





Version 6: Heat and Vehicle Features

> Martin Griffith Software Team Leader Howden Ventsim

> > **Revolving Around You**[™]

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New Features:

Electric Vehicles

Heaters and Coolers

To come:

Dynamic Heat Simulations

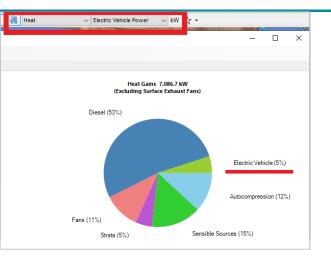
Electric Vehicles

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

ᡒ Ventsim DESIGN Preset Val	ues											_		\times
File Edit 🔟														
Resistances								NOx	со	Point	Electric			
Friction Factors		Name	lcon	# in use (total all	Dust Source	Utilisation Factor	DPM g/kW.hr	Yield Rate	Yield Rate	Diesel Power	Vehicle Power	Point Sensible kW	Point Latent kW	Point Moisti ml/se
🕴 Shock Losses				stages)				g/kW.hr	g/kW.hr	kW	kW	ĸvv	KVV	mi/se
🤹 Air Type		Conveyor Heat	-	2	~	1	0.1	9.2	3.5	0	0		0	0
🕹 Primary Layers		Crusher Heat	200	1	~	1	0.1	9.2	3.5	0	0	50	0	0
🕹 Secondary Layers		Loader R2900		4	~	0.5	0.12	9.2	3.5	280	0		0	0
💮 Fans		Pump Station		1	~	1	0.1	9.2	3.5	0	0	00	0	0
Regulators		Stope Heat			~	1	0.1	9.2	3.5	0	0		0	0
🚯 Heat Moisture Diesel		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
🚑 Vehicles		Pofessention Plant 2MM/P	\$ 9 \$		- v	1	0.1	9.2	2.5	0	0		0	0
Wetness Fractions	•	Electric Vehicle	÷		Default 🗸 🗸	0.3					350			
Rock Types														



8	Ventsim [™] Settings		_	×
	₽↓			
>	Costing			^
>	Dynamic Scripts / VentLog			
>	General			
>	Graphics			
~	Simulation			
>	Airflow			
>	Contaminant			
>	Diesel			
>	Dust			
>	Dynamic			
>	Environment			
>	Escape Routes			
>	Fire			
>	Gas			
~	Heat			_
	[RESET]	No		
	Air-to-Air Heat Exchanger Accuracy	1.0 kW		
	Conveyor-Airway Heat Transfer	Yes		
	Diesel Efficiency	35.0 %		
	Diesel Load Factor	1		
	Electric Vehicle Efficiency	95.0 %		
	Electric Vehicle Latent Heat Factor	50.0 %		

Electric Vehicles

Fires



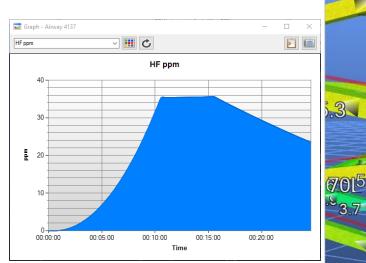
 Battery fires can now be configured as part of the VentFIRE simulation Heat and Contaminant yield configured per unit of energy capacity (kWh) 								Evel Types LFP Lithium Ba Hydraulic Oil Rubber	ttery V X V X	Total Fue 300 € 400 € 3500 €	kW.h	~			
									1		Fire Events	Total Fire Time Delay Fire Start Growth Period	H M S 1 00 00 00 00 00 00 20 00		
Combustion Fuels Battery Combustion	Name	Heat of Combustion MJ/kWh	02 Consume	y CO2 kg/kWh	y CO kg/kWh	y NO kg/kWh	y SO2 kg/k\	yHF h kg/kWh	y HCL kg/kWh	y Soot kg/kWh		Sustain Period	00 20 00 00 20 00 00 2d 00		
*	LFP Lithium Battery	50.4	4.5713	6.095	0.1524	0.0242	0.0265	0.2	0.0035	0.05	6934 Jo HG S200 at At S200 at S200 at S200 at S200 at S200 at At S200 at S200 at S200 at At S200 at At At At At At At At At At A	900 180 Time S	0 2700 3	+540 -405 -270 -135 -0 600	Burn Rate kWh/hr

