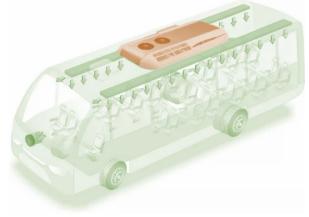


Powered by

**THERMAL-XR®** powered by GMG Graphene is a coating system for restoring and improving energy efficiency to refrigeration and air conditioning coils. The process coats and rebuilds lost thermal conductivity by leveraging the physics of GMG's Graphene to increase the heat transfer rate, resulting in efficiency improvement, and reductions in both energy and CO<sub>2</sub> emission for customers.

Graphene Manufacturing Group Ltd (GMG) has conducted a mobility trial on a passenger bus to ascertain operational improvements when **THERMAL-XR**<sup>®</sup> powered by GMG Graphene is applied to the condenser coil of the vehicle's air conditioning system.



The bus airconditioning coating trial was designed to record any improvement reduction that **THERMAL-XR®** has on:

- 1. Pull Down Rate of the Bus's Air Conditioning System.
- 2. Fuel Usage; and
- 3. Emission Reductions Post-Test.

# SAVINGS RESULTS

The Time Reduction of the Pull-Down Test highlights an improvement in both driver and passenger comfort.

The Fuel Savings show a direct correlation that the bus's HVAC system is operating more efficiently with less compressor operating time.

The Australian Government's National Greenhouse Accounts, factor that every litre of fuel saving is equivalent to an emission reduction saving of 2.7 kg  $CO_2$ -e/GJ.

	Pull Down Test 45°C to 22°C	Fuel Used
Baseline Trial	24 minutes	12.70 litres
THERMAL-XR Coated Trial	18 minutes	12.36 litres
Improvement Reduction	6 minutes less ▼	0.34 litres less ▼
improvement reduction	25% ▼	2.7%▼
Emission Reductions	2.7 kg CO₂-e/GJ.	





# **TEST DESIGN SUMMARY**

Two separate data sets were collected on the same bus to record both a baseline result without **THERMAL-XR®** coating on the coil, and one set inclusive of the coating, to compare results.

In a controlled temperature environment, the pull-down rate of the air conditioning unit was measured whilst the bus was in idle over a two hour period.

In parallel, fuel consumption during both trials were also recorded by a Volvo Automotive telematics system.

#### Activity

THERM

Baseline Trial Bus continued standard operation Condenser coil removed and coated with Thermal XR Bus continued standard operation Thermal XR coating Trial

## Timeline

06 May 2021 07 May to 12 May 2021 13 May 2021 15 May to 20 May 2021 21 May 2021

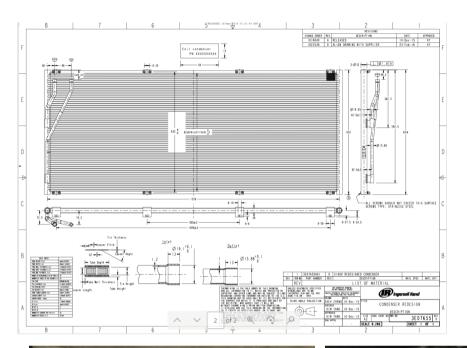
#### **EQUIPMENT SUMMARY**

- Volvo B7RLE Bus
- The bus has average operation time of 250 hours per month and normal operating conditions are within a Capital City passenger routes.
- The bus has a X1000 Ingersoll Rand redesigned condenser coil. The coil had approximately 13,000 hours of operation at time of test.
- A Thermo King DAS (Data Acquisition System), standalone data recorder, (not connected to the AC system) with TK Wintrac 5 software was used to download the data for the Pull Down Test.
- A proprietary Volvo Telematic System recorded the fuel data.
- Temperature controlled environment was conducted inside a Spray 'n' Bake paint booth Model TNT-3-20/6.





