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Effects of preventable faults on air-conditioning systems at T3

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Prepared for the Ozone and Climate Protection, Atmosphere and Reporting Branch, Environment Protection Division, Department of Climate Change, Energy, the Environment and Water

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The results of this report only apply to the specifically identified unit under test, under the conditions of the tests.

This test report does not extend to any modification of the system. This test report cannot be applied to another product.

Where test results are subject to a pass/fail criterion and the laboratory uncertainty of measurements may affect the outcome of the pass/fail decision, these results are noted with the pass or fail designation based on the measured results and accompanied with a notation that the pass/fail result is within the bounds and subject to the uncertainty of measurement of the laboratory.

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4 Introduction

As the title suggests, 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. This report aims to analyse 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. For example, a compressor failure would not be expected to produce a long-term impact on the owner as it would be noticed and remedied quickly.

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

Overall, the T3 test conditions were too harsh for the device under test, and this impacted the accuracy of the results. However, this report still gives insight into the trends and overall impacts of the faults.

A summary of the test conditions and the effect on cooling capacity and power usage is shown below. Appendix B gives insight into the rating label system and its correlation to percentage change in each value compared to baseline.

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	High Decrease	Significant Decrease
2	F-C2 - 75% Blockage *	High Decrease	Extreme Decrease
3	F-R1 - 80% Charge	High Decrease	Negligible Increase
4	F-R2 - 60% Charge	High Decrease	Significant Decrease
5	F-R3 - 120% Charge *	Moderate Increase	Moderate Decrease

**** F-C2 and F-R3 exceeded the safety pressure limits of the test device causing it to shutdown multiple times. The results of this test are unreliable.***

The key takeaways from these results are that the test conditions were too harsh for the device under test and most of the faults resulted in large changes in cooling capacity, usually a decrease. It is the authors opinion that all faults would be noticed immediately by the equipment owner and would likely be rectified as quickly. Interestingly, F-R3 (the overcharge condition) produced an increase in cooling capacity and a decrease in power usage. This would suggest that in this condition an overcharge would be preferential compared to the standard charge assuming that the system does not trip the high-pressure safety switch. It is unclear if continually adding charge would result in further increases in cooling capacity, but it is expected that a limit exists. This limit is expected to be reached by either no further increase in cooling capacity or a pressure limit.

8 Device Under Test

8.1 Information

Table 2 - Device Under Test Details

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 T3.

9.1 Test Condition 1

Table 3 – Test Conditions

Outdoor Room Temperature Setpoint	46°C
Indoor Room Temperature Setpoint	29°C
Indoor Room Humidity Setpoint	38%
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 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	T3	Cooling Capacity/EER	29°C Dry-bulb, 19°C Wet-bulb Indoor 46°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	4.784	3.157	1.52
2	F-C1 - 50% Blockage	3.113	2.880	1.08
3	F-C2 - 75% Blockage *	2.425	1.512	1.60
4	F-R1 - 80% Charge	3.481	3.175	1.10
5	F-R2 - 60% Charge	3.09	2.883	1.07
6	F-R3 - 120% Charge *	5.372	2.791	1.92

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

13 Analysis

When analysing the results, it is important to take note of the maximum variation values, which were not insignificant in some cases. Overall, the CRDHTF had difficulty in running the experiments due to the device under test not being able to function correctly with the severe high temperature test conditions. Even so, the results will show significant errors between the average indoor humidity and the target humidity. This is due to the test conditions “over-powering” the outdoor unit which severely hindered its ability to reject heat and thus strip humidity from the indoor room.

13.1 Effect of Blockages

During the baseline run the unit was having difficulty rejecting heat across the condenser coil. This is evident through the small differential temperature across the coil (mean differential temperature was 1.478°C). It should come as no surprise then that a 50% blockage of the coil reduced the effective cooling capacity by ~35%. The accompanying reduction in compressor power of ~9% was likely a result of the reduced differential pressure across the compressor, effectively reducing the load. This is supported by the results which show a 6.3% reduction in compressor differential pressure. Curiously both the suction and discharge pressure of the F-C1 test was lower than the baseline run even though the expectation was that the unit would operate at a higher pressure overall due to the blockage. It is possible that this discrepancy is a result of the electronic expansion valve which attempts to track a superheat of 12°C. An in-depth analysis of the cause of this effect is outside the scope of this report.

