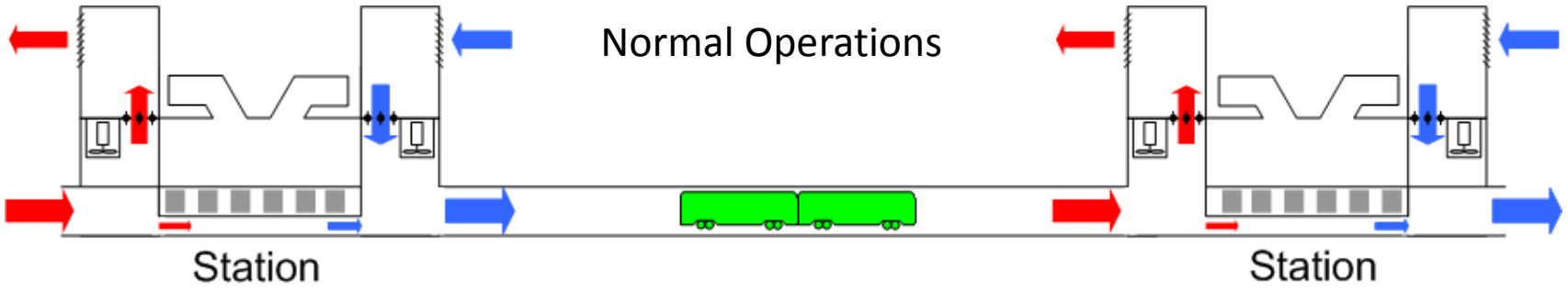
Regenerative braking reduces heat by capturing kinetic energy.

Increase receptivity of traction system for regenerative braking by:

- sizing traction package for braking effort;
- longer traction power sections;
- inverter substations;
- energy storage; and
- braking rate management

Improve traction efficiency Minimise drag and weight

Methods of Cooling - Ventilation

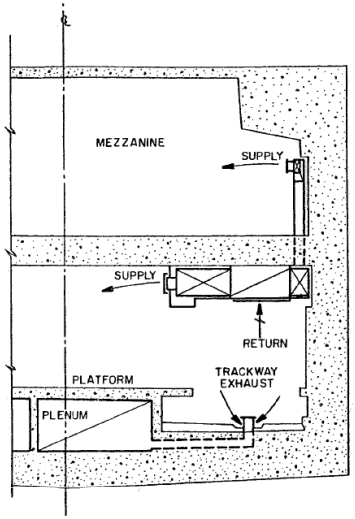


Draught relief shafts:

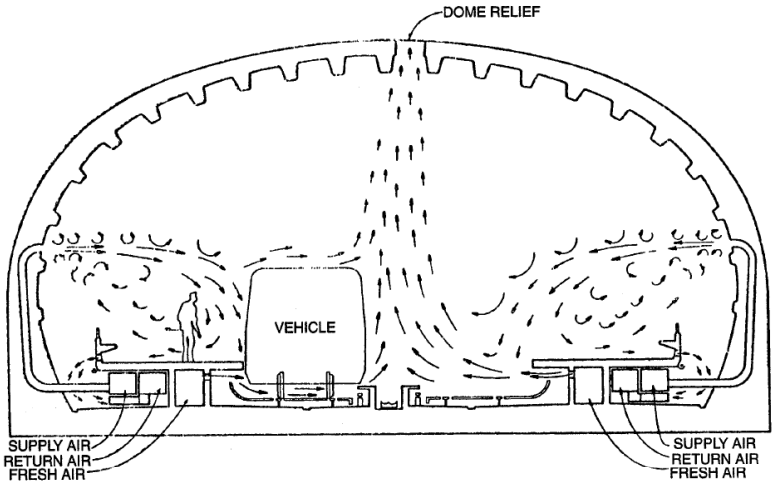
- typically 10m² per station end;
- cooling and velocity control.

Fan operations typically at stations only for most metros.

