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Effects of preventable faults on air-conditioning systems at T2

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4 Introduction

This report summarises testing conducted to identify and quantify the effect of preventable and common faults on refrigeration and air-conditioning equipment. The faults simulated are blocked coils and under and over-charged refrigerant.

The intent of this report is to aid the Department of Climate Change, Energy, the Environment and Water in informing users of refrigeration and air-conditioning equipment of the potential effects of poor maintenance on such equipment. Major faults (such as a compressor failure) are not in the scope of this report as such faults would quickly be identified and remedied. As such, this report aims to analyse those faults that do not produce an effect that is immediately noticeable to the equipment owner but do have a significant long-term impact on the owner and/or environment.

5 Declaration

I declare that the details stated in this test report summary are correct and are based on test data which we hold.

Test Officer:	Brendon Hazlewood	09/06/2022
Authorising Officer:	Ian Nankivell	09/06/2022

6 Customer Details

This report was prepared by Cresstec Pty Ltd at the Cresstec Research & Development HVAC-R Test Facility (CRDHTF) for the Ozone and Climate Protection, Atmosphere and Reporting Branch, Environment Protection Division, Department of Climate Change, Energy, the Environment and Water.

7 Executive Summary

A summary of the test conditions and the effect on cooling capacity and power usage is shown below in Table 1.

The significance of the effect is based on the relative change in cooling capacity and power usage compared to a baseline as well as the opinions of this author. As such the magnitude of the significance varies with equipment and individuals. The exact figures are provided in section 9 of this report if the reader wishes to form their own conclusions tailored to the context in which they operate.

Note: Cooling capacity is a measure of the equipment's performance and ability to cool the space in which it operates. Power usage is the power drawn from the electrical grid to perform such cooling.

Table 1 - Summary of effect of faults on cooling capacity and power usage

Test	Test Conditions	Effect on Cooling Capacity	Effect on Power Usage
1	F-C1 - 50% Blockage	Negligible Decrease	Significant Increase
2	F-C2 - 75% Blockage *	Extreme Decrease	High Decrease
3	F-R1 - 80% Charge	High Decrease	Significant Decrease
4	F-R2 - 60% Charge	High Decrease	Moderate Decrease
5	F-R3 - 120% Charge	Negligible Increase	Significant Increase

**** F-C2 exceeded the safety pressure limits of the test device causing it to shutdown multiple times. The results of this test are unreliable.***

Appendix B provides an overview of the rating system used above.

The key takeaways from these results are fault conditions F-C1 and F-R3. Both faults produce negligible effect on cooling capacity, which suggests it would not be noticeable to the equipment owner, but a significant increase in power usage and thus running costs.

8 Device Under Test

8.1 Information

Table 2 - Device Under Test Information

Manufacturer / Brand	Withheld	
Model Name	Indoor	Withheld
	Outdoor	Withheld
Serial Number	Indoor	Withheld
	Outdoor	Withheld
Air Conditioner Type	Ducted Split System	
Air Conditioner Functions	Both Cooling and Heating	
Air Conditioner Air Distribution	Internal Fan	
Heat Transfer Medium	Air	
Mounting		
Rated Voltage	230V	
Rated Frequency	50 Hz	
Variable speed compressor?	No	

8.2 Installation

The outdoor unit was placed in the corner of the outdoor test room approximately 300mm from each wall with the exhaust outlet facing the cold air fan. Refrigerant pressure sensors were attached to the suction and discharge side of the compressor. Temperature probes were attached to the outer wall of both pipes and insulated. Air temperature and humidity duct probes were mount on each side of the condenser coil.

The indoor unit was setup approximately 500mm off the ground and fed into an external duct housing and an air velocity sensor. Like the outdoor room, refrigerant temperature probes and air temperature and humidity duct probes were utilised in the appropriate locations. Refrigerant pressure sensors were not placed directly in the flow path but rather in the cabinet of the REED device.

The REED device houses a bladder accumulator as well as the remaining pressure sensors for the circuit. It also contains a network of solenoid valves and needle valves to allow movement of charge into and out of the system without opening the room doors and disturbing the temperature equilibrium. The REED device contains a master and system data acquisition system used to acquire data from the above-mentioned sensor suite.

Before testing began, an evacuation of 500 microns was pulled with a decay of 800 microns over 12 hours to ensure the system had no leaks.

9 Test Conditions

All tests performed shall reflect AS/NZS3823.1.2:2012 condition T2.

9.1 Test Condition 1

Table 3 – Test Conditions

Outdoor Room Temperature Setpoint	27°C
Indoor Room Temperature Setpoint	21°C
Indoor Room Humidity Setpoint	53%
Unit Temperature Setpoint	16°C
Stabilisation Period	~4hrs*

**** The first test of the day was allowed 4 hours to settle, but the REED system allowed a settle time of ~1 hour for subsequent tests during that day.***

Note that these tests conditions are constant temperature conditions.

10 Test Methodology

Two fault types were simulated: blocked coils and refrigerant under/over charge. Blocked coils were simulated through a solid cut-out that blocked 50% or 75% off the coil by frontal area. 50% blockage is intended to simulate a significantly blocked coil, whereas 75% blockage is intended to simulate a significantly neglected coil.

120% charge level simulates an incorrect system commission or where the incorrect charge was weighed into the system. 80% and 60% charge level simulate a system that has a leak or has been incorrectly commissioned.

Table 4 – Description of Faults

Fault Code	Fault Condition	Description
F-C1	Blocked Outdoor (Condenser) Filter – 50%	50% blockage via the addition of solid cut-out
F-C2	Blocked Outdoor (Condenser) Filter – 75%	75% blockage via the addition of solid cut-out
F-R1	Refrigerant Undercharge 80% of Nameplate	20% charge removed via Cresstec REED System
F-R2	Refrigerant Undercharge 60% of Nameplate	40% charge removed via Cresstec REED System
F-R3	Refrigerant Overcharge 120% of Nameplate	20% charge added via Cresstec REED System

11 Test Schedule

Table 5 – Testing Schedule

Test Number	Variables	Test Standard	Test Type	Test Conditions
1	Baseline	T2	Cooling Capacity/EER	21°C Dry-bulb, 15°C Wet-bulb Indoor 27°C Dry-bulb Outdoor
2	F-C1			
3	F-C2			
4	F-R1			
5	F-R2			
6	F-R3			

12 Overview of Results

Table 6 - Comparison of cooling capacity, compressor power and EER for all faults

Test	Test Conditions	Calculated Cooling Capacity (kW)	Total Power to Equipment (kW)	Energy Efficiency Ratio (EER)
1	Baseline	5.708	2.483	2.30
2	F-C1 - 50% Blockage	5.705	2.606	2.19
3	F-C2 - 75% Blockage *	2.428	1.549	1.57
4	F-R1 - 80% Charge	4.239	2.341	1.81
5	F-R2 - 60% Charge	3.458	2.232	1.55
6	F-R3 - 120% Charge	5.785	2.652	2.18

**** Fault condition caused unit shutdown (high head pressure).***

13 Analysis

To assist in analysing the result, they have been summarised in Figure 1 and Table 7 below.