# X1000 INGERSOLL RAND REDESIGNED CONDENSER COIL

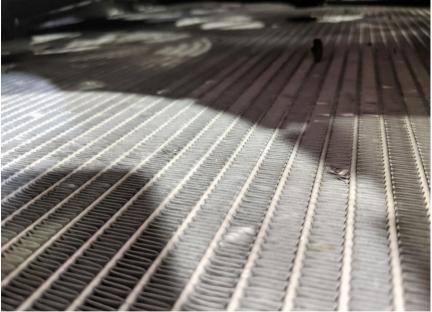




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# **TEST SPECIFICATIONS - PULL DOWN TEST IN A HEATED BOOTH**

The test specifications for this trial were specific to the customer for their standard Air Conditioning (A/C) testing for Internal Combustion (Diesel, CNG, etc.), Hybrid, or Full Electric drivetrain buses.

The purpose of this test is to demonstrate the cooling capability of the A/C system and to ensure the system is well balanced and comfortable for the driver and passengers in all operational and environmental conditions likely to be experienced during normal bus operations.

According to the Bureau of Meteorology, Brisbane, Australia has historical recorded ambient temperature range from 2°C minimum to 42°C maximum. Testing of an empty bus in a heated booth will not take into consideration the heat generated from a full passenger load (including driver), nor the effects of solar radiation through the windscreen and windows. Hence, for the purposes of simulating realistic operational conditions, allowing for passenger heat load and solar radiation, testing was conducted at a nominal 45°C set booth temperature (i.e. 42°C ambient + 3°C to simulate passenger and solar loading) with an objective to achieve the nominal 22°C set temperature inside the bus within 30 minutes.

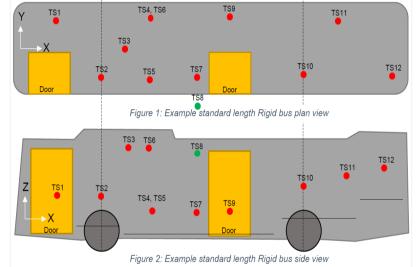
# **TEST PROCEDURE**

THERM

Temperature sensors were connected to a datalogger and placed in locations described below.

Red locations indicate interior measuring points, and green indicates an exterior ambient measuring point.

The bus was placed centrally and entirely within a heat chamber, with all systems turned off and heat soaked at 45°C (as read by sensor location T8) for a minimum of 1 hour. All doors, roof hatches and windows (including driver's window) were open during the heat soaking process.



Once fully heat soaked at 45°C, all doors, roof hatches and windows were closed. The engine was started, and revolutions increased to 1200. The A/C system was turned on with a 22°C set temperature. A datalogger recorded the time to reach this set temperature.

Once all internal temperature sensors have stabilised at set temperature, all passenger doors were opened for a period of 1 minute, then closed for 4 minutes to simulate a normal buses operation of stopping to collect passengers. This sequence was repeated for until duration of test concluded after two (2) hours.

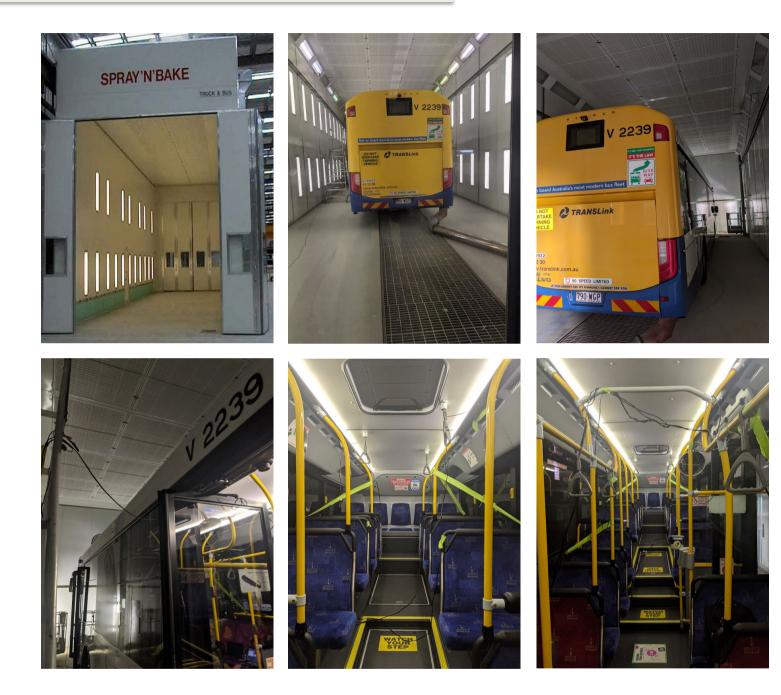
A Thermo King DAS (Data Acquisition System), standalone data recorder, (not connected to the AC system) with TK Wintrac 5 software was used to download the data for the Pull Down Test.