Similarly, the 75% blockage had the effect of reducing both cooling capacity and compressor power. However, in this scenario much of the reduction in both can be attributed to the unit tripping the high-pressure safety switch and turning off the compressor. It is difficult to draw accurate conclusions without a steady state test, but the results are still useful as they show the unit is unable to operate in these conditions with fault F-C2. Also, worth noting is both the cooling capacity and COP are skewed when the unit turns off as even though power usage drops to zero and the compressor turns off the thermal inertia of the evaporator still provides meaningful cooling capacity. During this circumstance EER is theoretically infinite. When analysing the results, this creates a divide by zero error which is handled by overriding EER to zero when compressor power is zero. The actual cooling capacity and EER is likely lower than reported here.

Figure 1 below shows this graphically. When power usage goes to zero, cooling capacity is still significant.

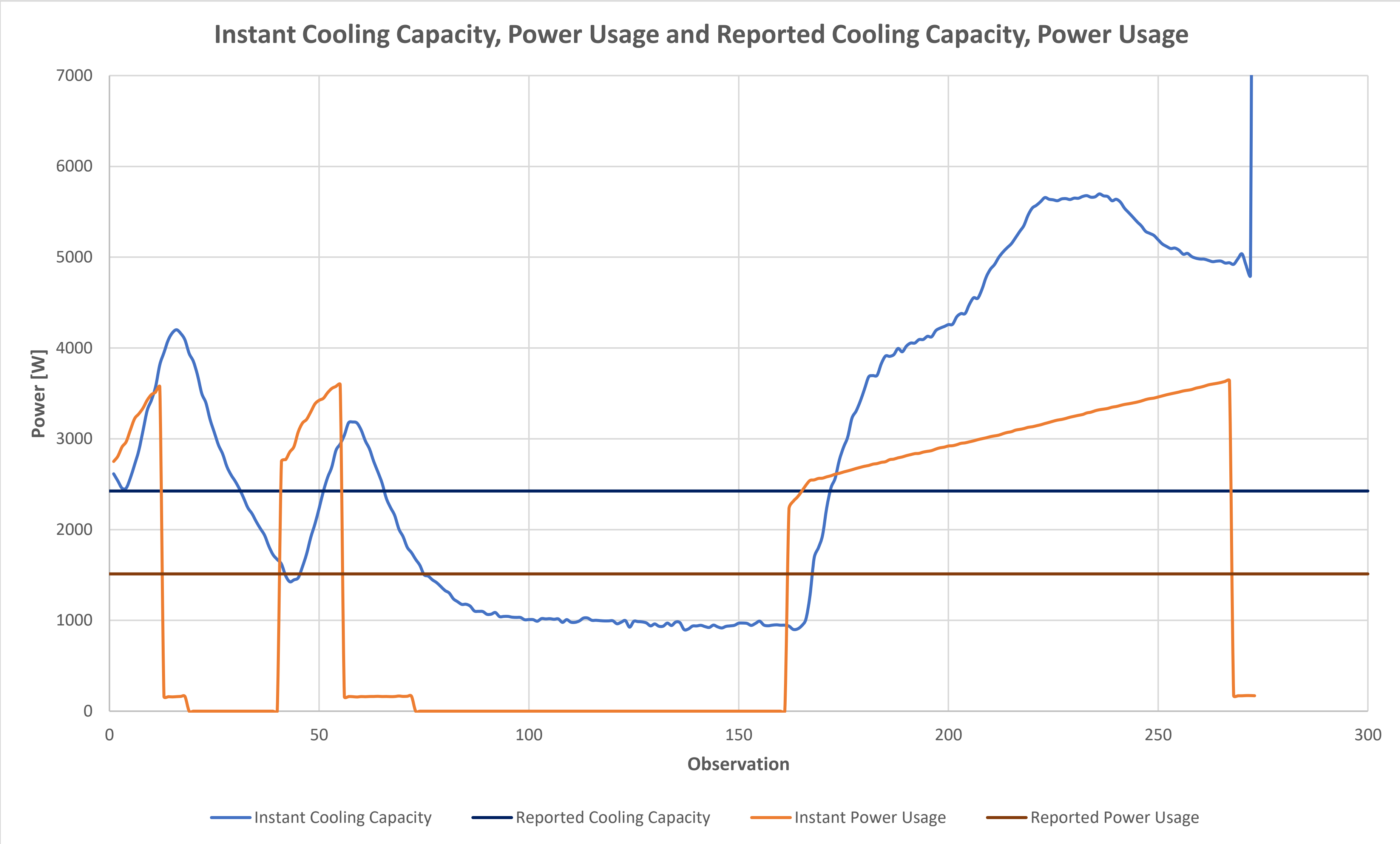

Figure 1 - Instant and Reported Cooling Capacity and Power Usage for F-C2 (75% Blockage)

13.2 Effect of Modified Charge

Both F-R1 and F-R2 (80% and 60% charge levels respectively) caused a very significant reduction in cooling capacity, however, only F-R2 had a significant reduction in power usage. Like above, a 6.4% reduction in compressor differential pressure could be attributed to the reduction in power usage for F-R2. F-R1 did not have a reduction in compressor differential pressure but rather an increase of 6.6%. This suggests that there are other factors contributing to compressor power that are not accounted for or that the inherent instability of the test and significant variations make this difficult to analyse.

Fault condition F-R3 (120% charge) had the opposite effect with a 19% increase in cooling capacity and 11.6% decrease in power usage. Compressor differential pressure was lower than baseline (7.1%) likely due to the increase in condenser cooling and large setpoint error during testing.

Although not evident from the results, F-R3 was very difficult to run as the increase in charge brought the overall system pressure up significantly which caused it to trip on high head pressure multiple times during testing. The results used for F-R3 were the most stable result set with the smallest setpoint error from all F-R3 tests. The reduction in power usage could be proportionally attributed to the instability of the test and the results should be used with caution.

The results may be better visualised using Figure 2 and Table 7 below.