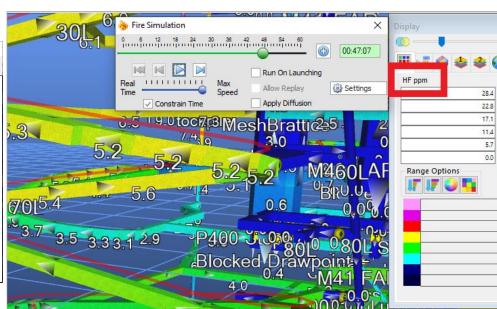
Electric Vehicles

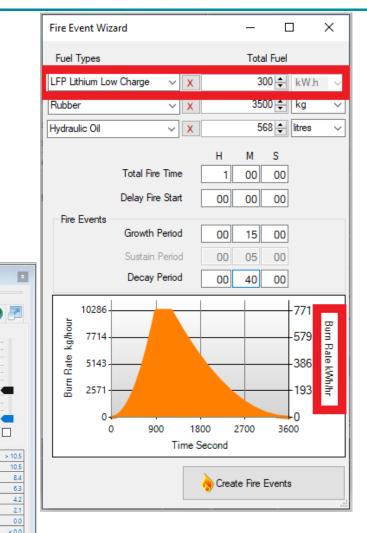
Fires



- 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







ppm



New Features:

Electric Vehicles

Heaters and Coolers

To come:

Dynamic Heat Simulations



- 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

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Tools Select 🔟	
S 0 5 8 9 9 8	۱
Heat	× ×
Point Source	\sim
Linear Source	\sim
Heater	^
Heater Type	None -
	None
	Indirect
	Direct
	Electric
	Air-to-Air Exchanger
Cooler	^
Cooler Type	None
	None
	Fix Refrigeration Capacity
	Fix Discharge Temperature

Coolers

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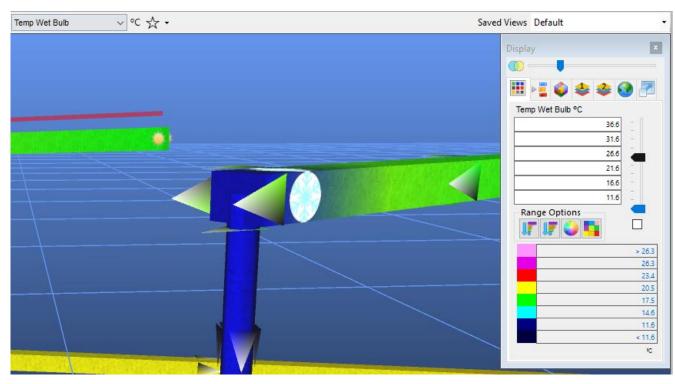
Cooler

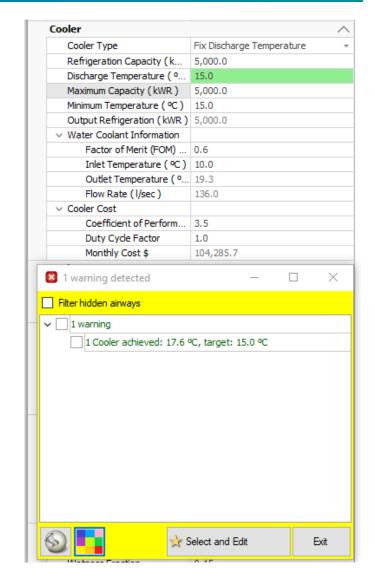
Cooler Type Fix Refrigeration Capacity Refrigeration Capacity (k... 5,000.0 Fix Refrigeration Capacity Discharge Temperature (º... 15.0 • Maximum Capacity (kWR) 0.0 Minimum Temperature (°C) 15.0 Output Refrigeration (kWR) 2,572.0 Minimum Temperature stops cooler cooling to unrealistic temperatures ٠ Vater Coolant Information Factor of Merit (FOM) ... 0.6 Inlet Temperature (°C) 10.0 Outlet Temperature (º... 16.0 Flow Rate (I/sec) 86.9 Cooler Cost ~ ~ ~ ~ Saved Views Default Temp Wet Bulb Coefficient of Perform... 3.5 * Duty Cycle Factor 1.0 Monthly Cost \$ 104,285.7 Temp Wet Bulb °C 36.6 31.6 26.6 21.6 16.6 11.6 Range Options IF IF 🥥 🌄 > 26.3 26.3 23.4 20.5 17.5 14.6 11.6 < 11.6 IC. © Howden Group 2023

