Howden

VENTSIM™

Version 6: Heat and Vehicle Features

Martin Griffith
Software Team Leader
Howden Ventsim

Revolving Around You™

Heat and Vehicles: Features

New Features:

Electric Vehicles

Heaters and Coolers

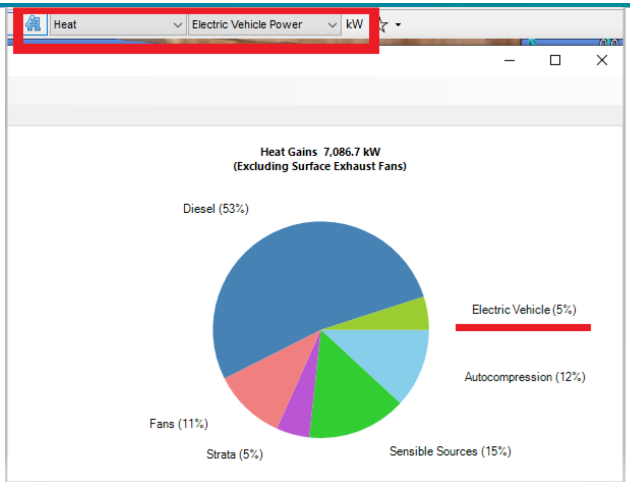
To come:

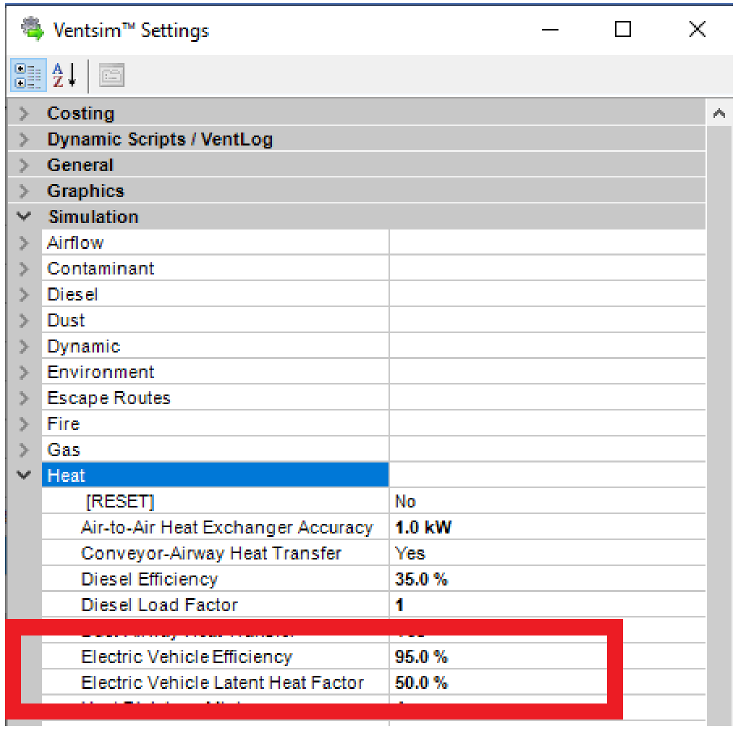
Dynamic Heat Simulations

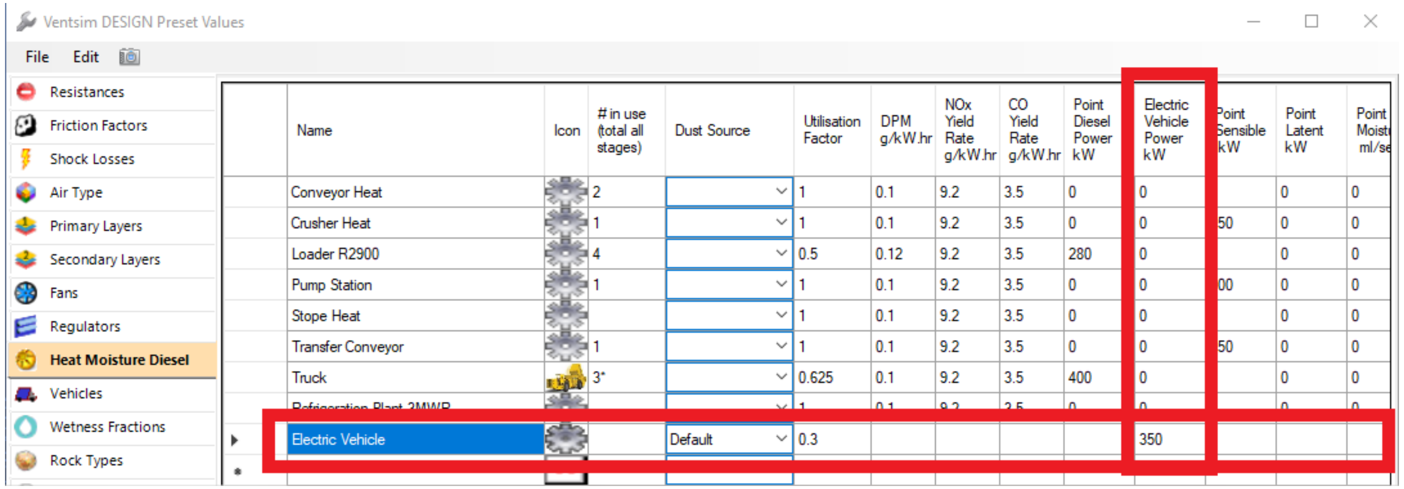
Electric Vehicles

Configuration

- Configured same way as for Diesel Vehicles
  - Entering power as maximum rated power of machine
  - With appropriate Utilisation Factor
- Heat output of Electric Vehicle calculated from Electric Vehicle Efficiency Setting
- Break-up between sensible and latent heat is determined by the Electric Vehicle Latent Heat Factor setting





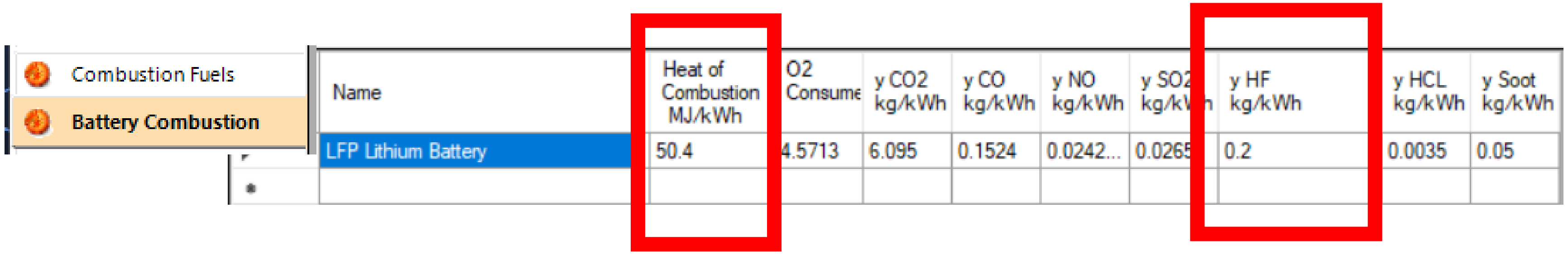


Name	Icon	# in use (total all stages)	Dust Source	Utilisation Factor	DPM g/kW.hr	NOx Yield Rate g/kW.hr	CO Yield Rate g/kW.hr	Point Diesel Power kW	Electric Vehicle Power kW	Point Sensible kW	Point Latent kW	Point Moist ml/se
Conveyor Heat		2		1	0.1	9.2	3.5	0	0		0	0
Crusher Heat		1		1	0.1	9.2	3.5	0	0	50	0	0
Loader R2900		4		0.5	0.12	9.2	3.5	280	0		0	0
Pump Station		1		1	0.1	9.2	3.5	0	0	00	0	0
Stope Heat				1	0.1	9.2	3.5	0	0		0	0
Transfer Conveyor		1		1	0.1	9.2	3.5	0	0	50	0	0
Truck		3*		0.625	0.1	9.2	3.5	400	0		0	0
Refrigeration Plant 2MWR				1	0.1	9.2	3.5	0	0		0	0
Electric Vehicle			Default	0.3					350			