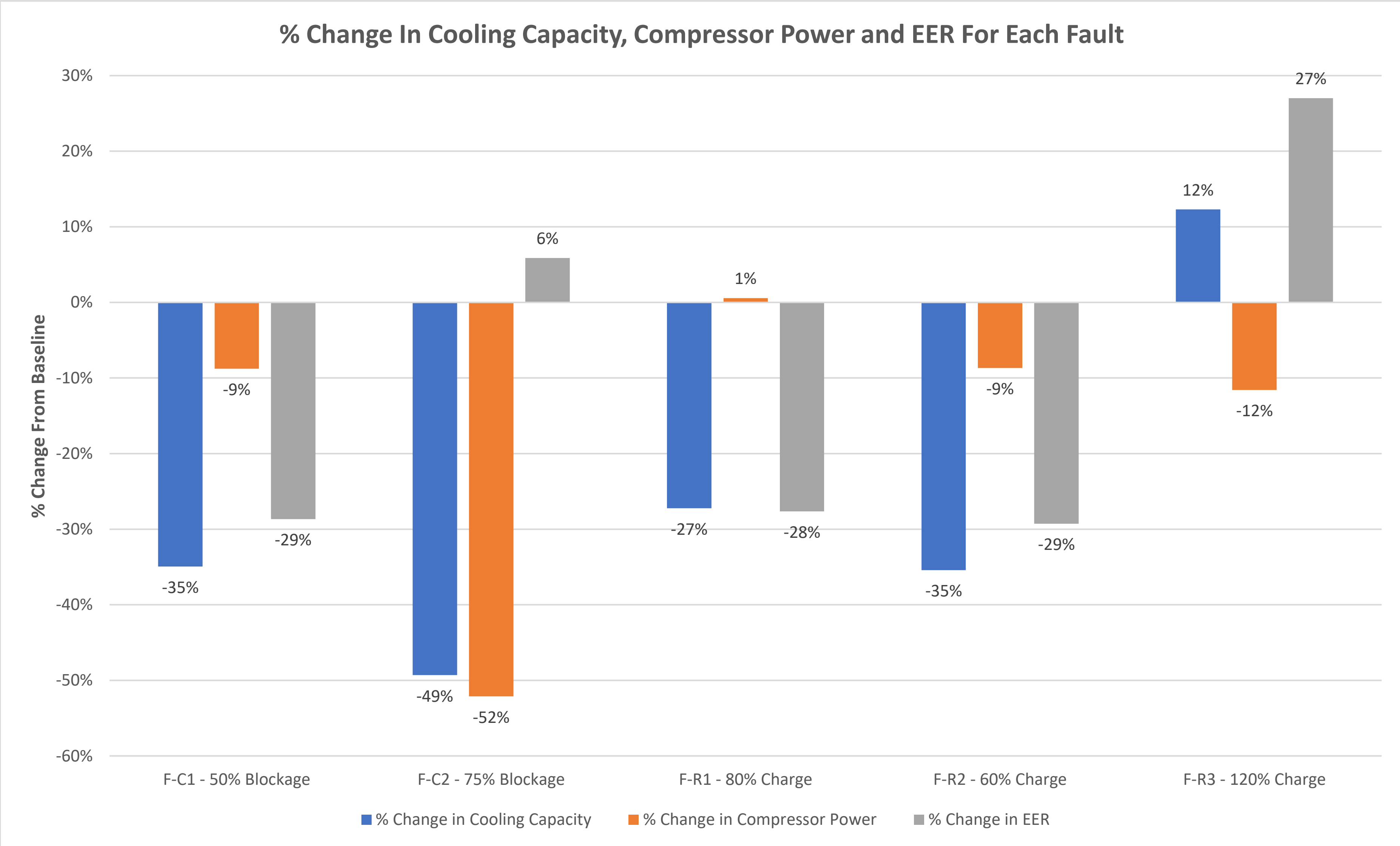

Figure 2 - Graphical summary of results

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)	% Change in EER
1	Baseline	-	-	-
2	F-C1 - 50% Blockage	-34.929%	-8.772%	-28.672%
3	F-C2 - 75% Blockage *	-49.310%	-52.121%	5.870%
4	F-R1 - 80% Charge	-27.237%	0.572%	-27.650%
5	F-R2 - 60% Charge	-35.410%	-8.678%	-29.272%
6	F-R3 - 120% Charge *	12.291%	-11.591%	27.013%

**** Fault condition caused unit shutdown (high head pressure). See notes for more information.***

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.