Coolers



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

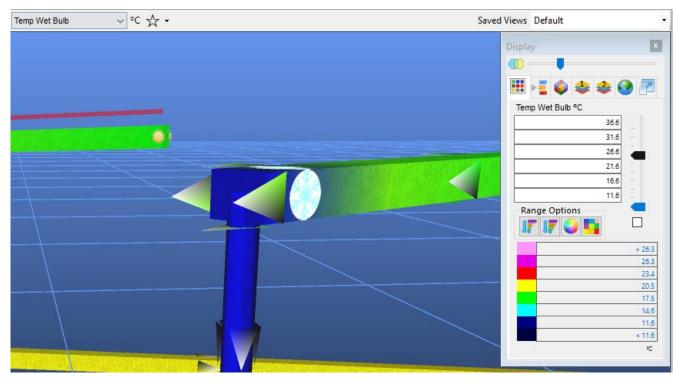




Coolers



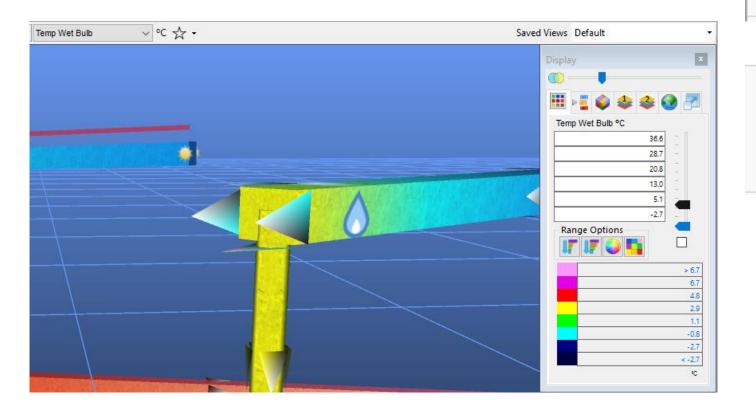
- To come
 - A setting for required airflow
 - Derating of the cooler performance if adequate airflow is not reaching the cooler



Heaters



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





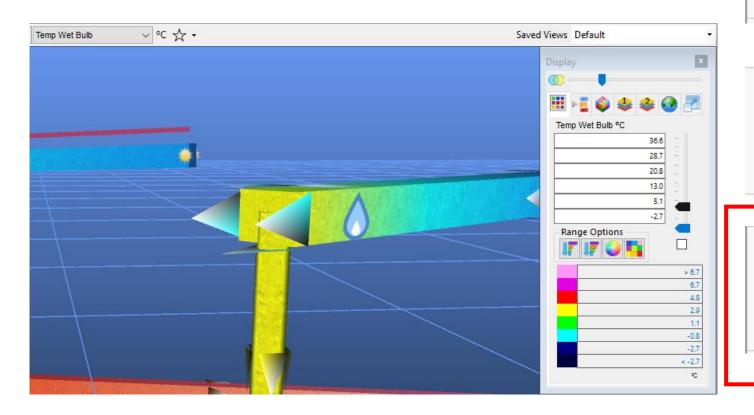
Heater	^
Heater Type	Direct -
Heater Temperature (°C)	5.0
Heater Fuel	Propane 👻 🖉
Heater Power Output (kW)	1,610.0
Heater Monthly Fuel (kg)	84,621.0

Heater		~
Heater Type	Indirect	-
Heater Temperature (°C)	5.0	
Heater Fuel	Propane	- <i>Ş</i> i
Heater Power Output (kW)	1,533.8	
Heater Monthly Fuel (kg)	94,844.0	

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	- ju
Heater Power Output (kW)	1,533.8	
Heater Monthly Fuel (kg)	94,844.0	

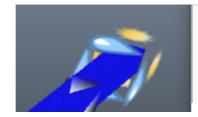
Heater		~
Heater Type	Electric	Ŧ
Heater Temperature (°C)	5.0	
Heater Power Output (kW)	1,533.8	
Monthly Electricity (kW.h)	1,119,685.0	
Monthly Cost (\$)	111,969.0	