Methods of Cooling - Open Systems



Caracas



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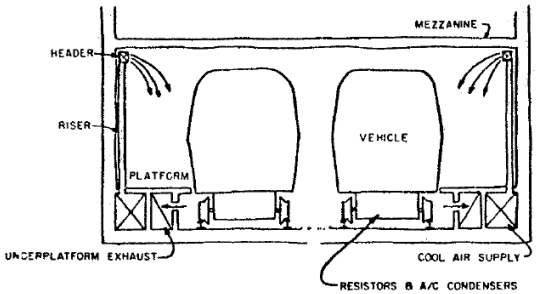
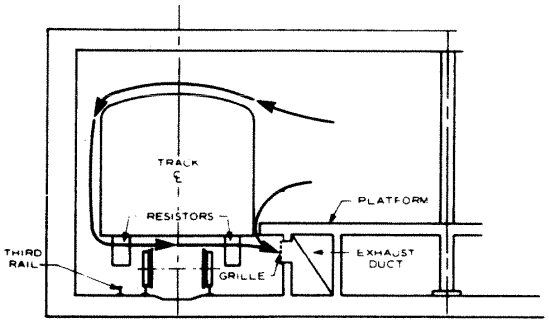
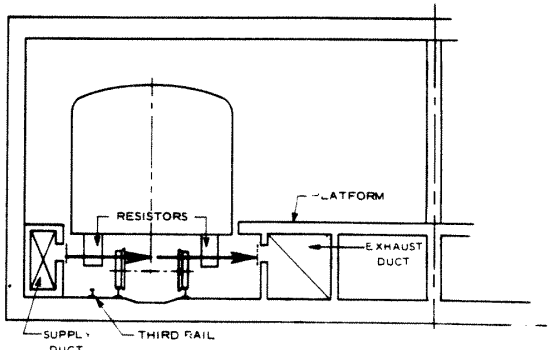


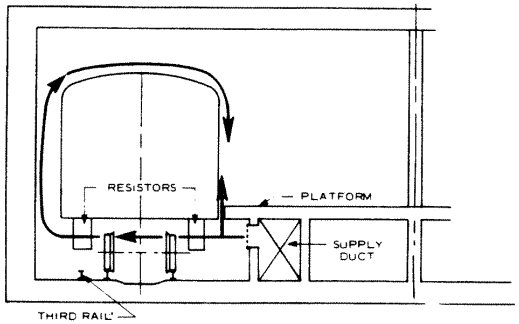
MARTA



Under platform exhaust



Under platform supply and exhaust

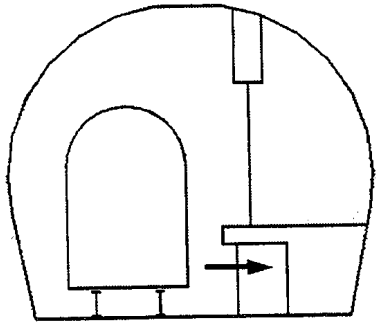


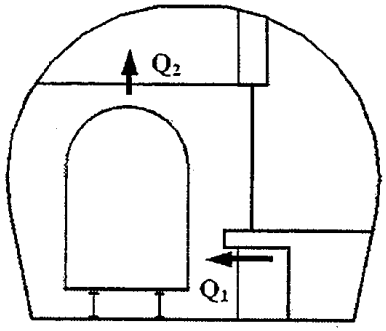
Under platform supply

Source: Tunnel Engineering Handbook and SEDH Vol 1

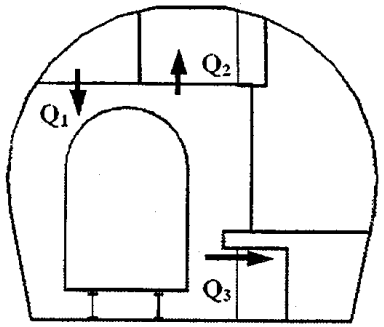
Methods of Cooling - Closed Systems

- Platform screen doors can limit the heat displaced into the stations.
- Probably only suitable for air conditioned railways: tunnels would otherwise be too hot.
- Various types of ventilation possible: Limiting the extent of infiltration of warm tunnel air into an air conditioned station is a key benefit.





$Q_1 < Q_2$



$Q_1 < Q_2 + Q_3$

Ventilation Summary

Advantages:

- can be used for tunnel smoke control;
- can be used during stalled train events;
- can be energy efficient;
- can be low maintenance.

Disadvantages:

- Can consume a lot of space;
- Can be costly to retrofit;
- Cooling effect truncated on warm days;
- More difficult to recover waste heat.

Methods of Cooling – Wet Systems

Cooling water sources – air cooled chillers:

- can be efficient if the chilled water temperatures are high enough to avoid latent cooling;
- Requires roof space.

Seepage water from the sumps:

- requires seepage water (only two to three LUL stations);
- requires the water to be clean (further limits availability).