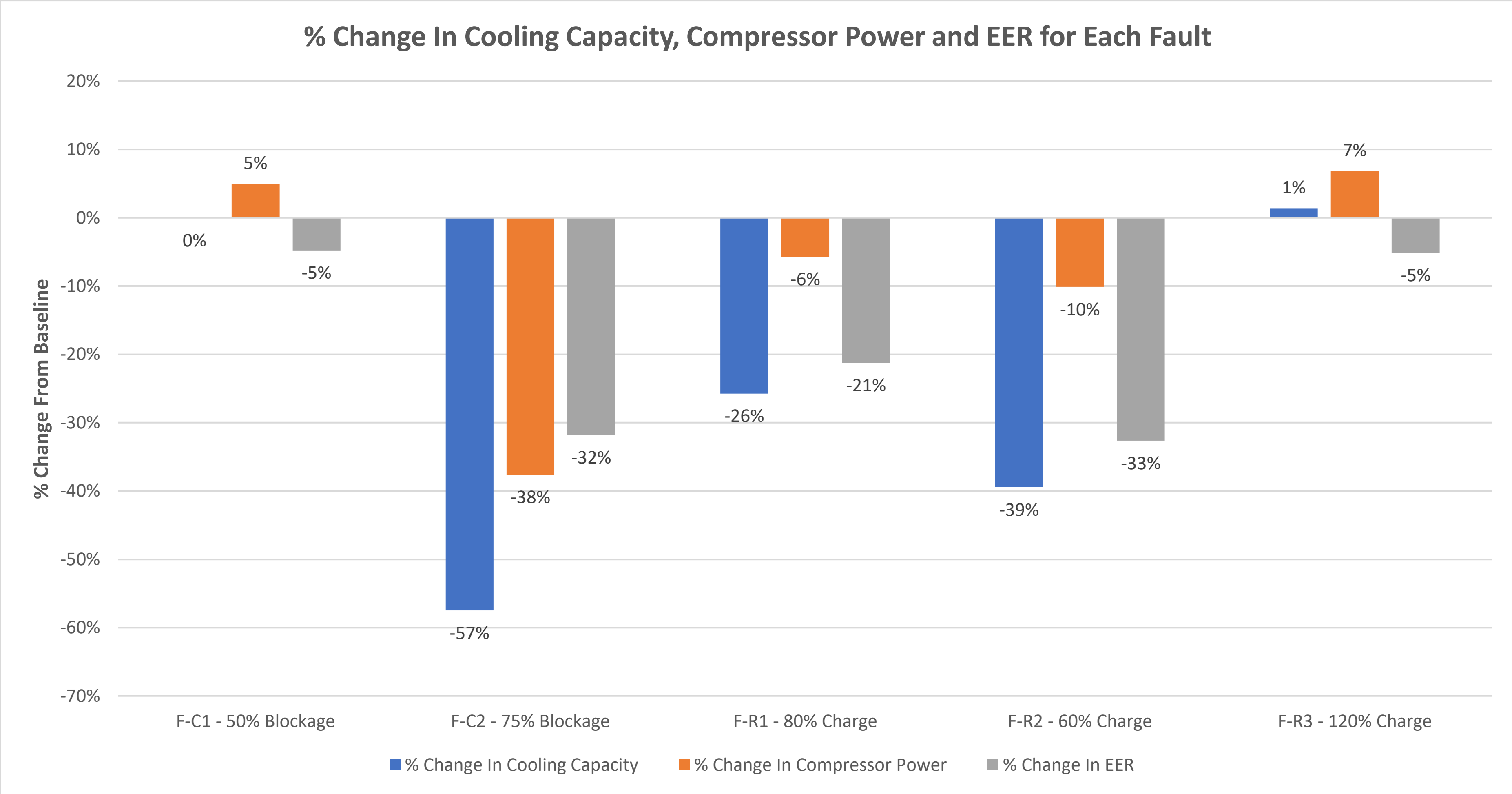

Figure 1 - Summary of Results (Bar Chart)

13.1 Effect of Blockages

As can be seen from the results, a 50% blockage at the condenser had a small negative impact on cooling capacity, but a significant increase in compressor power. This resulted in a ~5% increase in power usage and 0.053% drop in cooling capacity.

A 75% blockage effectively disabled the unit as it activated the high-pressure safety switch 6 times during the 1 hr sample window. This means the test was not able to stabilise on the desired temperature and humidity targets and that we cannot discern with confidence the exact effect of this fault on cooling capacity and power usage. However, during this test the power usage was as high as ~3.7kW, which is approximately a 50% increase over baseline, which may provide some indication as to the severity of the fault.

For more information on why this fault was not able to stabilise see Appendix D.

13.2 Effect of Modified Charge

A charge of 60% of the normal charge has the expected effect of reducing both cooling capacity and power usage. The drop in cooling capacity was ~40% over baseline and the drop in power usage was ~10% over baseline.

Further, a charge of 80% also had the expected effect of reducing cooling capacity and power usage. The drop in cooling capacity was ~26% over baseline and the drop in power usage was ~6% over baseline.

A charge of 120% had the opposite effect, with an increase in both cooling capacity and power usage. The increase in cooling capacity was ~1.4% over baseline and the increase in power usage was ~7% over baseline.

These results are summarised below in Table 7.

Table 7 - Comparison of the relative change in cooling capacity, compressor power and EER against baseline for all faults

Test	Test Conditions	% Change in Cooling Capacity (kW)	% Change in Compressor Power (kW)
1	Baseline	-	-
2	F-C1 - 50% Blockage	-0.053%	4.954%
3	F-C2 - 75% Blockage *	-57.463%	-37.616%
4	F-R1 - 80% Charge	-25.736%	-5.719%
5	F-R2 - 60% Charge	-39.418%	-10.109%
6	F-R3 - 120% Charge	1.349%	6.806%

**** Fault condition caused unit shutdown (high head pressure).***

13.3 Comparison of Test Conditions

To better understand the test conditions, a comparison between tests run at 100% charge (baseline) for T1, T2 and T3 are shown below.