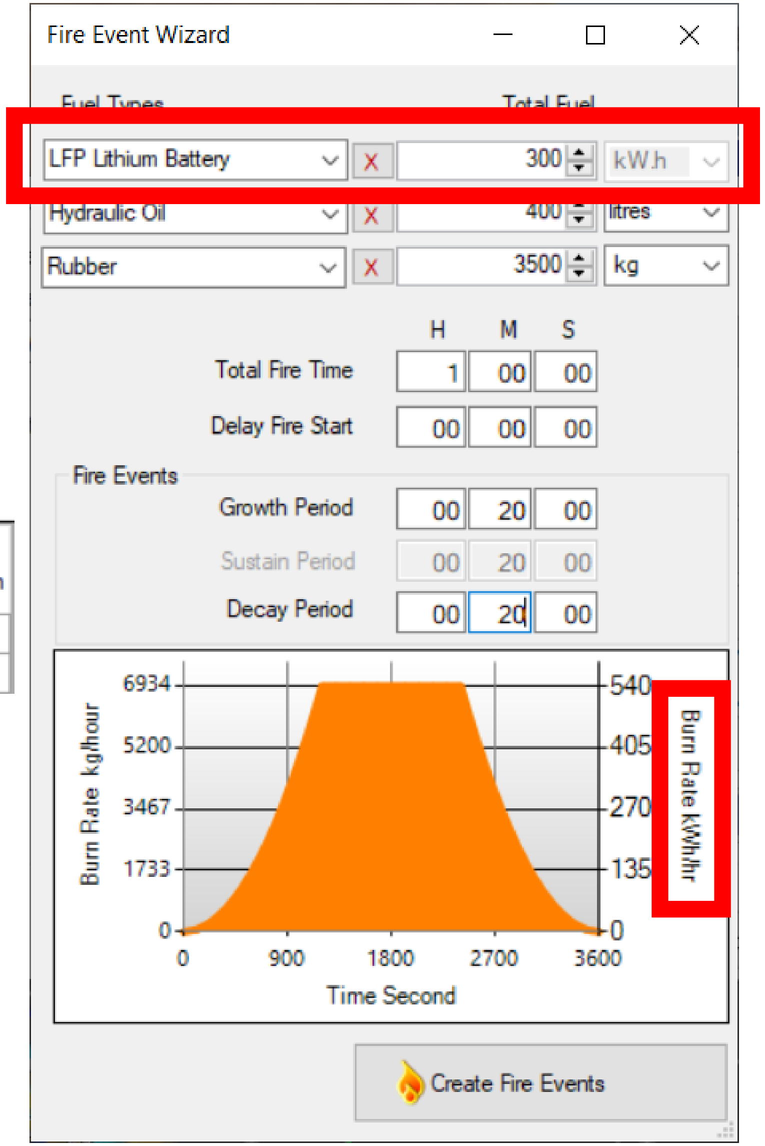
Electric Vehicles

Fires

- Battery fires can now be configured as part of the VentFIRE simulation
  - Heat and Contaminant yield configured per unit of energy capacity (kWh)



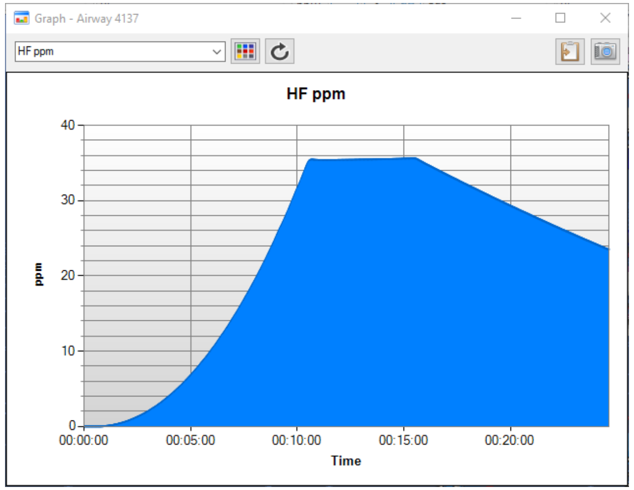
Name	Heat of Combustion MJ/kWh	O2 Consume	y CO2 kg/kWh	y CO kg/kWh	y NO kg/kWh	y SO2 kg/kWh	y HF kg/kWh	y HCL kg/kWh	y Soot kg/kWh
LFP Lithium Battery	50.4	4.5713	6.095	0.1524	0.0242...	0.0265	0.2	0.0035	0.05

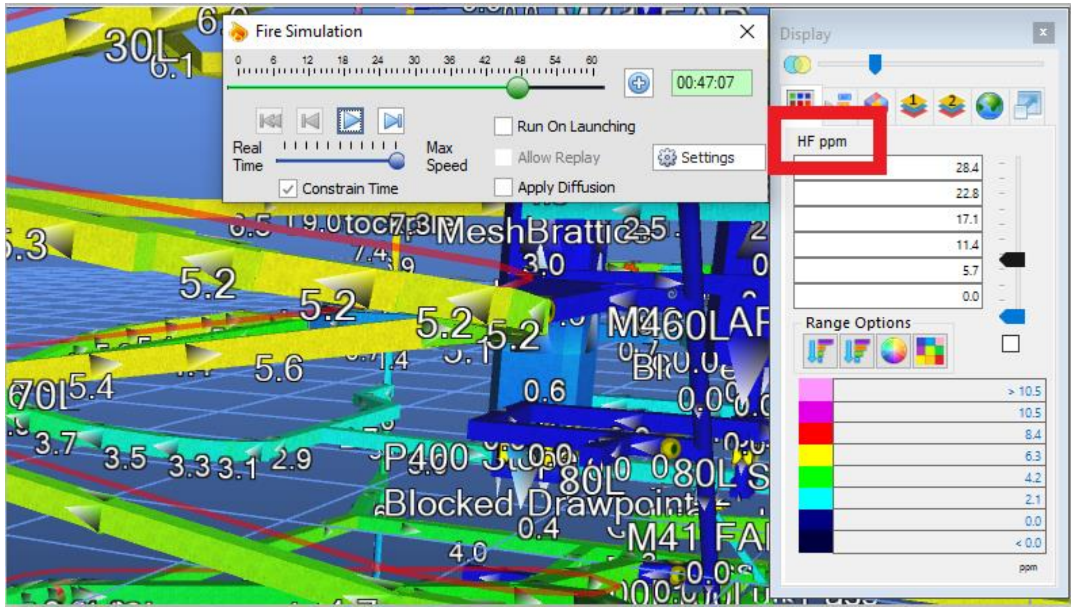


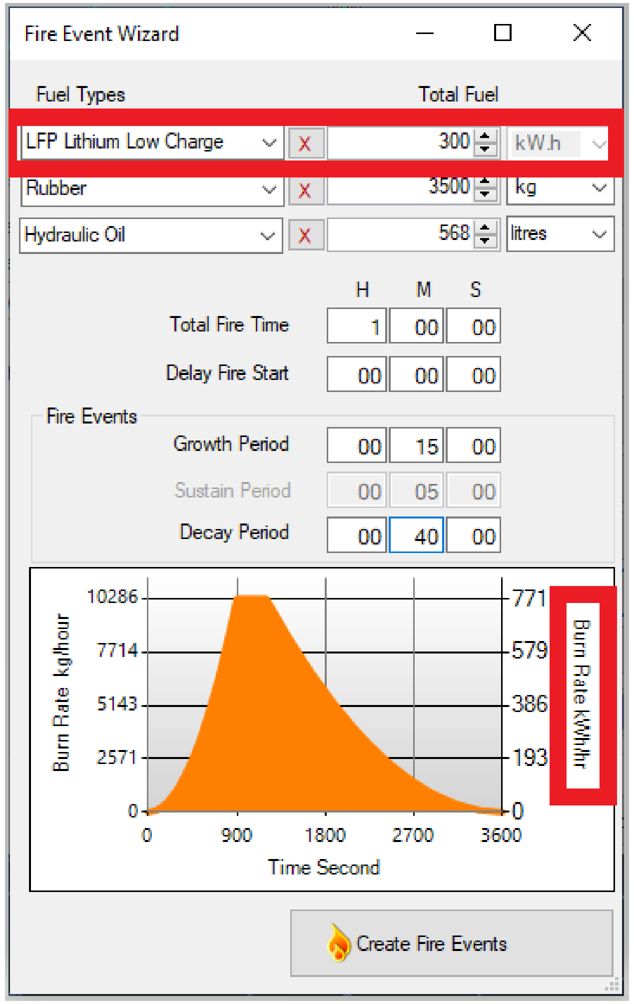
Electric Vehicles

Fires

- Battery fires can now be configured as part of the VentFIRE simulation
  - Heat and Contaminant yield configured per unit of energy capacity (kWh)
- Introduction of Hydrogen Fluoride as one of the default gases in Ventsim