Borehole water:

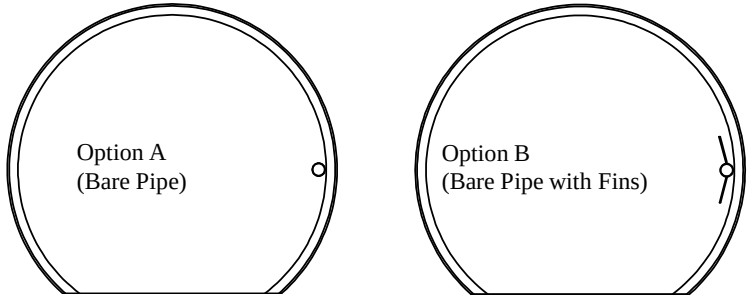
- used on Green Park station;
- need about 200m between boreholes;
- can be difficult and expensive to achieve.

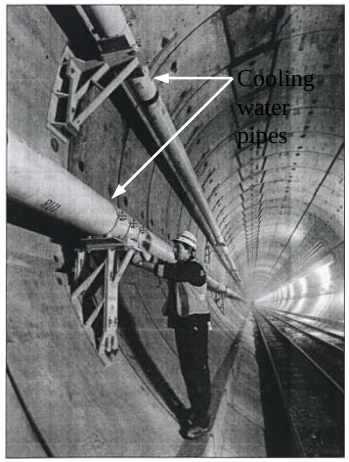
Balanced thermal storage:

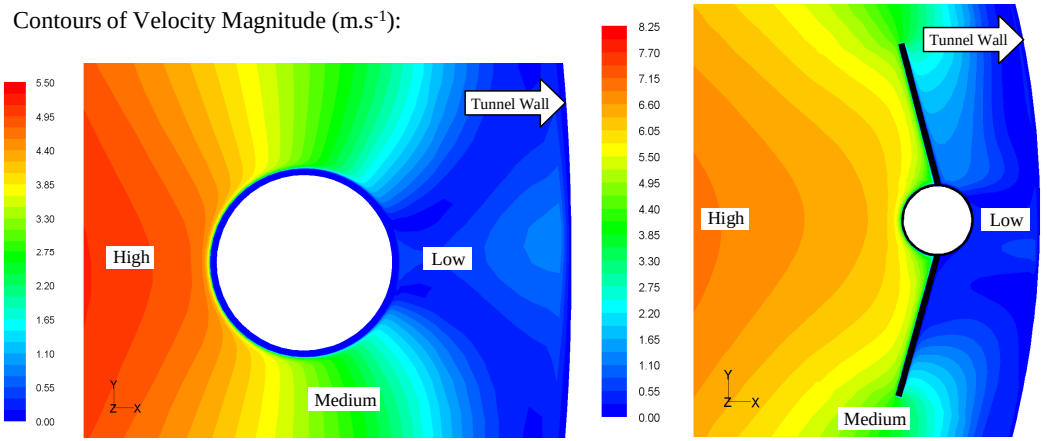
- station cooling loads are not normally thermally balanced so there is a need for a large heat sink;
- Need suitable stakeholders to take the waste heat to make a reasonable sized store.

Methods of Cooling Delivery – Cooling Pipes

- Used on Channel Tunnel.
- Smaller pipes with fins plausible for LUL.
- Fins double the effective heat transfer.
- Approximately 150 W/m can be achieved per pipe.
- Costly to retrofit.







Emerging Technology – Active Tunnel Liner

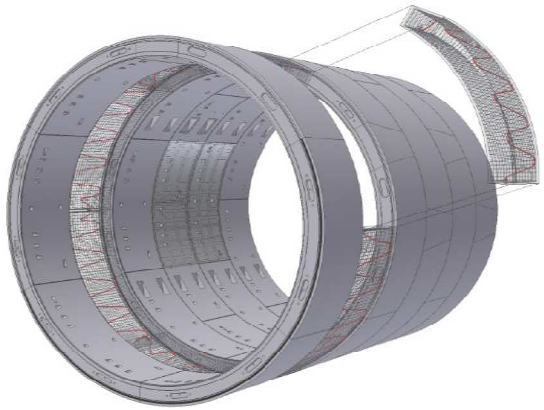
Embedded cooling pipes within the tunnel liner.

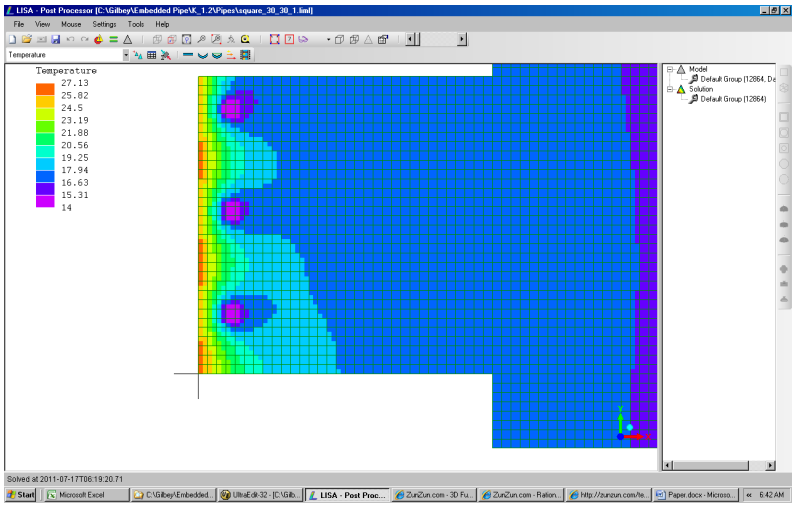
Advantages:

- low maintenance and running costs;
- removes heat in major braking zones prior to platform entry.

Disadvantages:

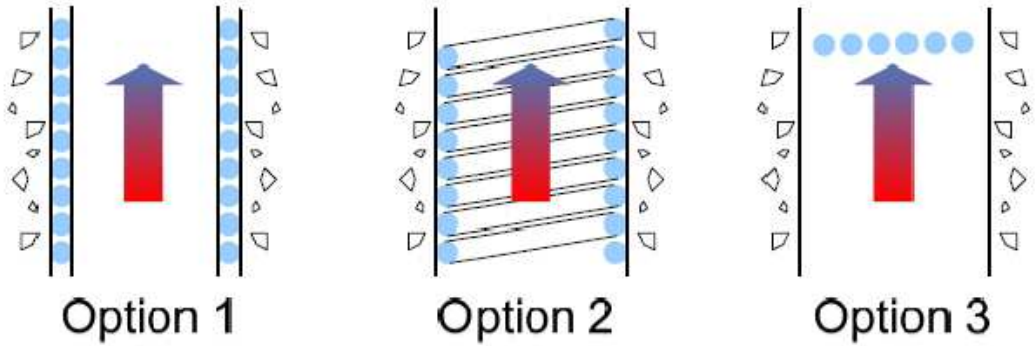
- not normally practicable to retrofit;
- can require long tunnel sections for adequate heat transfer;
- need to make sure heat is not being leached from warm soil.