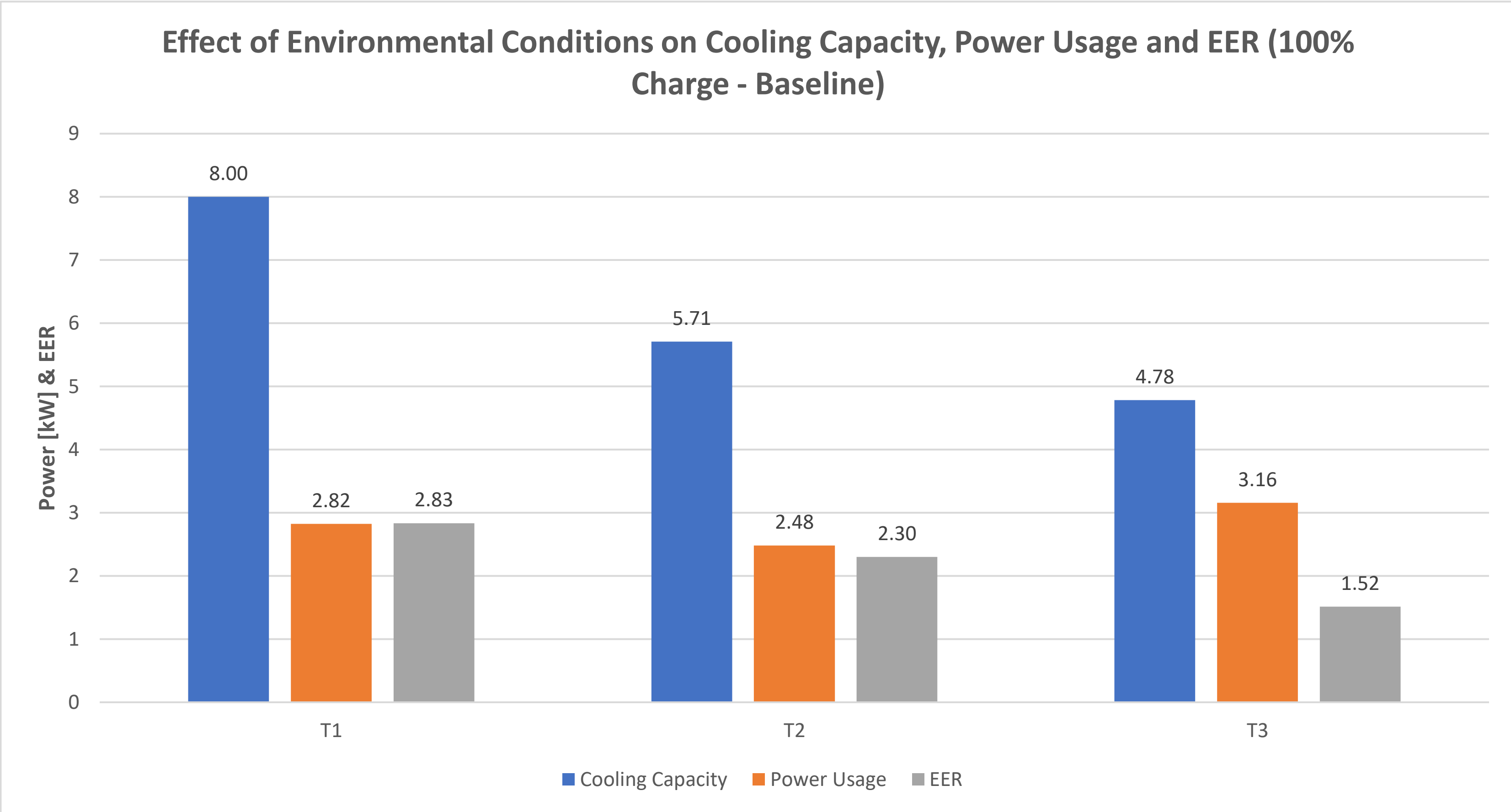

Figure 2 - Comparison of T1, T2 and T3 conditions for baseline test

The device under test (and most devices in the Australian market) has its energy rating tested at MEPS T1 conditions, it is therefore unsurprising that it performs best in this category.

The unit is not designed for T3 conditions so underperformance in this area is not surprising. T2 is surprising as it is a condition that the unit is far more likely to operate in. Figure 3 and Figure 4 below shows the frequency of the maximum temperature throughout the year 2020 in Melbourne CBD and Brisbane CBD.