Heat and Vehicles: Features

New Features:

Electric Vehicles

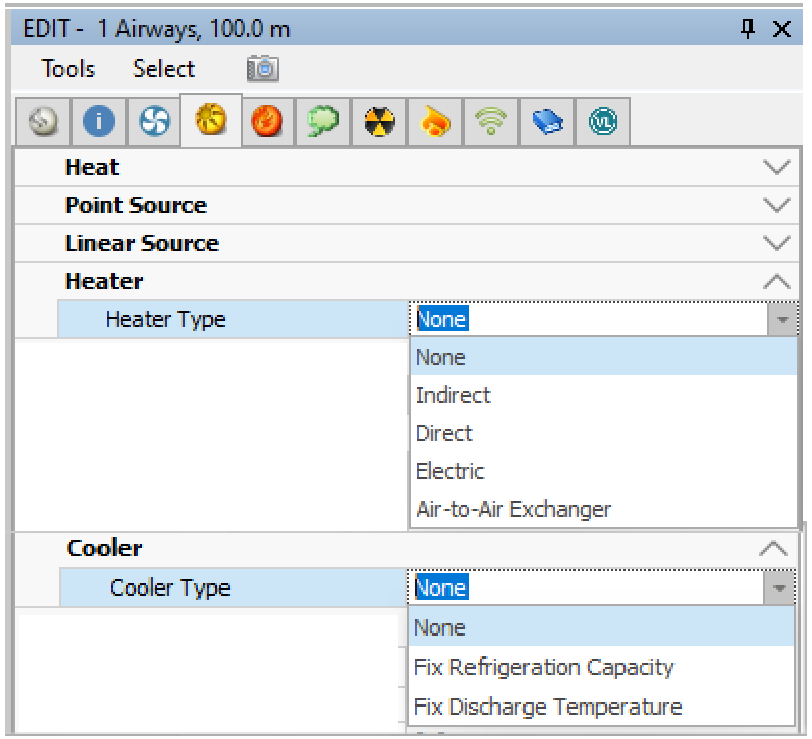
Heaters and Coolers

To come:

Dynamic Heat Simulations

Heaters & Coolers

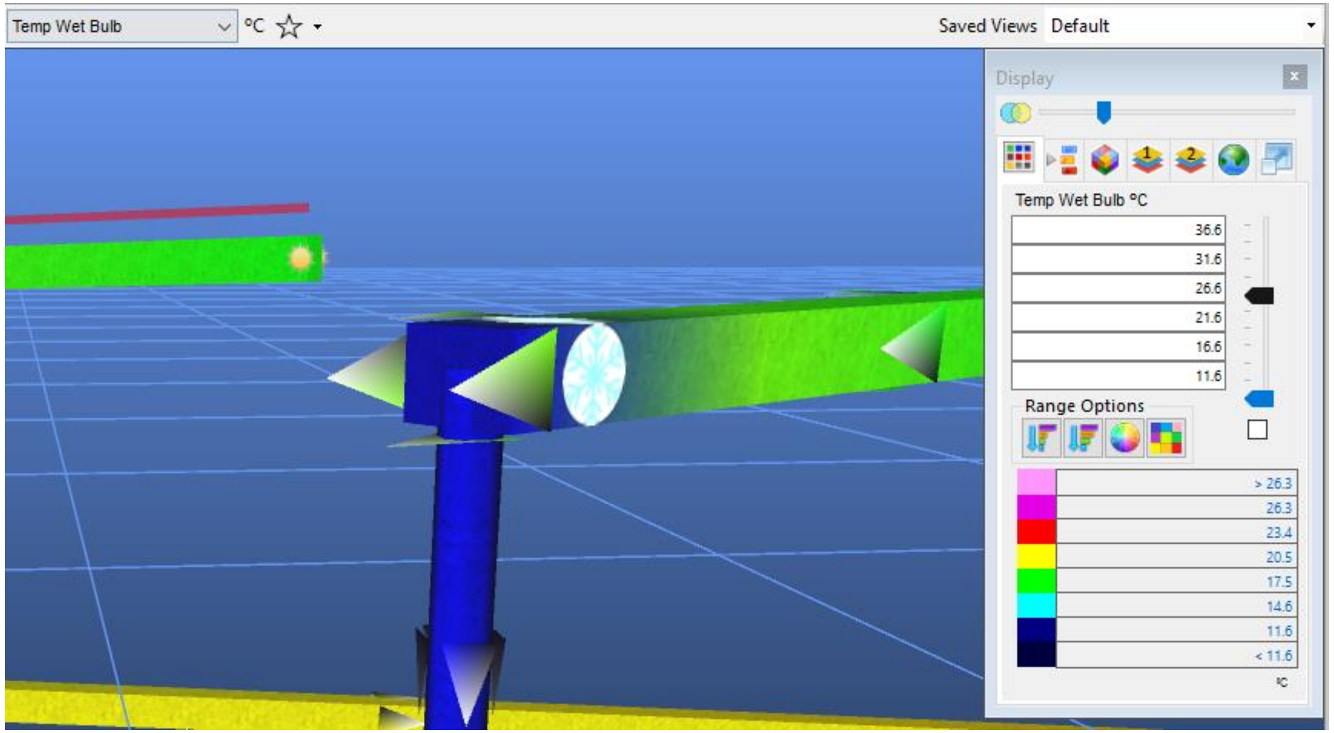
- Moving away from simple fixed temperatures, or fixed capacities
- Making the cooler/heater behave more like it would in reality
- Coolers
  - Fix Refrigeration Capacity
  - Fix Discharge Temperatures
- Heaters
  - Indirect
  - Direct
  - Electric
  - Air-to-air Exchanger



Heaters & Coolers

Coolers

- Fix Refrigeration Capacity
- Minimum Temperature stops cooler cooling to unrealistic temperatures