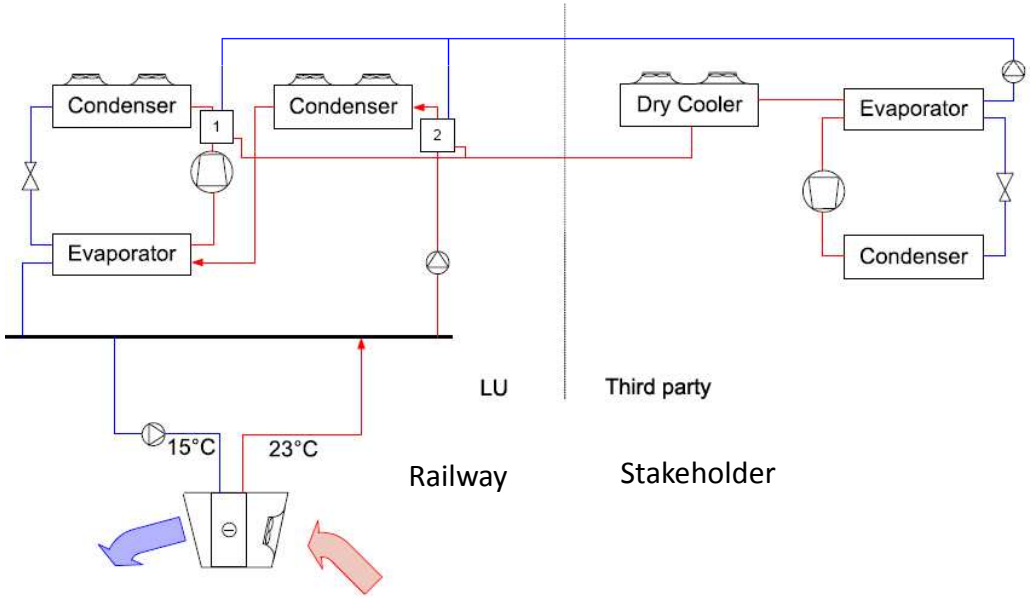


Heat Recovery – The Integrated Opportunity

Ventilation shafts or tunnels



Chillers

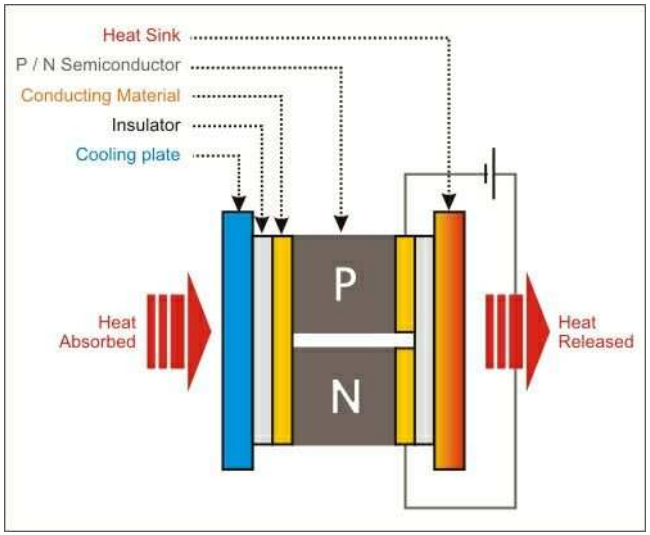


For more details see Gilbey et al. in CIBSE technical symposium September 2011

Water Based Cooling Summary

- A variety of water sources, some of which can be quite sustainable
- Cost effective cooling delivery is important
- Passive technologies can work well, if considered early
- Good opportunities for heat recovery
- Good opportunities for innovation

Emerging Technology – Peltier Cooling

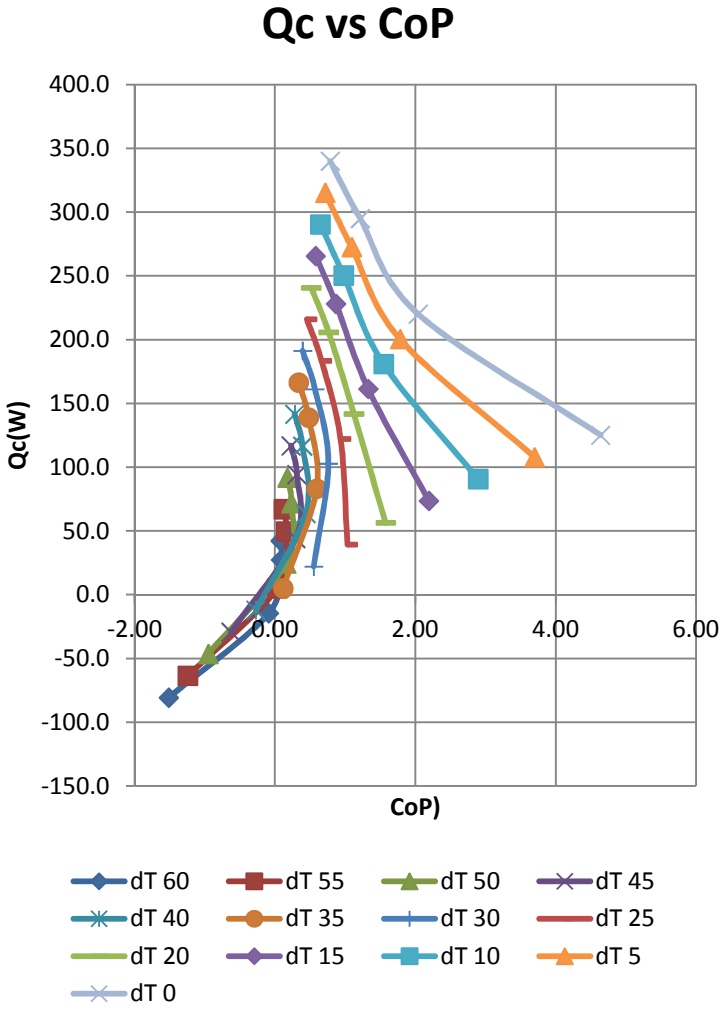


Advantages:

- excellent form factor;
- stable temperature provision;
- reversible (can provide heating and cooling from the same device).

Disadvantages:

- low CoP (in most practical cases);
- most efficient when able to control temperature range that device operates with.



Other Innovations – What to ask?

New innovations can be found anywhere in many complimentary fields:

- e.g. liquid air energy storage, heat pump technology, thermoelectric cooling, etc.

How to distinguish between the options? The Key questions:

- Does the technology solve the problem you have?
- Is the technology more practicable/cost effective than other options?
- Has the technology been applied to a similar problem?

Never underestimate the value of the back of the envelope calculation.

Conclusions

- Urban railways need cooling for the well being and comfort of passengers.
- The most effective way to cool is not to heat, i.e. an energy efficient railway.
- Ventilation remains an important method, but the effect can become limited in a warming climate.
- Water based systems offer a number of opportunities and cooling delivery method is important.
- Heat recovery from metros will become increasingly attractive and important and cooling systems need to be able to accommodate this.