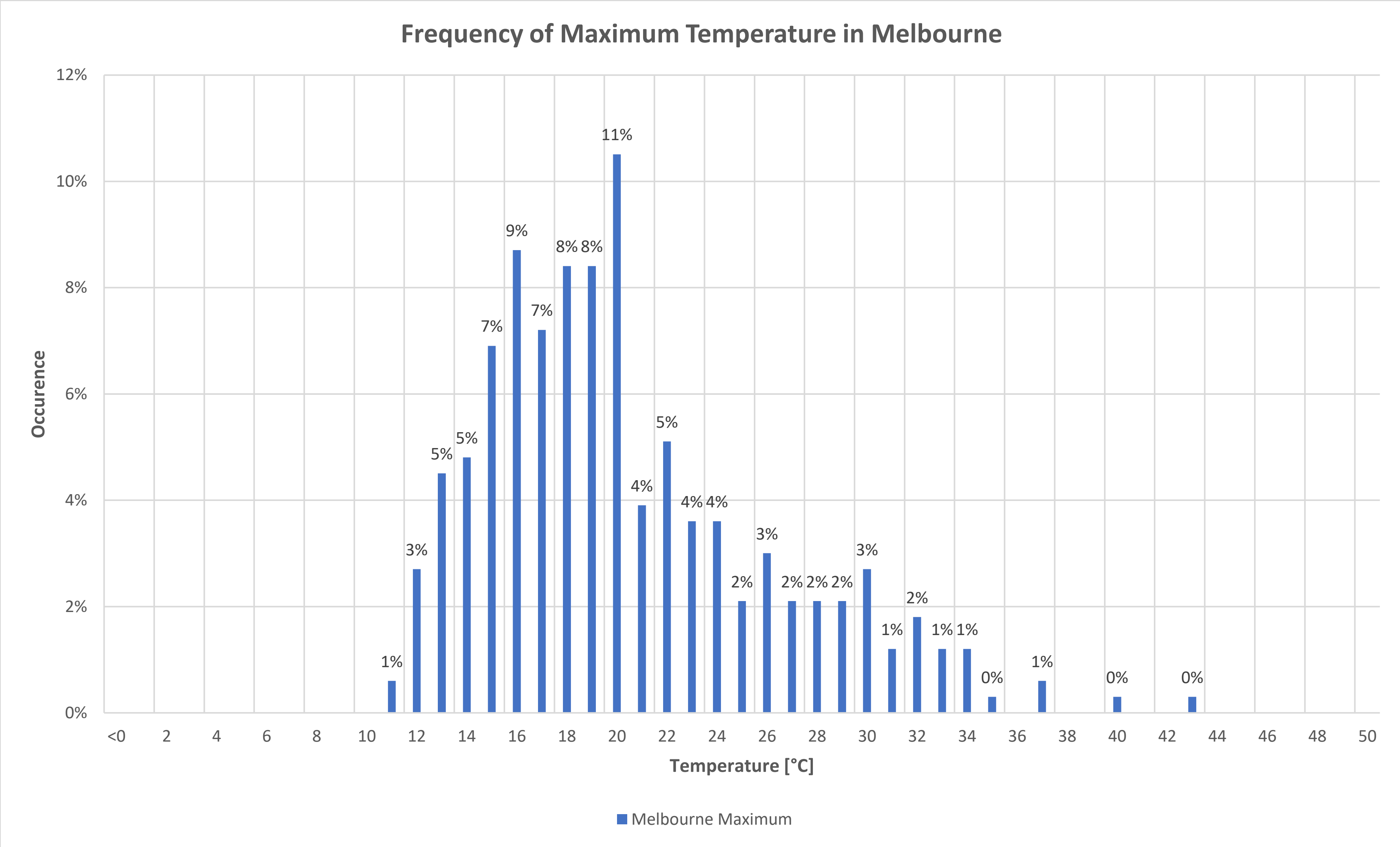

Figure 3 - Frequency of maximum temperature in Melbourne

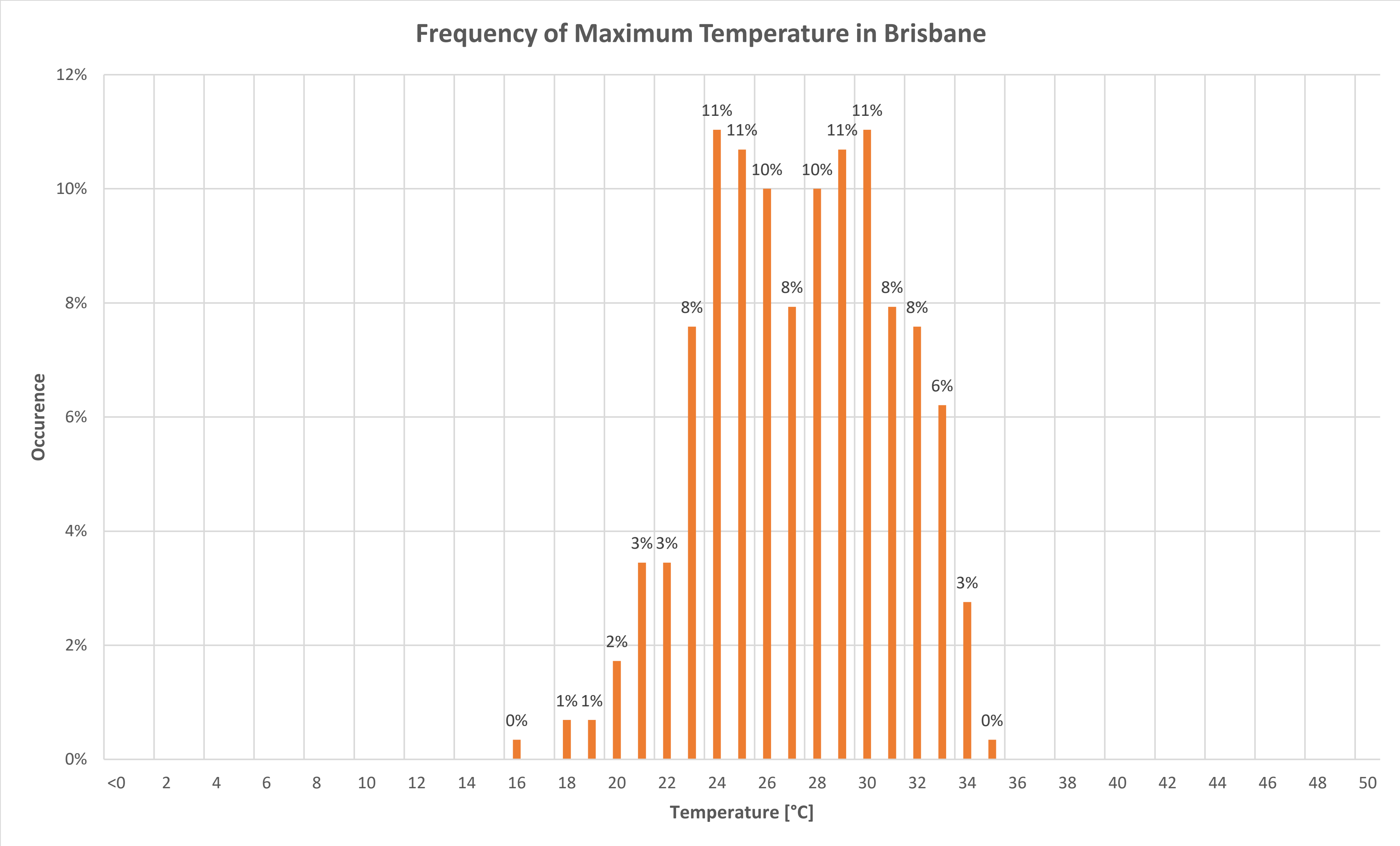

Figure 4 - Frequency of maximum temperature in Brisbane

As a reminder, the table below shows the outdoor temperature of each condition.

Table 8 - Summary of MEPS T1, T2 and T3 outdoor temperatures

Condition	Outdoor Temperature
T1	35°C
T2	27°C
T3	46°C

As we can see above, the unit (at least in the locations described above) is far more likely to operate in a T2 condition than a T1 or T3 condition.

This is not intended to be an exhaustive analysis of the operating conditions of air conditioning system, but rather intends to add context to the results.

14 Conclusion

Faults F-C2 (75% blockage), F-R1 (80% charge) and F-R2 (60% charge) had a very significant impact on the system with severe reductions in cooling capacity. It is the opinion of the authors that these faults would become evident to the equipment owner quickly in the form of increased room temperatures. However, seeing as these tests were conducted at constant temperature and not constant heat load it is not certain the exact effect of this on an occupied room.

Faults F-C1 (50% blockage) and F-R3 (120% charge) were found to be more “sinister” in their effect as the negligible reduction in cooling capacity would not make the fault evident to the equipment owner, but the not insignificant increase in power usage impacts the owner in the long term in the form of increased running costs.

Based on a rudimentary analysis of the frequency of maximum temperature between two major cities in Australia, it can be concluded that the T2 conditions are the most common operating conditions, suggesting that the negative impacts of fault F-C1 and F-R3 mentioned above have far reaching impacts. Further analysis in this area is advised before drawing any hard conclusions.

15 Further Work

The results above reveal changes in cooling capacity of 0.2%. It is the opinion of this author that this change in cooling capacity would not be noticeable by an equipment owner. However, whilst this is based on sound intuition, further work could be conducted to quantify the effect of cooling capacity on indoor room temperature to identify at what point a change in cooling capacity becomes apparent to the equipment owner. This test should be conducted at constant heat load and not constant temperature across a range of heat loads and cooling capacities.

From the results above we find that a 75% blocked coil is a significant blockage such that it caused the unit to trip out on high head pressure. Further testing could be conducted to test different amounts of blockages to identify the point at which a blockage becomes noticeable.