# SPRAY N BAKE PAINT BOOTH MODEL TNT-3-20/6



www.graphenemg.com info@graphenemg.com +617 3040 5716





# TABLE OF RESULTS

	Fuel Used First	Fuel Used Second	Total Fuel Used
	hour (Litres)	hour (Litres)	(Litres)
<b>Baseline Trial</b> 6th May – Pull Down Results	6.68	6.01	12.7
<b>THEMAL-XR<sup>®</sup> Coated Trial</b> 21st May – Pull Down Results	6.47	5.88	12.36
Improvement Reduction	0.21 ▼	0.13 ▼	0.34 <b>▼</b>
Improvement (%)	3.10% ▼	2.20% ▼	2.70% <b>▼</b>

#### **Emission Saving Calculations**

During normal operations, the bus averages 250 hours per month on various city passenger routes. Applying the above fuel usage data against the  $CO_2$  emission data for this vehicle type (Euro iv or higher), the emission savings were calculated as follows:

2.7% Diesel fuel saving with THEMRAL-XR<sup>®</sup> Coated trial = 1.4 MTreduction of CO<sub>2</sub> per year.

	Fuel Combusted	Energy Content Factor GJ/kl	Emission Factor Kg CO2-e/GJ (relevant oxidation factors incorporated)				
Heavy Vehicles conforming to Euro Designs Standards			CO <sub>2</sub>	CH₄	N <sub>2</sub> O		
Euro IV or higher	E IV Diesel Oil	38.6	69.9	0.07	0.4		

Source: National Greenhouse Accounts Factors 2020

Test	Litres Used in 2 hour Trial	Average hrs/month	Months/ Year	Fuel Use kl/Year	
<b>Baseline Trial</b> 6th May – Pull Down Results	12.7	250	12	19.1	
THEMAL-XR <sup>®</sup> Coated Trial 21st May – Pull Down Results	12.36	250	12	18.5	
Eiv Diesel oil	Volume kilolitres/yr	CO <sub>2</sub>	CH₄	N <sub>2</sub> O	T of CO <sub>2</sub> -e/yr
<b>Baseline Trial</b> 6th May – Pull Down Results	19.1	51.40	0.05	0.29	51.7
THEMAL-XR <sup>®</sup> Coated Trial 21st May – Pull Down Results	18.5	50.02	0.05	0.29	50.4