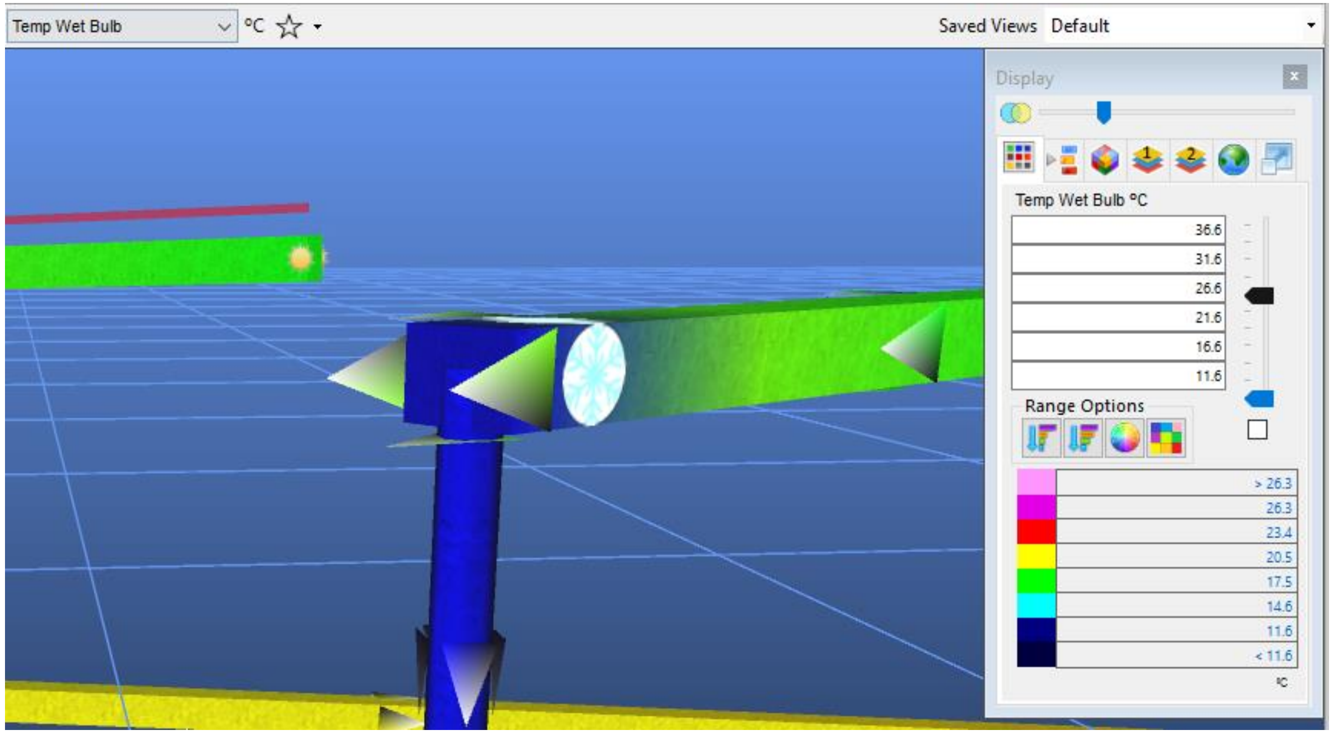
Cooler	
Cooler Type	Fix Refrigeration Capacity
Refrigeration Capacity (k...	5,000.0
Discharge Temperature (°...	15.0
Maximum Capacity (kWR)	0.0
Minimum Temperature (ºC)	15.0
Output Refrigeration (kWR)	2,572.0
Water Coolant Information	
Factor of Merit (FOM) ...	0.6
Inlet Temperature (ºC)	10.0
Outlet Temperature (°...	16.0
Flow Rate (l/sec)	86.9
Cooler Cost	
Coefficient of Perform...	3.5
Duty Cycle Factor	1.0
Monthly Cost $	104,285.7

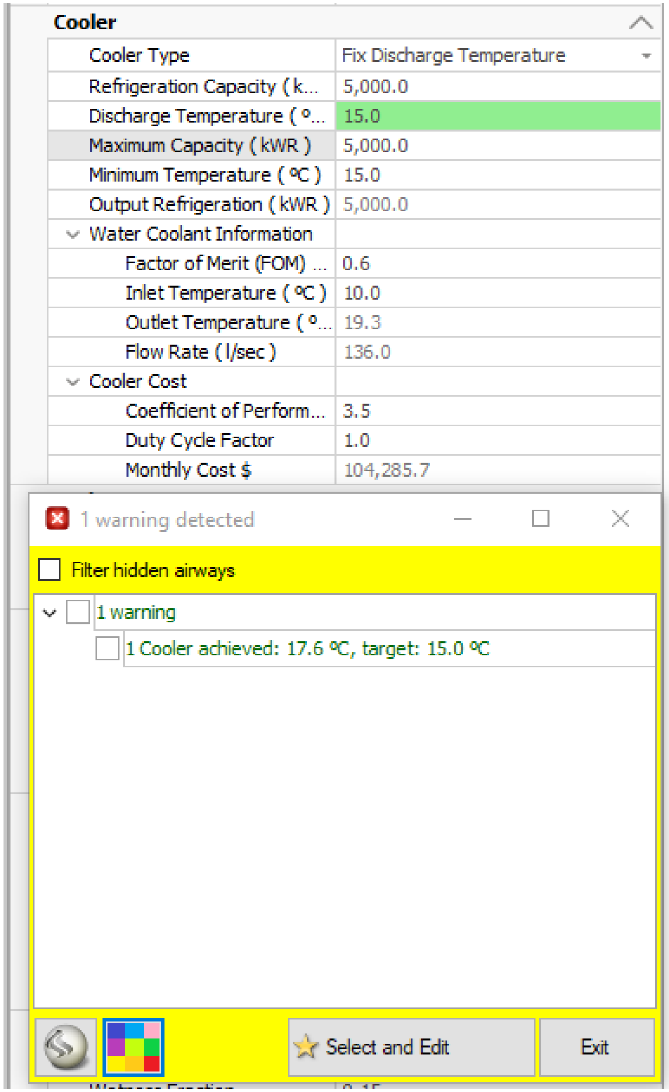
Heaters & Coolers

Coolers

- Fix Discharge Temperature

- Can set a maximum capacity, triggering a warning if cooling target not achieved

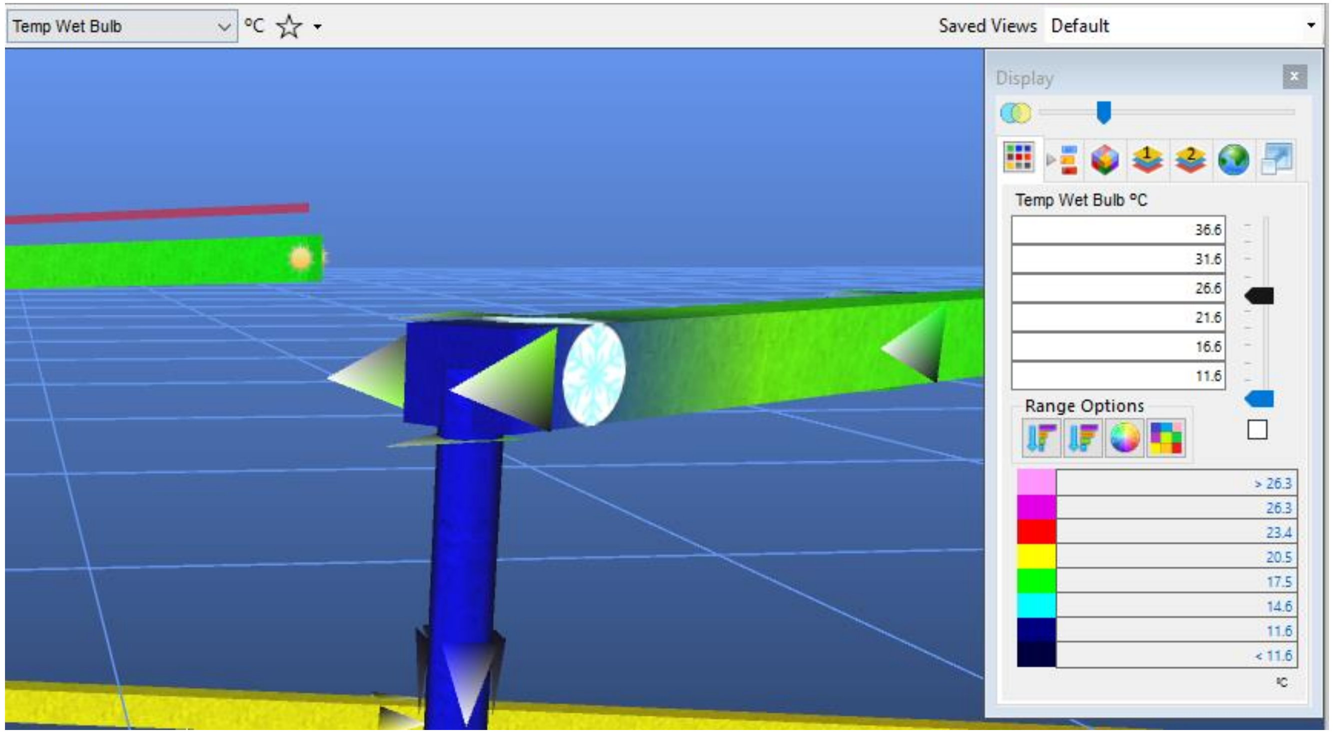




Heaters & Coolers

Coolers

- To come
  - A setting for required airflow
  - Derating of the cooler performance if adequate airflow is not reaching the cooler