16 Appendix A – Test Data

Table 9 - Test Data for 100% Charge (Baseline)

Item	Description		Units	Test Results
1	Product type			Air Conditioner (AC)
2	Product sub-type 1			Ducted Systems, <10kW
3	Product sub-type 2			Ducted split system
4	Product brand			Withheld
5	Product model (outdoor unit)			Withheld
6	UUT serial number (outdoor)			Withheld
7	Product model (indoor unit)			Withheld
8	UUT serial number (indoor)			Withheld
9	UUT rated supply voltage		V	230
10	Refrigerant			R410a
11	Refrigerant charge		kg	3.2kg (100%)
12	Inverter setting/Compressor Speed			Not applicable
13	Date of test			8/03/2022
14	Test officer			Ian Nankivell
15	Test mode			Cooling
16	Test type			Cooling Capacity
17	Nominal test condition			T2
18	Test room type indoor equipment			Calorimeter
19	Test room type outdoor equipment			Calorimeter
20	Test standard(s)			AS/NZS3823.1.2:2012
21	Fan speed settings, indoor			High
22	Fan speed settings, outdoor			Not applicable
23	Supply air louvre position			Not applicable
24	Stabilisation period		min	>60 minutes
25	Test period		min	60
26	Reading frequency for measurements		s	10
	Indoor Room Temperature			
27		Target	°C	21
28		Mean	°C	20.988
29		Maximum Variation from Setpoint	°C	0.120
	Indoor Room Humidity			
30		Target	%	53
31		Mean	%	53.007
32		Maximum Variation from Setpoint	%	0.387
	Outdoor Room Temperature			

Item	Description		Units	Test Results
33		Target	°C	27
34		Mean	°C	27.006
35		Maximum Variation from Setpoint	°C	0.444
	Indoor Room Total Cooling Capacity			
36		Mean	W	5708.499
37		Maximum Variation	W	257.847
	Indoor Room Sensible Cooling Capacity			
38		Mean	W	5126.837
39		Maximum Variation	W	98.822
	Indoor Room Latent Cooling Capacity			
40		Mean	W	581.662
41		Maximum Variation	W	167.290
	Supply Voltage L1-N / L2-N / L3-N			
42		Mean	V	232 / 0 / 0
43		Maximum Variation	V	4.878 / 0 / 0
	Supply Power L1-N / L2-N / L3-N			
44		Mean	V	2483.457 / 0 / 0
45		Maximum Variation	V	81.004 / 0 / 0
	Energy Efficiency Ratio (EER) or Coefficient of Performance (CoP)			
46		Mean	kW/kW	2.299
47		Maximum Variation	kW/kW	0.118
	Evaporator Air Velocity			
48		Mean	m/s	1.600
49		Maximum Variation	m/s	0.100
50	Duct Area at Air Velocity Probe		m^2	0.292
	Evaporator Air Entry Temperature			
51		Mean	°C	20.327
52		Maximum Variation	°C	0.172
	Evaporator Air Exit Temperature			
53		Mean	°C	11.410
54		Maximum Variation	°C	0.163
	Condenser Air Entry Temperature			
55		Mean	°C	24.987
56		Maximum Variation	°C	1.159

Item	Description		Units	Test Results
	Condenser Air Exit Temperature			
57		Mean	°C	34.639
58		Maximum Variation	°C	1.143
	Suction Line Pressure			
59		Mean	kPa	1024.342
60		Maximum Variation	kPa	25.419
	Suction Line Temperature			
61		Mean	°C	25.353
62		Maximum Variation	°C	0.800
	Discharge Line Pressure			
63		Mean	kPa	3036.157
64		Maximum Variation	kPa	114.042
	Discharge Line Temperature			
65		Mean	°C	70.993
66		Maximum Variation	°C	1.500
	Liquid Line Pressure			
67		Mean	kPa	2822.516
68		Maximum Variation	kPa	121.736
	Liquid Line Temperature			
69		Mean	°C	34.012
70		Maximum Variation	°C	1.700
	Vapour Line Pressure			
71		Mean	kPa	1398.421
72		Maximum Variation	kPa	39.365
	Vapour Line Temperature			
73		Mean	°C	19.315
74		Maximum Variation	°C	1.000

Table 10 - Test Data for 50% Blockage (F-C1)

Item	Description		Units	Test Results
1	Product type			Air Conditioner (AC)
2	Product sub-type 1			Ducted Systems, <10kW
3	Product sub-type 2			Ducted split system
4	Product brand			Withheld
5	Product model (outdoor unit)			Withheld
6	UUT serial number (outdoor)			Withheld
7	Product model (indoor unit)			Withheld
8	UUT serial number (indoor)			Withheld
9	UUT rated supply voltage		V	230
10	Refrigerant			R410a
11	Refrigerant charge		kg	3.2kg (100%)

Item	Description		Units	Test Results
12	Inverter setting/Compressor Speed			Not applicable
13	Date of test			9/03/2022
14	Test officer			Ian Nankivell
15	Test mode			Cooling
16	Test type			Cooling Capacity
17	Nominal test condition			T2
18	Test room type indoor equipment			Calorimeter
19	Test room type outdoor equipment			Calorimeter
20	Test standard(s)			AS/NZS3823.1.2:2012
21	Fan speed settings, indoor			High
22	Fan speed settings, outdoor			Not applicable
23	Supply air louvre position			Not applicable
24	Stabilisation period		min	>60 minutes
25	Test period		min	60
26	Reading frequency for measurements		s	10
	Indoor Room Temperature			
27		Target	°C	21
28		Mean	°C	20.995
29		Maximum Variation from Setpoint	°C	0.232
	Indoor Room Humidity			
30		Target	%	53
31		Mean	%	53.012
32		Maximum Variation from Setpoint	%	0.509
	Outdoor Room Temperature			
33		Target	°C	27
34		Mean	°C	26.951
35		Maximum Variation from Setpoint	°C	0.991
	Indoor Room Total Cooling Capacity			
36		Mean	W	5705.551
37		Maximum Variation	W	275.768
	Indoor Room Sensible Cooling Capacity			
38		Mean	W	5117.077
39		Maximum Variation	W	148.413
	Indoor Room Latent Cooling Capacity			
40		Mean	W	588.475
41		Maximum Variation	W	183.455