#### Annual Reduction (tonnes of CO2) /Per Bus

Reduction

1.4 mt 2.7%

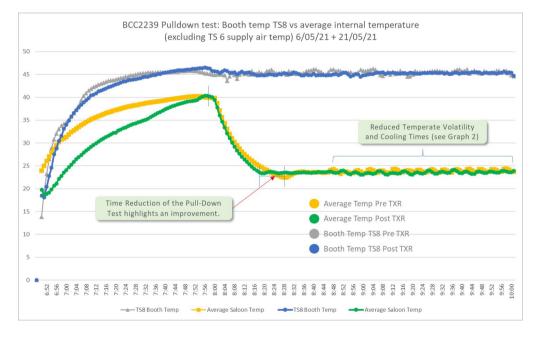


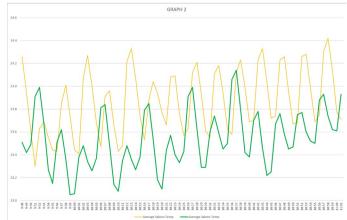


# **TABLE OF RESULTS**

		Probe	Key:												
		TS1	Drivers se	at rear	point			TS7	1m for	ward of	rear do	or nea	rside		
Fest Device: TK DAS		TS2	Front who	el axle	centre	line		TS8	Ambie	nt senso	r Vehicl	e midr	olane		
ogger ID: X1000		TS3	Return ai	r grille				TS9	Rear de	oor cent	reline o	ffside			
Serial number: 000000	077790	TS4	Wheelcha	ir offsi	de area	1		TS10	Rear as	de centr	eline ne	arside	2		
		TS5	Wheelcha	ir near	side ar	ea		TS11	1m rea	r of axle	offside				
		TS6	A/C evap	blower	outlet	in duct		TS12	Rear se	at near	side				
														Average	
Date & Time	Time	TS8	TS1	TS2	TS3	TS4	TS5	TS6	TS7	TS9	TS10	TS11	TS12	Saloon	Notes
														Temp	
	9:00														Test
6/05/2021 9:00	9:00	44.9	41.2	39.5	39.6	39	39.4	35	39	39.4	40.4	40	40.2	39.3	Starte
6/05/2021 9:01	9:01	45	39.8	38.4	37.5	38.4	38.3	28.3	38.3	38.8	39.3	39.3	38.9	37.8	
6/05/2021 9:02	9:02	45	37.9	36.7	34.9	37.3	36.8	24.6	37.1	37.8	37.6	37.7	37.3	36.0	
6/05/2021 9:03	9:03	45	36.3	35.1	32.8	36.2	35.3	22.5	35.8	36.7	36.1	36.3	35.8	34.4	
6/05/2021 9:04	9:04	44.8	34.8	33.5	31.3	35.1	34	21.1	34.5	35.6	34.8	34.9	34.6	33.1	
6/05/2021 9:05	9:05	43.6	33.6	32	30.1	33.9	32.7	19.9	33.3	34.5	33.5	33.7		31.9	
6/05/2021 9:06	9:06	44.6		30.9	29.1	32.8	31.4	18.7	32.3	33.4		32.5	32.4	30.8	
6/05/2021 9:07	9:07	45.5	31.7	29.9	28.3	31.9	30.4	17.9	31.3	32.4	31.3	31.5	31.6	29.8	
6/05/2021 9:08	9:08	44.9		28.9	27.7	31	29.6	17.2		31.5		30.6	30.8	29.0	
6/05/2021 9:09	9:09	44.1		28.2	27.1		28.7	16.3		30.7	29.7		30.1	28.2	
6/05/2021 9:10	9:10	45		27.5	26.6		28	15.7		29.8	28.9	28.9	29.5		
6/05/2021 9:11	9:11	45.5		26.8	26	28.8	27.3	15.2		29.1		28.3	28.9		
6/05/2021 9:12	9:12	45.1		26.3	25.6		26.8	14.8		28.5	27.7		28.4	26.4	
6/05/2021 9:13	9:13	45.2		25.8	25.2		26.2	14.3		27.9	27.2	27	28	25.9	
6/05/2021 9:14	9:14	45		25.3	24.8		25.7	13.9		27.4	26.7		27.6		
6/05/2021 9:15	9:15	45.7		24.8	24.4		25.2	13.6		26.8	26.3	26.1	27.2	25.0 24.6	
6/05/2021 9:16	9:16	45		24.4	24.1		24.7	13.3		26.4			26.9		
6/05/2021 9:17	9:17	45.2		24.1 23.7	23.8	25.8	24.3 24.2	12.9		25.9 25.6	25.5	25.3	26.6	24.2 23.9	
6/05/2021 9:18	9:18							_				24.9			
6/05/2021 9:19	9:19	45.3		23.3	23.2		24	12.5		25.2	24.7	24.6 24.3	26.1 25.8	23.6	
6/05/2021 9:20 6/05/2021 9:21	9:20 9:21	45.1		22.9	22.9	24.7	23.9 23.6	12.2	24.9	24.8 24.5	24.5 24.3	24.3	25.8	23.2	
	9:21	45.7		22.7	22.7	24.4	23.6	12.1		24.5	24.3		25.6	23.0	
6/05/2021 9:22			24	22.4		24.1	23.2	11.9	24.3	24.Z	24				
6/05/2021 9:23	9:23	46	23.8	22.1	22.2	23.9	22.7	11.7	24	24	23.8	23.5	25.2	22.4	