Heaters



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

Heated intake



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

Cooled exhaust



		1	
Heat	er		^
H	leater Type	Air-to-Air Exchanger	-
A	ir-to-Air Exchanger Pairs	107	Ŧ
A	ir-to-Air Effectiveness (k	. 36.00	🔳
H	leater Power Output (kW)	-1,156.1	

Heaters



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

Air-toAir Heat Exc	hanger Effectiveness Calco	ulator			×			
HEATED AIRST	REAM							
Mass flow	180.00 🚖	kg/s						
Inlet			Outlet					
Wet Bulb	-4.4	°C	Wet Bulb	-0.3	°C			
Dry Bulb	-4.4	۹C	Dry Bulb	2.0	۹C			
Pressure	102.6	kPa	Pressure	102.5	kPa			
COOLED AIRST Inlet Dry Bulb		°C	Outlet Dry Bulb	26.2	٩C			
RESULT Calculated Heat Effectiveness 36.10 kW/°C								
				Accept	Cancel			

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

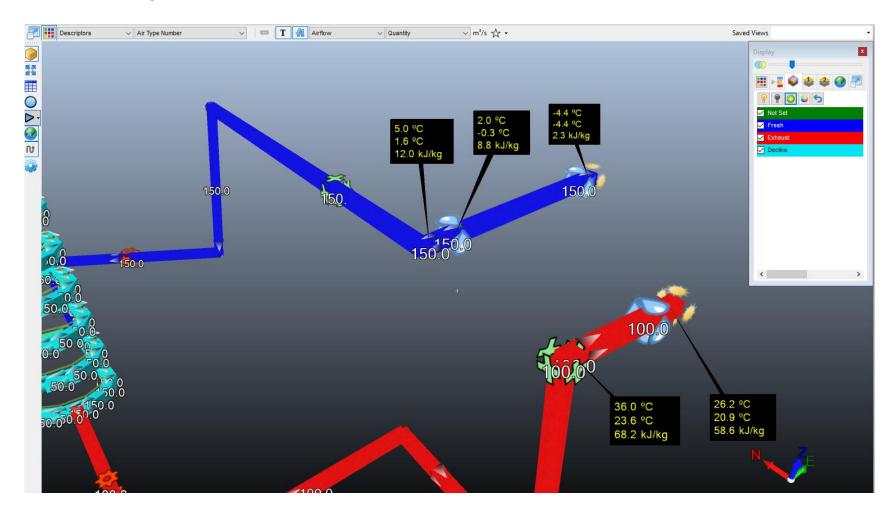


Heater		\wedge
Heater Type	Air-to-Air Exchanger	Ŧ
Air-to-Air Exchanger Pairs	107	Ŧ
Air-to-Air Effectiveness (k	36.00	
Heater Power Output (kW)	-1,156.1	

Heaters



• Air-to-Air Heat Exchanger





New Features:

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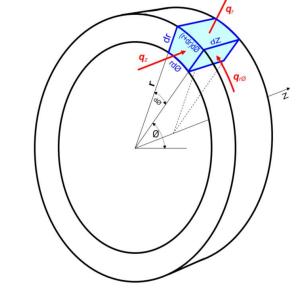
To come:

Dynamic Heat Simulations

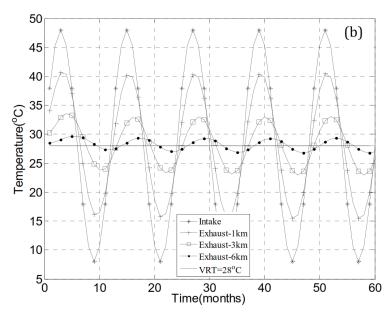
Time-dependent Heat Simulations



- 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



Further from the air intake, variations are damped and lagging

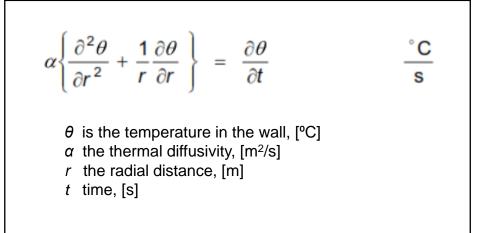
• Applies to daily and annual variations in atmospheric temperatures, and changes in underground operations