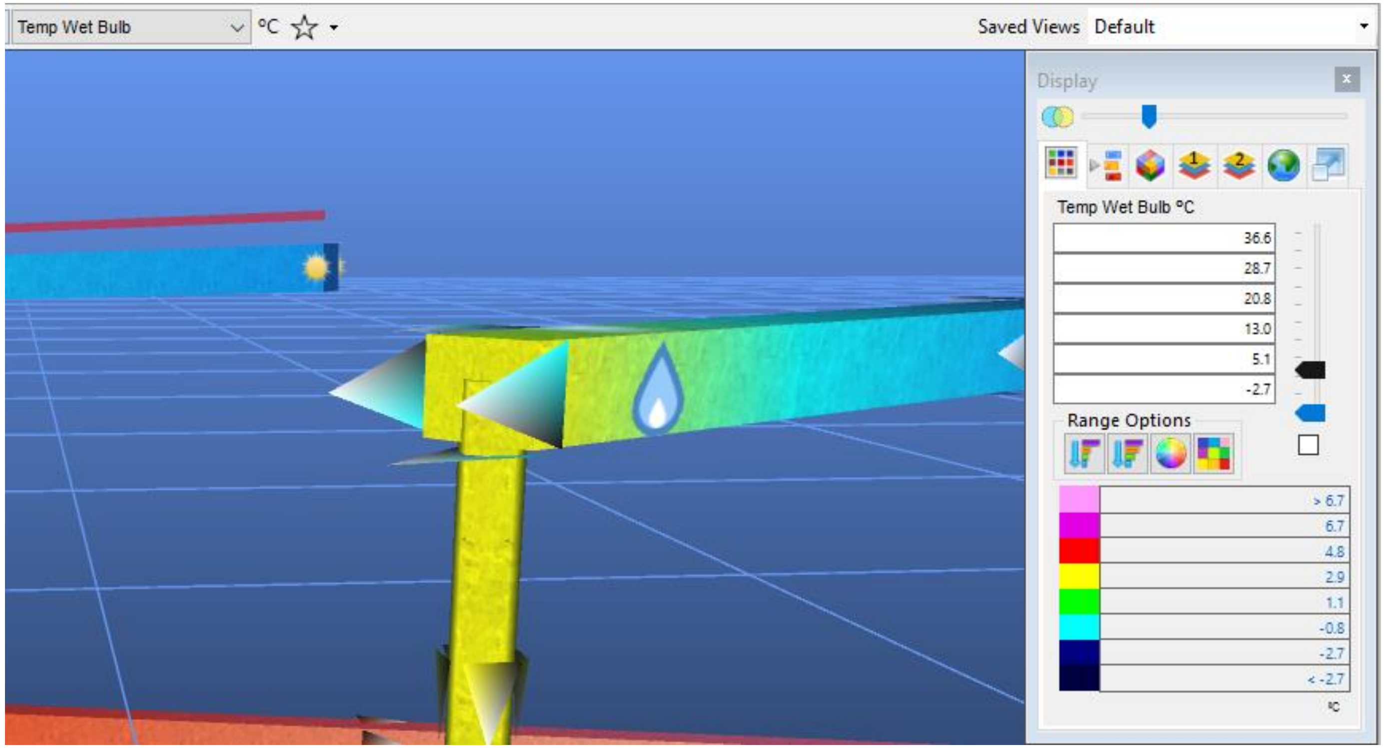
Heaters & Coolers

Heaters

- Heaters, direct and indirect
- Identical, except:
    - Indirect operates at 85 % efficiency, 100 % for Direct
    - Direct adds contaminant during Diesel and Gas simulation

Heater	
Heater Type	Direct
Heater Temperature (°C)	5.0
Heater Fuel	Propane
Heater Power Output (kW)	1,610.0
Heater Monthly Fuel (kg)	84,621.0

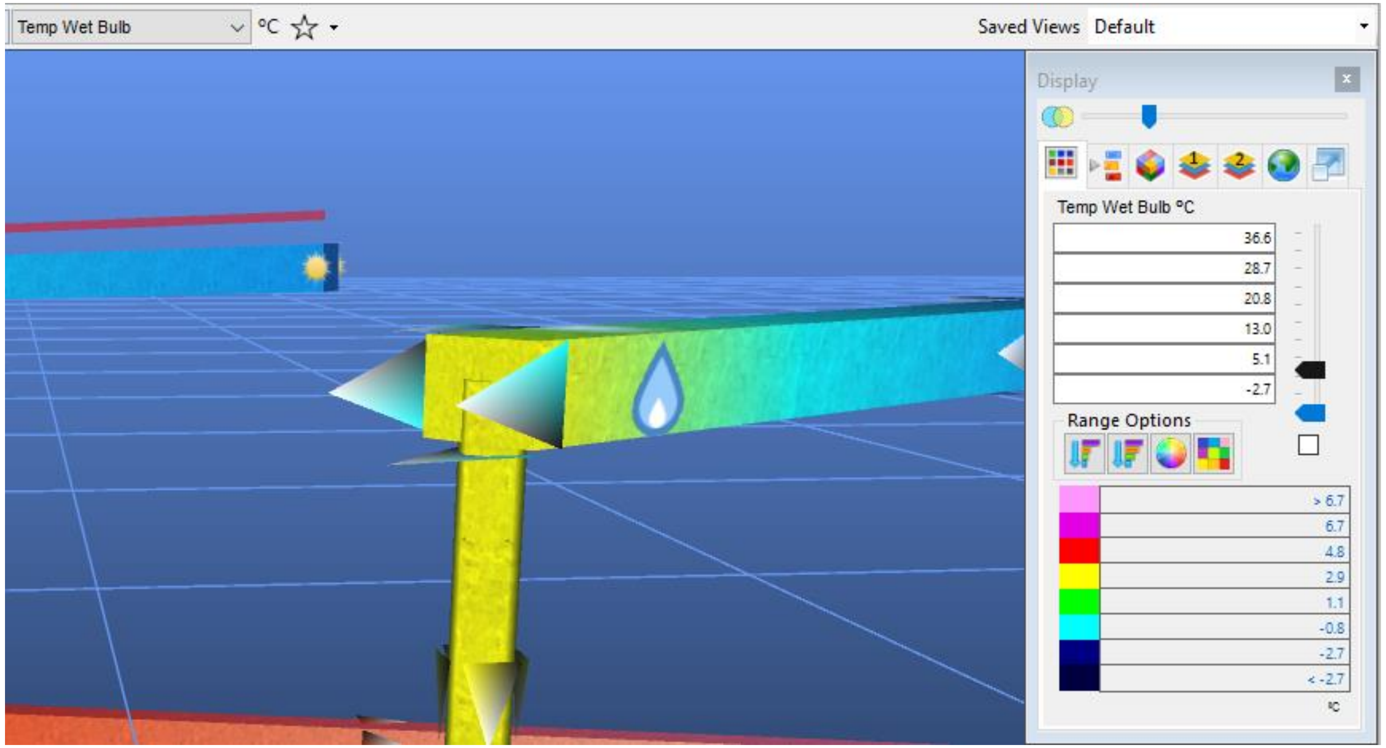
Heater	
Heater Type	Indirect
Heater Temperature (°C)	5.0
Heater Fuel	Propane
Heater Power Output (kW)	1,533.8
Heater Monthly Fuel (kg)	94,844.0



Heaters & Coolers

Heaters

- Heaters, Electric
- Same, 100% efficiency, but a electrical power usage instead



Heater

Heater Type	Direct
Heater Temperature (°C)	5.0
Heater Fuel	Propane
Heater Power Output (kW)	1,610.0
Heater Monthly Fuel (kg)	84,621.0

Heater

Heater Type	Indirect
Heater Temperature (°C)	5.0
Heater Fuel	Propane
Heater Power Output (kW)	1,533.8
Heater Monthly Fuel (kg)	94,844.0