Date & Time Time TS8 TS1 TS2 TS3 TS4 TS5 TS6 TS7 TS9 TS10 TS10 TS11 TS12 Sala   ZU(05/2021 8:00 8:00 45.7 40.6 38.9 38.7 38.8 73.6 39.5 38 40.4 40.4 40.2 39.7   ZU(05/2021 8:00 8:00 45.5 37.6 36.6 37.5 35.1 26.1 35.9 38.6 40.4 40.4 40.4 40.6 39.7 35.1 21.01 31.0 38.6 37.5 35.1 26.1 35.9 35.8 37.2 36.9 37.7 35.1 21.01 31.0 31.0 32.2 33.5 34.4 33.3 34.5 32.7 32.6 30.5 32.3 33.5 32.2 33.5 34.4 33.3 34.5 32.7 32.6 33.5 32.7 33.5 32.7 33.6 32.7 33.6 32.7 33.6 32.7 33.6 32.7 <th>Probe Key:</th> <th></th> <th></th> <th></th> <th></th> <th></th> <th></th> <th></th> <th></th> <th></th>	Probe Key:										
Logger ID: K1000 T53 Serial number: 0000007779000 T53 T54 Return air grille Wheelchair offside Marine measide area A/C evap blower outlet in duct T59 T50 Rear adoc centreline offside T510 T59 Rear adde offside T510 Rear adde offside Rear sade centreline nearside T510 Note offside Rear sade offside T510 Note Rear sade offside T510 Note Rear sade offside T510 Note Rear sade offside T510 Note T511 Note T511<	TS1 Drivers seat rear poin		TS7	1m forv	le						
Serial number: 000007779000 F34 Meekchair offside area NG (Meekchair nearside area (AC every biower outlet in duct T510 Rear sate centreline nearside tim near of axie offside Rear sate area T510 Rear sate centreline nearside tim near of axie offside   Date & Time Time TS8 TS1 TS2 TS3 TS4 TS4 Meekchair nearside area (Meekchair nearside area TS10 Rear sate centreline nearside TS10 TS11 TS10 TS10 TS11 TS10 TS11 TS10 TS10 TS11 TS10 TS11 TS10 TS11 TS10 TS11 TS11 TS10 TS1	TS2 Front wheel axle cent	e	TS8	Ambien	t sensor	Vehicle	midplar	ne			
T55 Wheekhair nearside area A/C evap blower outlet in duct T511 Im rear of axle offside T512 Rear seat nearside   Date & Time Time T51 T511 Im rear of axle offside T512 Rear seat nearside   Date & Time Time T51 T512 T512 Rear seat nearside   21/05/2021 8:00 8:00 45.7 40.6 38.7 38.6 37.5 37.6 37.1 30.6 38.7 36.6 39.5 38 40.4 <th cols<="" th=""><th>TS3 Return air grille</th><th></th><th>TS9</th><th>Rear do</th><th>or centr</th><th>eline off</th><th>side</th><th></th><th></th><th></th></th>	<th>TS3 Return air grille</th> <th></th> <th>TS9</th> <th>Rear do</th> <th>or centr</th> <th>eline off</th> <th>side</th> <th></th> <th></th> <th></th>	TS3 Return air grille		TS9	Rear do	or centr	eline off	side			