Item	Description		Units	Test Results
	Supply Voltage L1-N / L2-N / L3-N			
42		Mean	V	230.475 / 0 / 0
43		Maximum Variation	V	3.147 / 0 / 0
	Supply Power L1-N / L2-N / L3-N			
44		Mean	V	2606.843 / 0 / 0
45		Maximum Variation	V	171.44 / 0 / 0
	Energy Efficiency Ratio (EER) or Coefficient of Performance (CoP)			
46		Mean	kW/kW	2.190
47		Maximum Variation	kW/kW	0.215
	Evaporator Air Velocity			
48		Mean	m/s	1.600
49		Maximum Variation	m/s	0.100
50	Duct Area at Air Velocity Probe		m^2	0.292
	Evaporator Air Entry Temperature			
51		Mean	°C	20.318
52		Maximum Variation	°C	0.421
	Evaporator Air Exit Temperature			
53		Mean	°C	11.418
54		Maximum Variation	°C	0.325
	Condenser Air Entry Temperature			
55		Mean	°C	24.760
56		Maximum Variation	°C	2.386
	Condenser Air Exit Temperature			
57		Mean	°C	35.702
58		Maximum Variation	°C	2.453
	Suction Line Pressure			
59		Mean	kPa	1040.544
60		Maximum Variation	kPa	34.831
	Suction Line Temperature			
61		Mean	°C	24.571
62		Maximum Variation	°C	1.200
	Discharge Line Pressure			
63		Mean	kPa	3162.660
64		Maximum Variation	kPa	3422.771
	Discharge Line Temperature			
65		Mean	°C	71.766
66		Maximum Variation	°C	2.800

Item	Description		Units	Test Results
	Liquid Line Pressure			
67		Mean	kPa	2967.427
68		Maximum Variation	kPa	233.443
	Liquid Line Temperature			
69		Mean	°C	34.470
70		Maximum Variation	°C	3.300
	Vapour Line Pressure			
71		Mean	kPa	1415.247
72		Maximum Variation	kPa	51.044
	Vapour Line Temperature			
73		Mean	°C	19.164
74		Maximum Variation	°C	1.800

Table 11 - Test Data for 75% Blockage (F-C2)

Item	Description		Units	Test Results
1	Product type			Air Conditioner (AC)
2	Product sub-type 1			Ducted Systems, <10kW
3	Product sub-type 2			Ducted split system
4	Product brand			Withheld
5	Product model (outdoor unit)			Withheld
6	UUT serial number (outdoor)			Withheld
7	Product model (indoor unit)			Withheld
8	UUT serial number (indoor)			Withheld
9	UUT rated supply voltage		V	230
10	Refrigerant			R410a
11	Refrigerant charge		kg	3.2kg (100%)
12	Inverter setting/Compressor Speed			Not applicable
13	Date of test			9/03/2022
14	Test officer			Ian Nankivell
15	Test mode			Cooling
16	Test type			Cooling Capacity
17	Nominal test condition			T2
18	Test room type indoor equipment			Calorimeter
19	Test room type outdoor equipment			Calorimeter
20	Test standard(s)			AS/NZS3823.1.2:2012
21	Fan speed settings, indoor			High
22	Fan speed settings, outdoor			Not applicable
23	Supply air louvre position			Not applicable
24	Stabilisation period		min	>60 minutes
25	Test period		min	60

Item	Description		Units	Test Results
26	Reading frequency for measurements		s	10
	Indoor Room Temperature			
27		Target	°C	21
28		Mean	°C	21.200
29		Maximum Variation from Setpoint	°C	3.104
	Indoor Room Humidity			
30		Target	%	53
31		Mean	%	70.037
32		Maximum Variation from Setpoint	%	31.335
	Outdoor Room Temperature			
33		Target	°C	27
34		Mean	°C	25.851
35		Maximum Variation from Setpoint	°C	5.885
	Indoor Room Total Cooling Capacity			
36		Mean	W	2428.395
37		Maximum Variation	W	3339.421
	Indoor Room Sensible Cooling Capacity			
38		Mean	W	2130.531
39		Maximum Variation	W	3647.436
	Indoor Room Latent Cooling Capacity			
40		Mean	W	297.863
41		Maximum Variation	W	1119.604
	Supply Voltage L1-N / L2-N / L3-N			
42		Mean	V	236.175 / 0 / 0
43		Maximum Variation	V	12.061 / 0 / 0
	Supply Power L1-N / L2-N / L3-N			
44		Mean	V	1549.5 / 0 / 0
45		Maximum Variation	V	3717.305 / 0 / 0
	Energy Efficiency Ratio (EER) or Coefficient of Performance (CoP)			
46		Mean	kW/kW	2.036
47		Maximum Variation	kW/kW	26.217
	Evaporator Air Velocity			
48		Mean	m/s	1.600
49		Maximum Variation	m/s	0.100
50	Duct Area at Air Velocity Probe		m^2	0.292

Item	Description		Units	Test Results
	Evaporator Air Entry Temperature			
51		Mean	°C	20.465
52		Maximum Variation	°C	6.009
	Evaporator Air Exit Temperature			
53		Mean	°C	16.733
54		Maximum Variation	°C	10.084
	Condenser Air Entry Temperature			
55		Mean	°C	25.664
56		Maximum Variation	°C	9.751
	Condenser Air Exit Temperature			
57		Mean	°C	35.628
58		Maximum Variation	°C	17.942
	Suction Line Pressure			
59		Mean	kPa	1350.307
60		Maximum Variation	kPa	821.102
	Suction Line Temperature			
61		Mean	°C	37.273
62		Maximum Variation	°C	20.300
	Discharge Line Pressure			
63		Mean	kPa	3262.332
64		Maximum Variation	kPa	2341.090
	Discharge Line Temperature			
65		Mean	°C	71.820
66		Maximum Variation	°C	62.200
	Liquid Line Pressure			
67		Mean	kPa	3242.432
68		Maximum Variation	kPa	2218.941
	Liquid Line Temperature			
69		Mean	°C	36.730
70		Maximum Variation	°C	25.500
	Vapour Line Pressure			
71		Mean	kPa	1543.255
72		Maximum Variation	kPa	364.179
	Vapour Line Temperature			
73		Mean	°C	24.392
74		Maximum Variation	°C	9.900

Table 12 - Test Data for 80% Charge (F-R1)

Item	Description		Units	Test Results
1	Product type			Air Conditioner (AC)
2	Product sub-type 1			Ducted Systems, <10kW
3	Product sub-type 2			Ducted split system
4	Product brand			Withheld
5	Product model (outdoor unit)			Withheld
6	UUT serial number (outdoor)			Withheld
7	Product model (indoor unit)			Withheld
8	UUT serial number (indoor)			Withheld
9	UUT rated supply voltage		V	230
10	Refrigerant			R410a
11	Refrigerant charge		kg	2.54kg (80%)
12	Inverter setting/Compressor Speed			Not applicable
13	Date of test			8/03/2022
14	Test officer			Ian Nankivell
15	Test mode			Cooling
16	Test type			Cooling Capacity
17	Nominal test condition			T2
18	Test room type indoor equipment			Calorimeter
19	Test room type outdoor equipment			Calorimeter
20	Test standard(s)			AS/NZS3823.1.2:2012
21	Fan speed settings, indoor			High
22	Fan speed settings, outdoor			Not applicable
23	Supply air louvre position			Not applicable
24	Stabilisation period		min	>60 minutes
25	Test period		min	60
26	Reading frequency for measurements		s	10
	Indoor Room Temperature			
27		Target	°C	21
28		Mean	°C	21.004
29		Maximum Variation from Setpoint	°C	0.173
	Indoor Room Humidity			
30		Target	%	53
31		Mean	%	53.004
32		Maximum Variation from Setpoint	%	0.314
	Outdoor Room Temperature			
33		Target	°C	27
34		Mean	°C	26.934