Heater

Heater Type	Electric
Heater Temperature (°C)	5.0
Heater Power Output (kW)	1,533.8
Monthly Electricity (kW.h)	1,119,685.0
Monthly Cost ($)	111,969.0

Heaters & Coolers

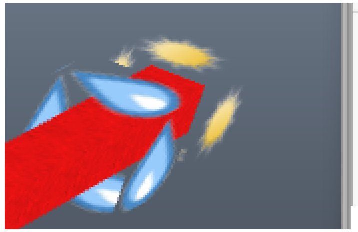
Heaters

- Air-to-Air Heat Exchanger
  - Exhaust heat to heat the intake
  - Performance based on an effectiveness in kW/ºC

Heated intake

Heater	
Heater Type	Air-to-Air Exchanger
Air-to-Air Exchanger Pairs	105
Air-to-Air Effectiveness (k...	36.00
Heater Power Output (kW)	1,155.9

Cooled exhaust

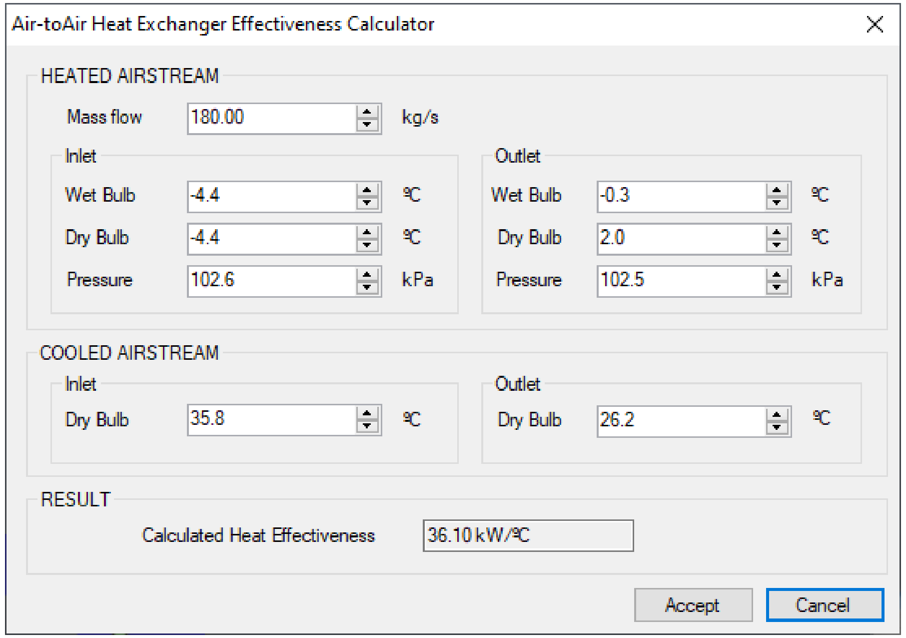


Heater	
Heater Type	Air-to-Air Exchanger
Air-to-Air Exchanger Pairs	107
Air-to-Air Effectiveness (k...	36.00
Heater Power Output (kW)	-1,156.1

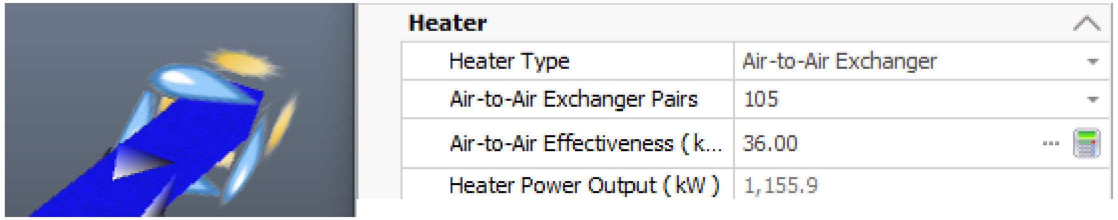
Heaters & Coolers

Heaters

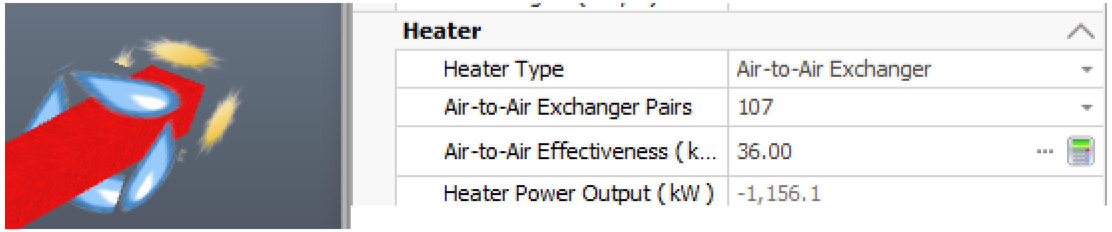
- Air-to-Air Heat Exchanger
  - Exhaust heat to heat the intake
  - Performance based on an effectiveness in kW/ºC
  - Calculator available



Heated intake



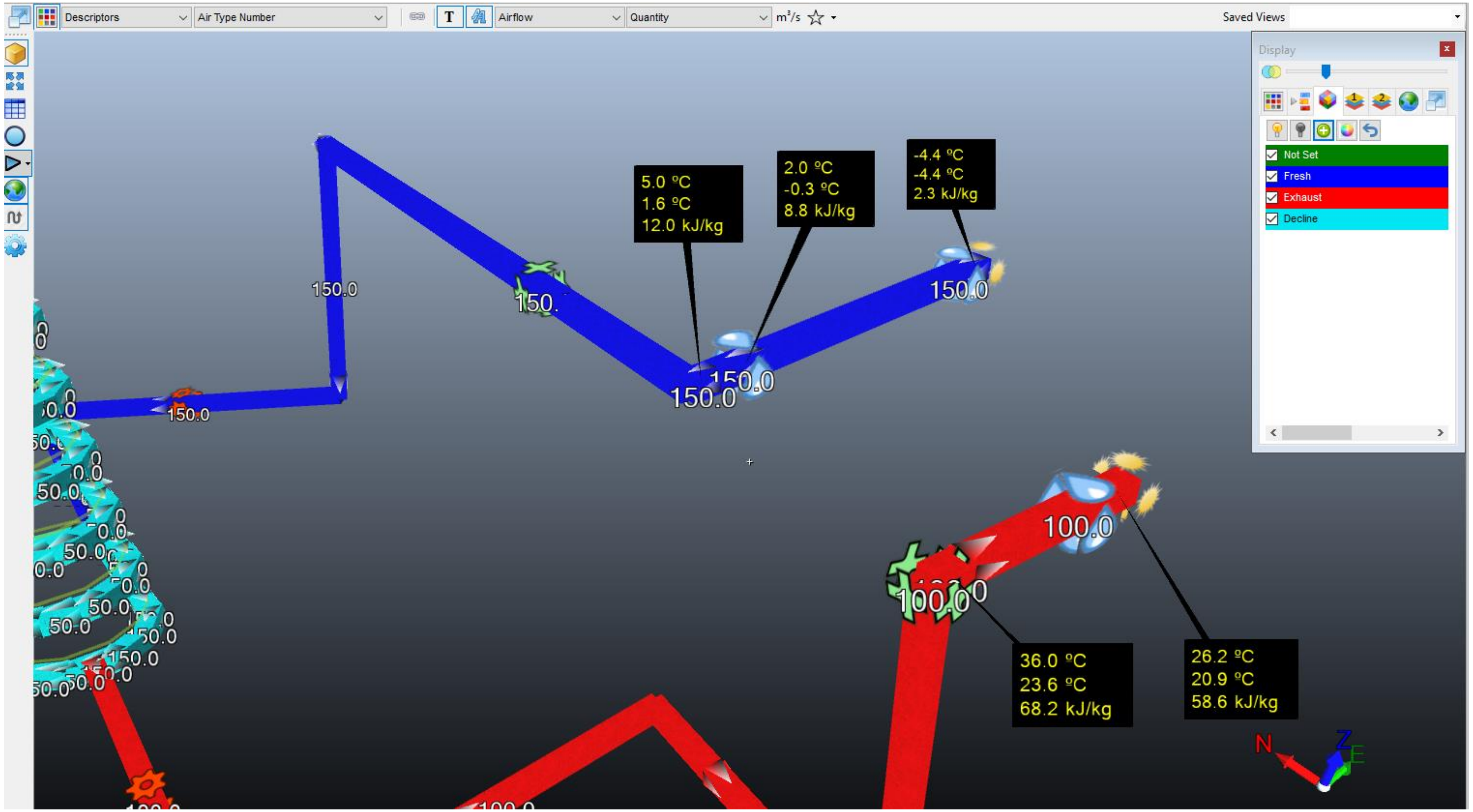
Cooled exhaust



Heaters & Coolers

Heaters

- Air-to-Air Heat Exchanger



Heat and Vehicles: Features

New Features:

- **Electric Vehicles**
- **Heaters and Coolers**

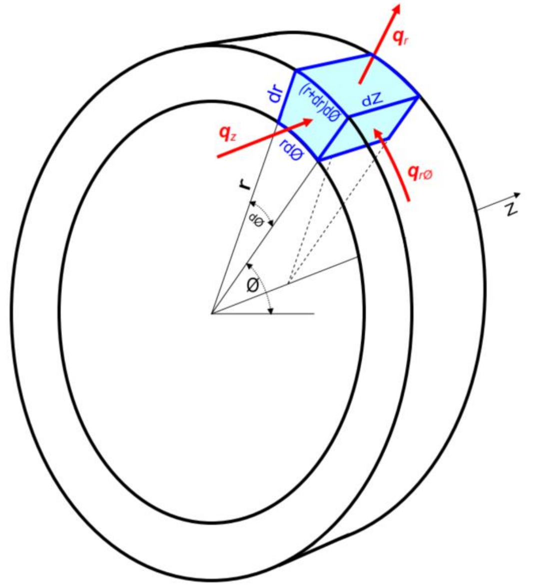
To come:

- **Dynamic Heat Simulations**

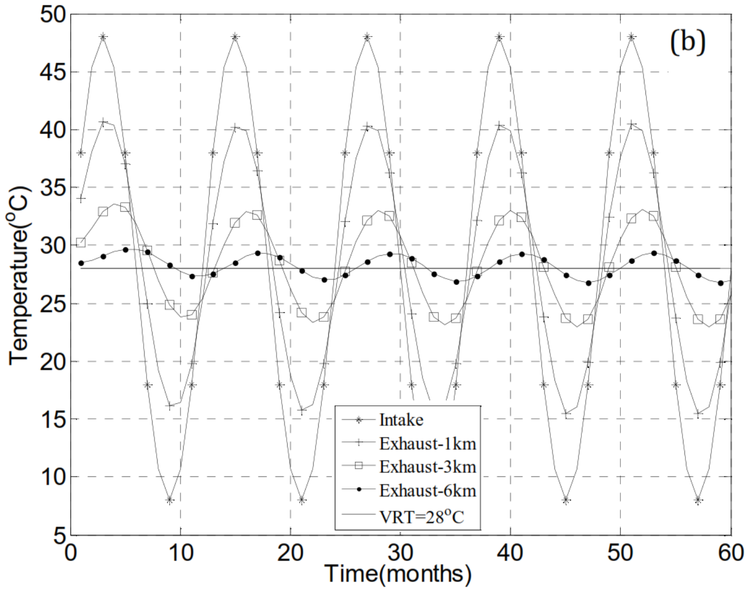
Dynamic Heat

Time-dependent Heat Simulations

- Rock strata heat responds dynamically over time to airway temperature, behaving as a heat capacitor:
  - Stores heat during times of high inlet temperatures
  - Releases heat during times of lower inlet temperatures



from McPherson, Subsurface Ventilation and Environmental Engineering



from Danko et al, Temperature variations in underground tunnels, 2012

- Further from the air intake, variations are damped and lagging
- Applies to daily and annual variations in atmospheric temperatures, and changes in underground operations

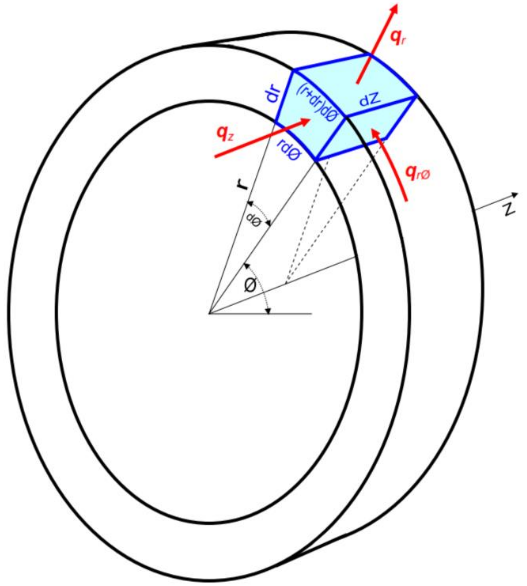
Dynamic Heat

Radial Heat Equation

- Rock strata temperature in the wall can be modelled using the 1D radial heat conduction equation

$$\alpha\left\{\frac{\partial^2\theta}{\partial r^2} + \frac{1}{r}\frac{\partial\theta}{\partial r}\right\} = \frac{\partial\theta}{\partial t} \qquad \frac{^\circ C}{s}$$

θ is the temperature in the wall, [ºC]
α the thermal diffusivity, [m^2/s]
r the radial distance, [m]
t time, [s]



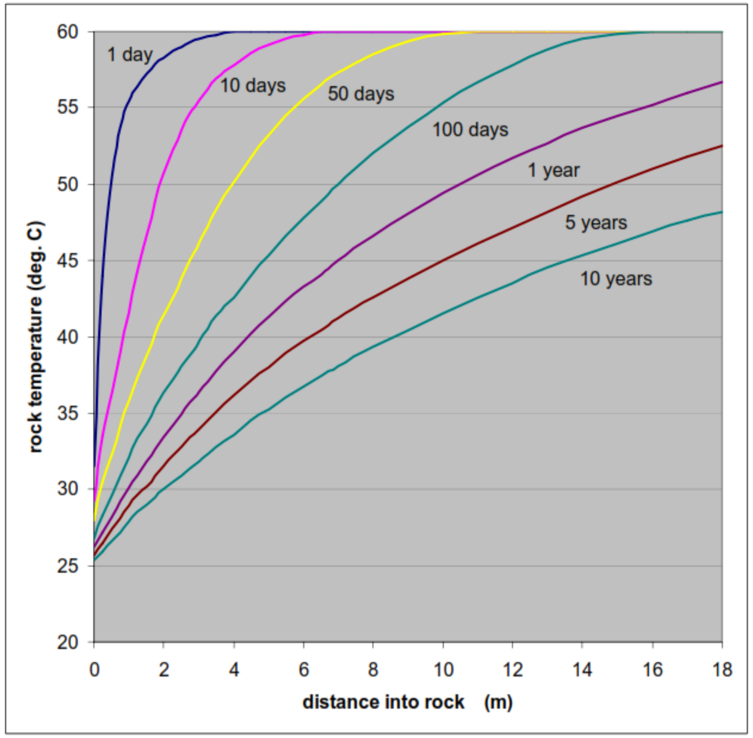
Dynamic Heat

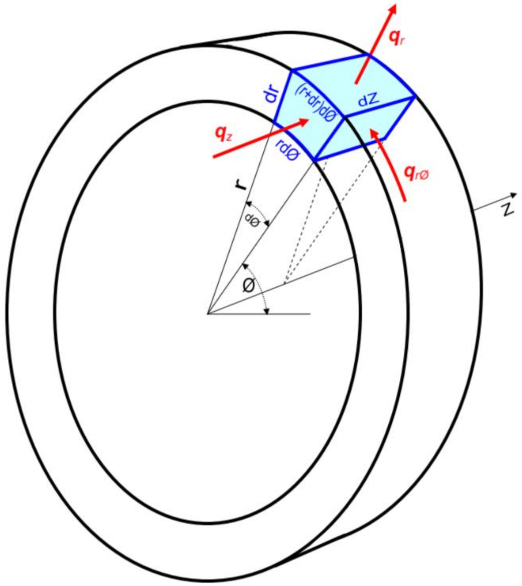
Radial Heat Equation

- Rock strata temperature in the wall can be modelled using the 1D radial heat conduction equation
- Currently in Heat Simulation, a function is used to make this easy, (the Gibson function) but with the following important assumption:
  - Constant air flow and air temperature over the life of the tunnel

$$\alpha\left\{\frac{\partial^2\theta}{\partial r^2}+\frac{1}{r}\frac{\partial\theta}{\partial r}\right\}=\frac{\partial\theta}{\partial t} \qquad \frac{^\circ C}{s}$$