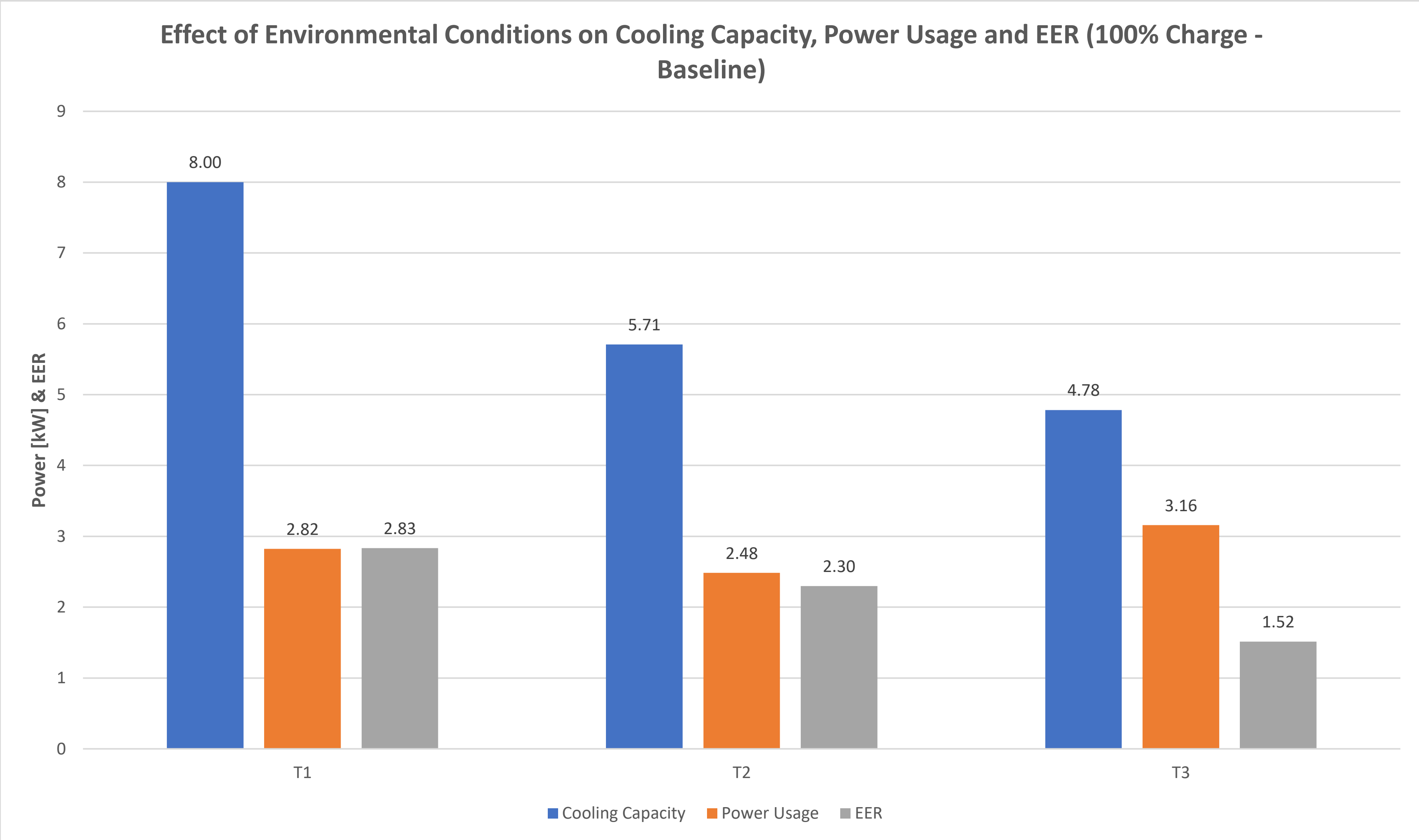

Figure 3 - Comparison of T1, T2 and T3 conditions at baseline

The device under test (and most devices in the Australian market) had 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 4 and Figure 5 below shows the frequency of the maximum temperature throughout the year 2020 in Melbourne CBD and Brisbane CBD