Item	Description		Units	Test Results
35		Maximum Variation from Setpoint	°C	1.070
	Indoor Room Total Cooling Capacity			
36		Mean	W	4239.193
37		Maximum Variation	W	372.057
	Indoor Room Sensible Cooling Capacity			
38		Mean	W	3812.526
39		Maximum Variation	W	154.881
	Indoor Room Latent Cooling Capacity			
40		Mean	W	426.667
41		Maximum Variation	W	389.394
	Supply Voltage L1-N / L2-N / L3-N			
42		Mean	V	231.313 / 0 / 0
43		Maximum Variation	V	2.922 / 0 / 0
	Supply Power L1-N / L2-N / L3-N			
44		Mean	V	2341.838 / 0 / 0
45		Maximum Variation	V	175.878 / 0 / 0
	Energy Efficiency Ratio (EER) or Coefficient of Performance (CoP)			
46		Mean	kW/kW	1.811
47		Maximum Variation	kW/kW	0.202
	Evaporator Air Velocity			
48		Mean	m/s	1.600
49		Maximum Variation	m/s	0.100
50	Duct Area at Air Velocity Probe		m^2	0.292
	Evaporator Air Entry Temperature			
51		Mean	°C	20.459
52		Maximum Variation	°C	0.253
	Evaporator Air Exit Temperature			
53		Mean	°C	13.828
54		Maximum Variation	°C	0.174
	Condenser Air Entry Temperature			
55		Mean	°C	24.947
56		Maximum Variation	°C	2.868
	Condenser Air Exit Temperature			
57		Mean	°C	32.591

Item	Description		Units	Test Results
58		Maximum Variation	°C	2.858
	Suction Line Pressure			
59		Mean	kPa	880.412
60		Maximum Variation	kPa	57.158
	Suction Line Temperature			
61		Mean	°C	28.957
62		Maximum Variation	°C	0.800
	Discharge Line Pressure			
63		Mean	kPa	2797.509
64		Maximum Variation	kPa	262.159
	Discharge Line Temperature			
65		Mean	°C	77.031
66		Maximum Variation	°C	2.900
	Liquid Line Pressure			
67		Mean	kPa	2595.637
68		Maximum Variation	kPa	274.663
	Liquid Line Temperature			
69		Mean	°C	33.836
70		Maximum Variation	°C	3.600
	Vapour Line Pressure			
71		Mean	kPa	1239.759
72		Maximum Variation	kPa	95.081
	Vapour Line Temperature			
73		Mean	°C	16.003
74		Maximum Variation	°C	2.600

Table 13 - Test Data for 60% Charge (F-R2)

Item	Description		Units	Test Results
1	Product type			Air Conditioner (AC)
2	Product sub-type 1			Ducted Systems, <10kW
3	Product sub-type 2			Ducted split system
4	Product brand			Withheld
5	Product model (outdoor unit)			Withheld
6	UUT serial number (outdoor)			Withheld
7	Product model (indoor unit)			Withheld
8	UUT serial number (indoor)			Withheld
9	UUT rated supply voltage		V	230
10	Refrigerant			R410a
11	Refrigerant charge		kg	1.92kg (60%)
12	Inverter setting/Compressor Speed			Not applicable

Item	Description		Units	Test Results
13	Date of test			7/03/2022
14	Test officer			Ian Nankivell
15	Test mode			Cooling
16	Test type			Cooling Capacity
17	Nominal test condition			T2
18	Test room type indoor equipment			Calorimeter
19	Test room type outdoor equipment			Calorimeter
20	Test standard(s)			AS/NZS3823.1.2:2012
21	Fan speed settings, indoor			High
22	Fan speed settings, outdoor			Not applicable
23	Supply air louvre position			Not applicable
24	Stabilisation period		min	>60 minutes
25	Test period		min	60
26	Reading frequency for measurements		s	10
	Indoor Room Temperature			
27		Target	°C	21
28		Mean	°C	21.015
29		Maximum Variation from Setpoint	°C	0.232
	Indoor Room Humidity			
30		Target	%	53
31		Mean	%	53.024
32		Maximum Variation from Setpoint	%	0.297
	Outdoor Room Temperature			
33		Target	°C	27
34		Mean	°C	26.976
35		Maximum Variation from Setpoint	°C	0.874
	Indoor Room Total Cooling Capacity			
36		Mean	W	3458.937
37		Maximum Variation	W	10258.996
	Indoor Room Sensible Cooling Capacity			
38		Mean	W	3027.501
39		Maximum Variation	W	384.508
	Indoor Room Latent Cooling Capacity			
40		Mean	W	431.437
41		Maximum Variation	W	10209.405
	Supply Voltage L1-N / L2-N / L3-N			

Item	Description		Units	Test Results
42		Mean	V	231.876 / 0 / 0
43		Maximum Variation	V	4.541 / 0 / 0
	Supply Power L1-N / L2-N / L3-N			
44		Mean	V	2233.06 / 0 / 0
45		Maximum Variation	V	208.335 / 0 / 0
	Energy Efficiency Ratio (EER) or Coefficient of Performance (CoP)			
46		Mean	kW/kW	1.550
47		Maximum Variation	kW/kW	4.663
	Evaporator Air Velocity			
48		Mean	m/s	1.600
49		Maximum Variation	m/s	0.100
50	Duct Area at Air Velocity Probe		m^2	0.292
	Evaporator Air Entry Temperature			
51		Mean	°C	20.611
52		Maximum Variation	°C	0.264
	Evaporator Air Exit Temperature			
53		Mean	°C	15.346
54		Maximum Variation	°C	0.492
	Condenser Air Entry Temperature			
55		Mean	°C	25.202
56		Maximum Variation	°C	2.459
	Condenser Air Exit Temperature			
57		Mean	°C	31.514
58		Maximum Variation	°C	3.188
	Suction Line Pressure			
59		Mean	kPa	718.743
60		Maximum Variation	kPa	878.604
	Suction Line Temperature			
61		Mean	°C	31.500
62		Maximum Variation	°C	0.900
	Discharge Line Pressure			
63		Mean	kPa	2643.965
64		Maximum Variation	kPa	309.287
	Discharge Line Temperature			
65		Mean	°C	85.259
66		Maximum Variation	°C	2.700
	Liquid Line Pressure			
67		Mean	kPa	2445.028

Item	Description		Units	Test Results
68		Maximum Variation	kPa	285.655
	Liquid Line Temperature			
69		Mean	°C	34.103
70		Maximum Variation	°C	4.000
	Vapour Line Pressure			
71		Mean	kPa	1143.134
72		Maximum Variation	kPa	129.225
	Vapour Line Temperature			
73		Mean	°C	14.026
74		Maximum Variation	°C	3.300