θ is the temperature in the wall, [ºC]
α the thermal diffusivity, [m^2/s]
r the radial distance, [m]
t time, [s]





Dynamic Heat

Solving radial heat better

- The Ventsim Annual Thermal Flywheel models the change in temperatures per month throughout the year
- VentFIRE is calibrated for timeframes over a couple of hours
- Option being explored is to add a finite difference solver to Ventsim to more directly model the radial rock heat and do away with calibration factors

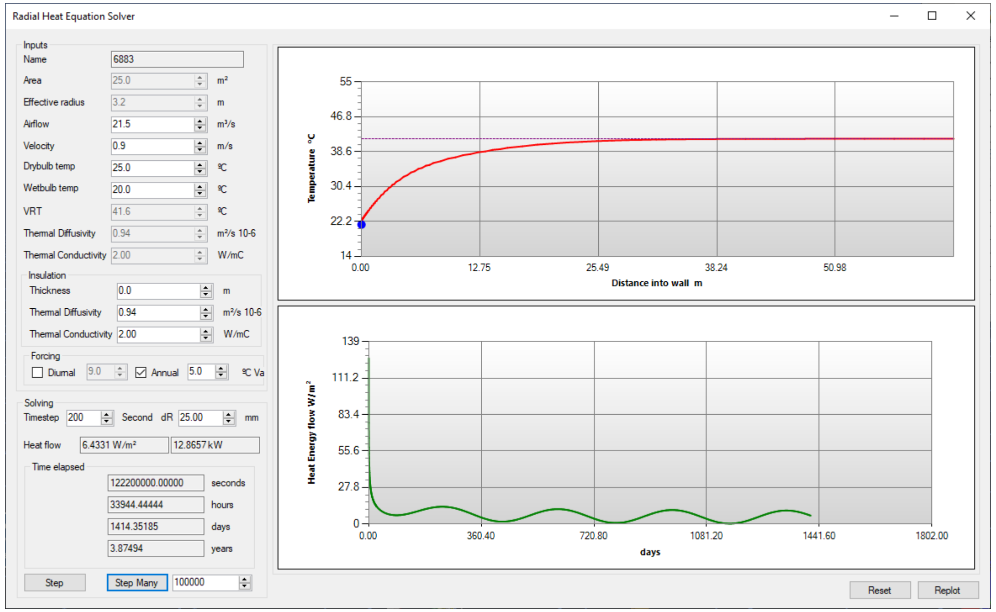
$$\alpha\left\{\frac{\partial^2\theta}{\partial r^2} + \frac{1}{r}\frac{\partial\theta}{\partial r}\right\} = \frac{\partial\theta}{\partial t} \qquad \frac{^\circ C}{s}$$

θ is the temperature in the wall, [ºC]
α the thermal diffusivity, [m^2/s]
r the radial distance, [m]
t time, [s]

Dynamic Heat

Finite Difference Solver

- The Ventsim Annual Thermal Flywheel models the change in temperatures throughout the year, but is not accurate in all cases
- VentFIRE is calibrated for timeframes over a couple of hours
- Option being explored is to add a finite difference solver to Ventsim to more directly model the radial rock heat and do away with calibration factors



$$\alpha\left\{\frac{\partial^2\theta}{\partial r^2}+\frac{1}{r}\frac{\partial\theta}{\partial r}\right\}=\frac{\partial\theta}{\partial t}\qquad\frac{^\circ C}{s}$$

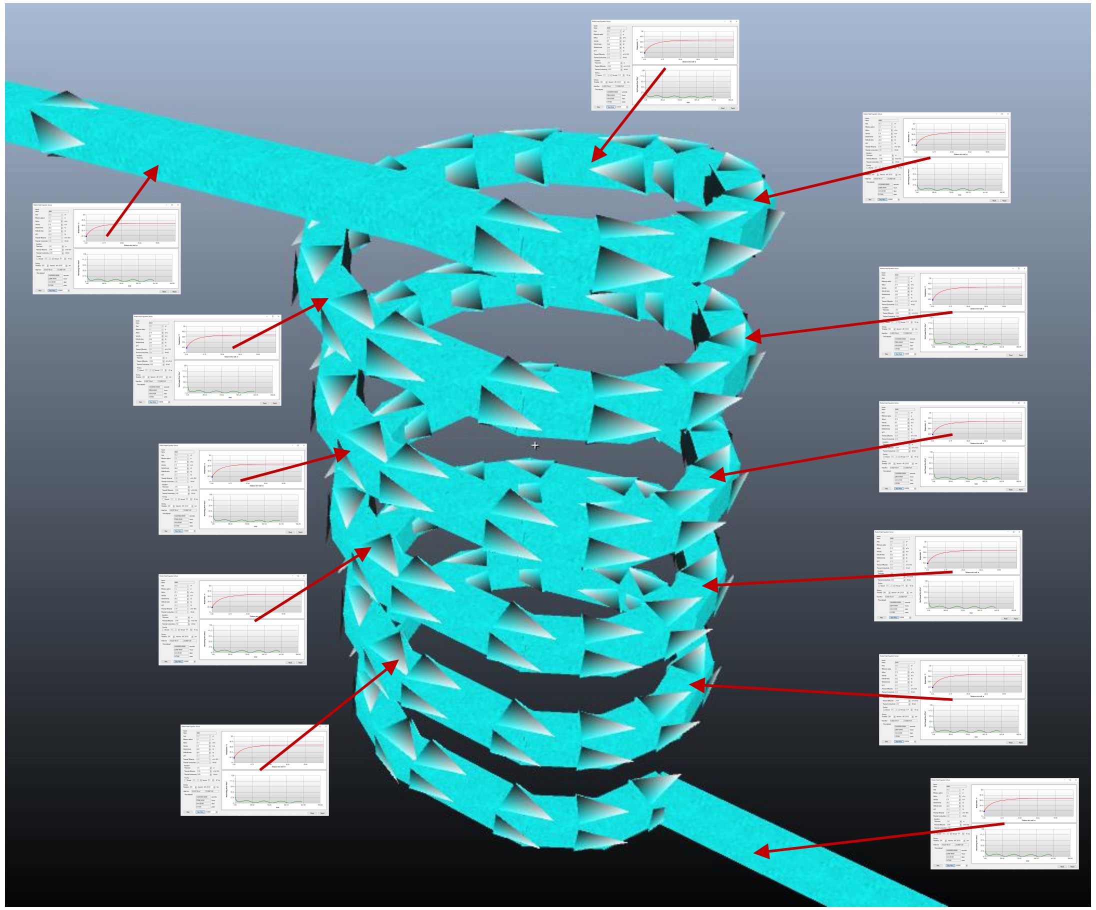
θ is the temperature in the wall, [ºC]
α the thermal diffusivity, [m^2/s]
r the radial distance, [m]
t time, [s]

Dynamic Heat

Finite difference across the model

- Extend the solver across every airway in the model, leading to:
  - Better Annual and Daily Flywheel simulation
  - More accurate Dynamic Heat Simulations for modelling transient effects
    - What is the effect on the heat of a fan shutting down?
    - The effect of a cooling plant shutting down
    - A large change in operation method

- Potential for mine whole of life heat simulations with greater accuracy than current methods,



Thank you

Revolving Around You™