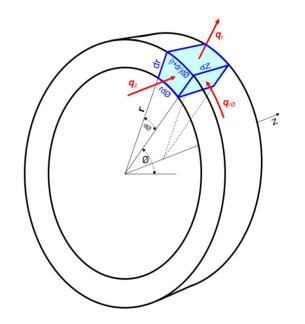
from Danko et al, Temperature variations in underground tunnels, 2012

Radial Heat Equation



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

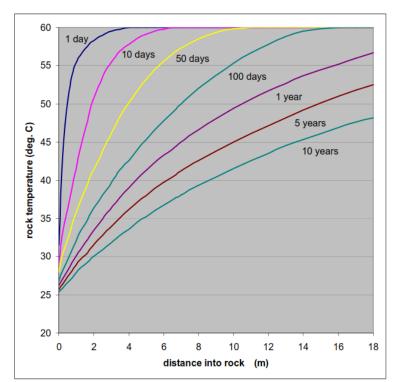


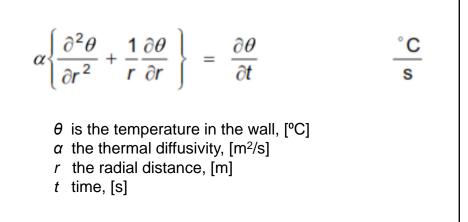


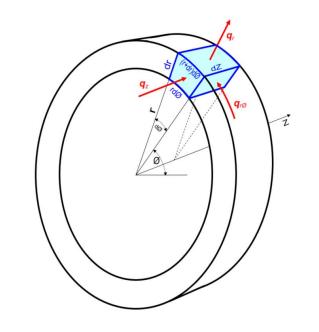
Radial Heat Equation



- 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



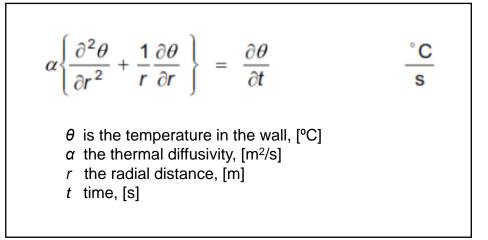




Solving radial heat better



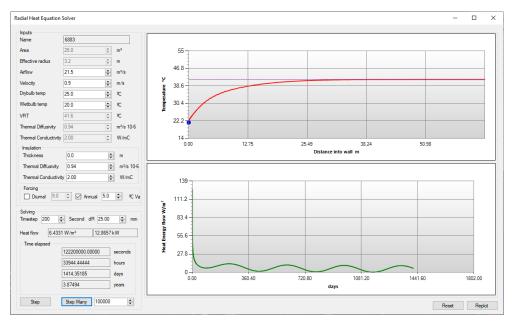
- The Ventsim Annual Thermal Flywheel models the change in temperatures per month throughout the year
- VentFIRE is calibrated for timeframes over a couple of hours
- Option being explored is to add a finite difference solver to Ventsim to more directly model the radial rock heat and do away with calibration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

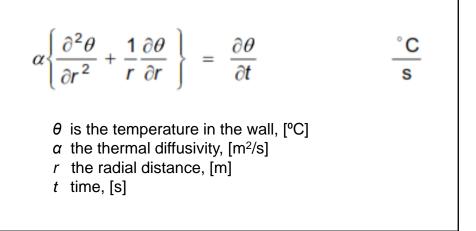


Finite Difference Solver



- 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

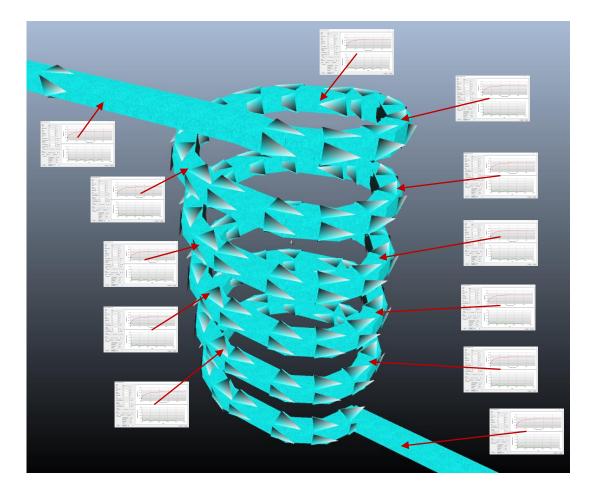




Finite difference across the model



- 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

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