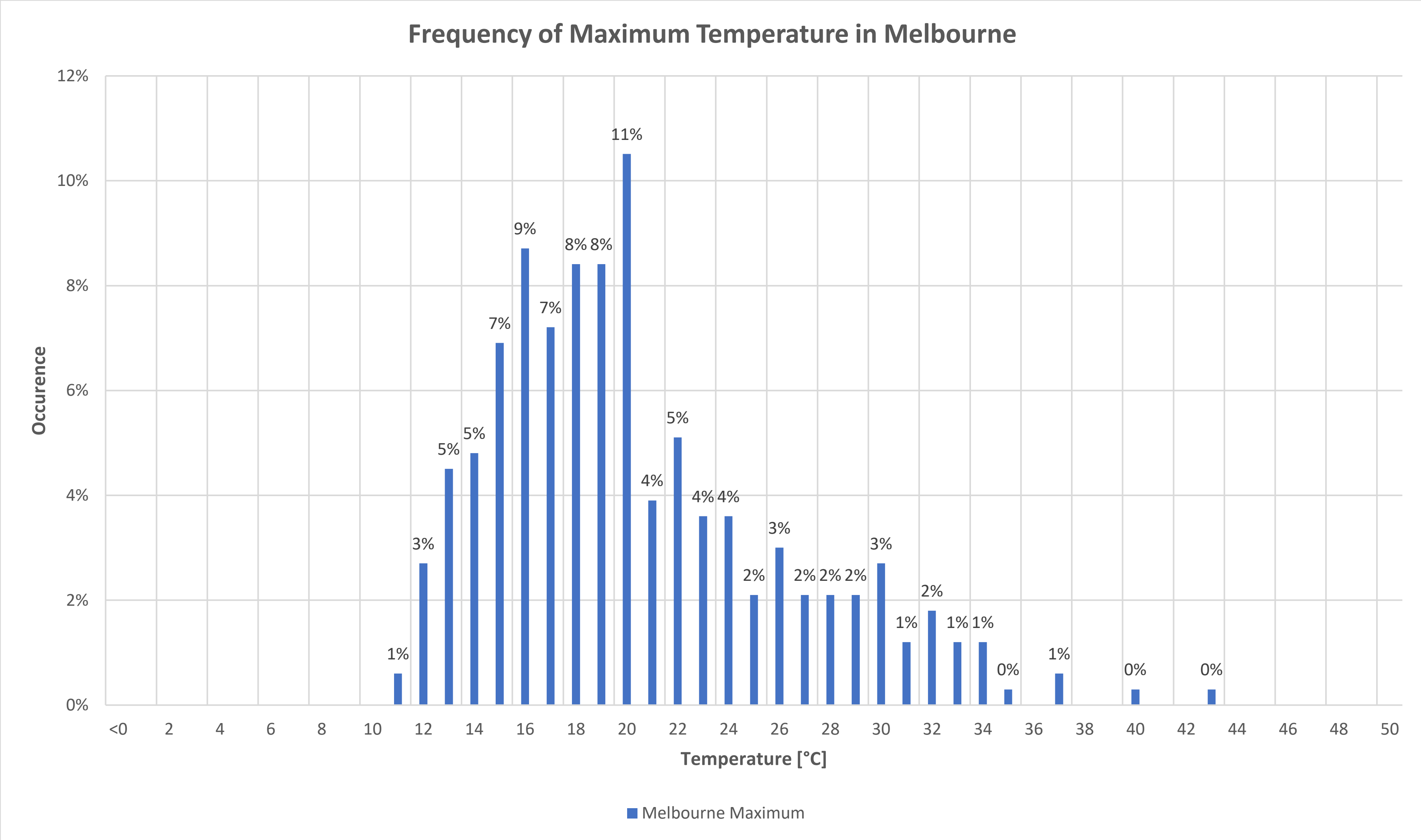

Figure 4 - Frequency of maximum temperature in Melbourne

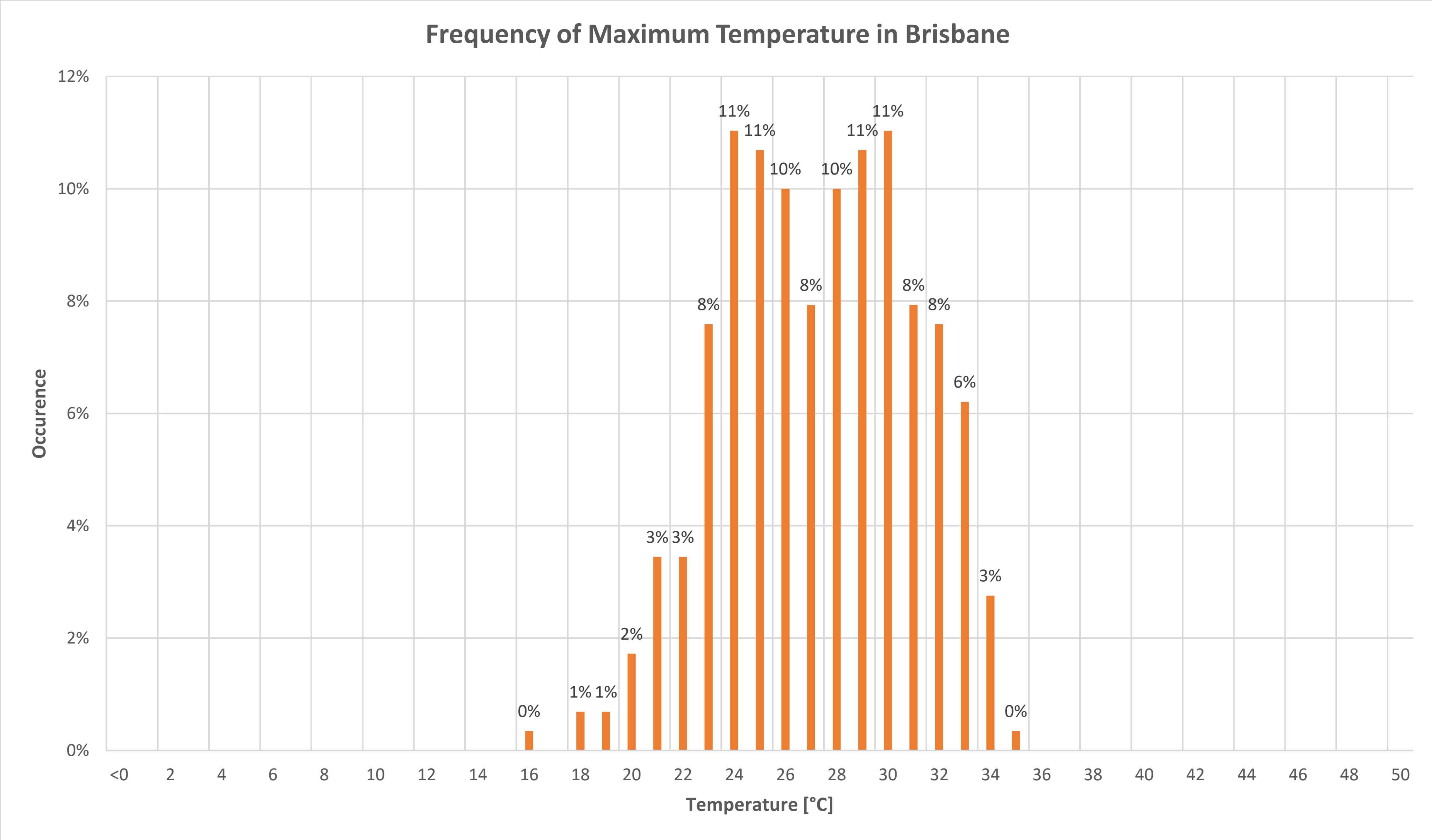

Figure 5 - Frequency of maximum temperature in Brisbane

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

In summary, these fault conditions, whilst severe, are expected to become apparent to the equipment owner very quickly and thus should be rectified quickly. The overall long-term impact on power usage and thus cost is expected to be small. However, operating in these conditions without the correct air-conditioning unit type would be expected to cause undue wear on the unit and shorten its operating life.

An overcharge condition is shown to increase the cooling capacity of the unit which may prove beneficial in these extreme conditions at the cost of unit stability (as a result of the high-pressure safety switch tripping). There is expected to be a limit to performance increases with increases in charge due to either an asymptotic “plateau” or system pressure.