Table 14 - Test Data for 120% Charge (F-R3)

Item	Description		Units	Test Results
1	Product type			Air Conditioner (AC)
2	Product sub-type 1			Ducted Systems, <10kW
3	Product sub-type 2			Ducted split system
4	Product brand			Withheld
5	Product model (outdoor unit)			Withheld
6	UUT serial number (outdoor)			Withheld
7	Product model (indoor unit)			Withheld
8	UUT serial number (indoor)			Withheld
9	UUT rated supply voltage		V	230
10	Refrigerant			R410a
11	Refrigerant charge		kg	3.84kg (120%)
12	Inverter setting/Compressor Speed			Not applicable
13	Date of test			10/03/2022
14	Test officer			Ian Nankivell
15	Test mode			Cooling
16	Test type			Cooling Capacity
17	Nominal test condition			T2
18	Test room type indoor equipment			Calorimeter
19	Test room type outdoor equipment			Calorimeter
20	Test standard(s)			AS/NZS3823.1.2:2012
21	Fan speed settings, indoor			High
22	Fan speed settings, outdoor			Not applicable
23	Supply air louvre position			Not applicable
24	Stabilisation period		min	>60 minutes
25	Test period		min	60
26	Reading frequency for measurements		s	10

Item	Description		Units	Test Results
	Indoor Room Temperature			
27		Target	°C	21
28		Mean	°C	21.007
29		Maximum Variation from Setpoint	°C	0.271
	Indoor Room Humidity			
30		Target	%	53
31		Mean	%	53.010
32		Maximum Variation from Setpoint	%	0.419
	Outdoor Room Temperature			
33		Target	°C	27
34		Mean	°C	26.988
35		Maximum Variation from Setpoint	°C	0.503
	Indoor Room Total Cooling Capacity			
36		Mean	W	5785.219
37		Maximum Variation	W	254.452
	Indoor Room Sensible Cooling Capacity			
38		Mean	W	5152.219
39		Maximum Variation	W	156.319
	Indoor Room Latent Cooling Capacity			
40		Mean	W	633.000
41		Maximum Variation	W	170.287
	Supply Voltage L1-N / L2-N / L3-N			
42		Mean	V	231.069 / 0 / 0
43		Maximum Variation	V	5.656 / 0 / 0
	Supply Power L1-N / L2-N / L3-N			
44		Mean	V	2652.858 / 0 / 0
45		Maximum Variation	V	107.635 / 0 / 0
	Energy Efficiency Ratio (EER) or Coefficient of Performance (CoP)			
46		Mean	kW/kW	2.181
47		Maximum Variation	kW/kW	0.148
	Evaporator Air Velocity			
48		Mean	m/s	1.600
49		Maximum Variation	m/s	0.100
50	Duct Area at Air Velocity Probe		m^2	0.292
	Evaporator Air Entry Temperature			

Item	Description		Units	Test Results
51		Mean	°C	20.314
52		Maximum Variation	°C	0.427
	Evaporator Air Exit Temperature			
53		Mean	°C	11.352
54		Maximum Variation	°C	0.323
	Condenser Air Entry Temperature			
55		Mean	°C	24.888
56		Maximum Variation	°C	1.385
	Condenser Air Exit Temperature			
57		Mean	°C	34.796
58		Maximum Variation	°C	1.303
	Suction Line Pressure			
59		Mean	kPa	1024.503
60		Maximum Variation	kPa	24.526
	Suction Line Temperature			
61		Mean	°C	24.285
62		Maximum Variation	°C	1.100
	Discharge Line Pressure			
63		Mean	kPa	3249.264
64		Maximum Variation	kPa	135.339
	Discharge Line Temperature			
65		Mean	°C	73.292
66		Maximum Variation	°C	1.800
	Liquid Line Pressure			
67		Mean	kPa	3100.539
68		Maximum Variation	kPa	125.309
	Liquid Line Temperature			
69		Mean	°C	34.049
70		Maximum Variation	°C	2.000
	Vapour Line Pressure			
71		Mean	kPa	1359.401
72		Maximum Variation	kPa	26.793
	Vapour Line Temperature			
73		Mean	°C	18.127
74		Maximum Variation	°C	1.000

17 Appendix B – Rating Scales

To further increase the readability of this report for non-technical audiences, a rating label system is used to align relative percentage changes in a performance metric to a commonly understood label.

Table 15 - Rating Label System

Rating Label	% Change
Negligible	< 2%
Significant	2-10%
Moderate	10-25%
High	25-50%
Extreme	> 50%

If a metric falls on a value between two rating labels, then the lower rating label shall be used.

18 Appendix C – Calculations of Results

Mean – Average of all values.

Maximum Variation from Setpoint – Difference between the highest or lowest value and the setpoint, whichever is larger in magnitude.

Maximum Variation – Difference between the highest and lowest value.

Total Cooling Capacity = Sensible Cooling Capacity + Latent Cooling Capacity

Sensible Cooling Capacity = $c_p * \rho * q * dt$

Latent Cooling Capacity = $\rho * h_{we} * q * dw_{kg}$

Energy Efficiency Ratio (EER) = $\frac{Total\ Cooling\ Capacity}{Total\ Power\ to\ Compressor}$

19 Appendix D – Operation of Test Rooms

The CRDHTF test rooms are cooling only calorimeter rooms with separate indoor and outdoor sections.

The outdoor test room is heated by the condenser of the device under test and if the temperature exceeds the setpoint then a 20kW chiller is used to cool the room.

The indoor test room is cooled by the evaporator of the device under test and if the temperature falls below the setpoint then a 12kW resistive heater is used to heat the room. The indoor test room controls humidity using a steam boiler that distributes steam into the indoor room as required.

Limitations

The outdoor test rooms rely on the device under test to reach the temperature required for testing. Under most circumstances this works well, but in severe high temperature conditions the device under test may not be able to reject enough heat into the room to meet the required setpoint temperature which can lead to significant setpoint errors.

The same concept applies to the indoor room but in reverse with respect to temperature and humidity. The test rooms will only add temperature and humidity, so if the device is not able to bring the temperature or humidity down to the required level then setpoint errors can result.

Constant Temperature Tests

Constant temperature tests use a PID controller to modify the indoor room temperature (by means of a resistive duct heater), indoor room humidity (by means of a steam generator) and outdoor room temperature (by means of an external chiller) as required to meet the desired setpoint.

These tests are used to calculate the maximum cooling capacity and compressor power in one specific set of conditions.

Constant Heat Load Tests

Constant heat load tests will provide a fixed amount of sensible heat load (by means of a resistive duct heater) and latent heat load (by means of a steam generator) regardless of the room temperature.

These tests are used to observe the effect of environmental conditions and loads on indoor room temperature and humidity.