T56 A/C evap blower outlet in duct T512 Rear seat nearside   Date & Time TSE TS1 TS2 TS3 TS4 TS5 TS6 TS7 TS0 S10 C1100/C021 Rear seat nearside   21/05/2021 8:00 6:00 45.6 35.8 TS6 TS7 TS9 S10 C111 C100/C021 S10 6 36.8 37.3 37.2 21/05/2021 8:00 8:00 45.6 36.8 37.3 35.1 26.1 37.3 32.2 35.0 36.6 37.2 36.6 37.2 31.2 21/05/2021 8:07 30.3 32.3 32.3 32.3 32.3 32.3 <th< th=""><th>0077790005 TS4 Wheelchair offside an</th><th></th><th>TS10</th><th>Rear ax</th><th>le centre</th><th>line nea</th><th>rside</th><th></th><th></th><th></th></th<>	0077790005 TS4 Wheelchair offside an		TS10	Rear ax	le centre	line nea	rside				
Date & Time Time TS8 TS1 TS2 TS3 TS4 TS6 TS6 TS7 TS9 TS10 TS11 TS12 S33 TS4 TS6 TS7 TS9 TS10 TS11 TS12 S33 TS4 TS6 TS6 TS7 TS9 TS10 TS11 TS12 S33 S38.9 38.7 38.6 39.5 38 40.4 40.4 40.2 39.7 32.2 21/05/2018.00 80.0 45.7 40.6 38.9 38.7 38.7 38.6 39.7 35.6 39.5 38 40.4 40.4 40.2 39.7 35.1 15.7 15.1 15.12 25.0 37.7 35.6 39.5 38.7 38.6 38.9 37.7 35.1 15.0 15.0 15.1 15.12 25.0 37.7 35.1 15.7 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0<	TS5 Wheelchair nearside a		TS11	1m rear	of axle	offside					
Date & Time Time TS8 TS1 TS2 TS3 TS4 TS5 TS6 TS7 TS9 TS10 TS10 TS11 TS12 Sale   21/05/2021 8:00 8:00 45.7 40.6 38.9 38.7 38.6 37.5 TS6 TS6 58 40.4 40.2 39:3   21/05/2021 8:00 8:00 45.6 37.6 35.6 37.7 35.1 26.1 35.9 38.7 38.6 37.5 35.1 26.1 35.9 37.2 36.9 37.7 35.1 21.0 35.9 38.7 38.6 37.5 35.1 26.1 35.9 35.8 37.2 36.9 37.7 35.1 21.0 35.9 34.3 33.7 35.7 35.1 20.0 23.3 34.0 34.3 33.7 35.7 35.1 20.0 23.5 34.4 33.1 30.8 27.7 27.0 23.5 34.3 33.3 32.7 32.7 32.7 32.7 32.7	TS6 A/C evap blower outle	duct	TS12	Rear se	at nearsi	ide					
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21/05/2011802 802 45.3 36.7 35.4 37.7 35.7 21.0 57.8 37.8 35.6 37.8 35.7 35.8 37.8 35.6 35.6 35.8 37.8 35.8 37.8 35.8 37.8 35.8 37.8 35.8 37.8 35.8 37.8 35.8 37.8 35.8 37.8 35.8 37.8 35.8 37.8 35.8 37.8 35.8 37.8 35.7 32.1 2105/20218.04 60.4 45.9 34.3 32.6 30.6 33.5 32.8 32.7 31.1 30.0 32.8 31.1 30.0 31.1 30.0 31.1 30.0 31.1 30.0 31.3 30.7 31.3 30.7 31.3 30.7 31.3 30.1 30.0 31.3 30.0 32.3 33.7 32.7 31.1 30.0 31.3 31.3 30.3 31.7 30.8 31.1 30.0 31.3 31.3 30.7 30.7 30.8 31.1									27.1	sturte	
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this low input cost source of graphene, the Company is developing value-added products that target the massive energy efficiency and energy storage markets.

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