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 real-world impact of T3 conditions is comparatively low on the basis that they are less likely to happen. Further analysis in this area is advised before drawing any hard conclusions.

15 Further Work

If the goal is to acquire further specific information (rather than overall trends) in T3 conditions, then it is suggested that the testing be conducted again on a unit rated specifically for T3 conditions.

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			15/04/2022
14	Test officer			Ian Nankivell
15	Test mode			Cooling
16	Test type			Cooling Capacity
17	Nominal test condition			T3
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	29
28		Mean	°C	29.020
29		Maximum Variation from Setpoint	°C	1.472
	Indoor Room Humidity			
30		Target	%	38
31		Mean	%	40.873
32		Maximum Variation from Setpoint	%	5.175

Item	Description		Units	Test Results
	Outdoor Room Temperature			
33		Target	°C	46
34		Mean	°C	46.290
35		Maximum Variation from Setpoint	°C	3.735
	Indoor Room Total Cooling Capacity			
36		Mean	W	4784.262
37		Maximum Variation	W	428.084
	Indoor Room Sensible Cooling Capacity			
38		Mean	W	3982.412
39		Maximum Variation	W	548.732
	Indoor Room Latent Cooling Capacity			
40		Mean	W	801.850
41		Maximum Variation	W	280.131
	Supply Voltage L1-N / L2-N / L3-N			
42		Mean	V	233.234 / 0 / 0
43		Maximum Variation	V	9.016 / 0 / 0
	Supply Power L1-N / L2-N / L3-N			
44		Mean	V	3157.104 / 0 / 0
45		Maximum Variation	V	975.654 / 0 / 0
	Energy Efficiency Ratio (EER) or Coefficient of Performance (CoP)			
46		Mean	kW/kW	1.533
47		Maximum Variation	kW/kW	0.548
	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	26.895
52		Maximum Variation	°C	3.711
	Evaporator Air Exit Temperature			
53		Mean	°C	19.969
54		Maximum Variation	°C	4.401
	Condenser Air Entry Temperature			
55		Mean	°C	39.331
56		Maximum Variation	°C	5.561
	Condenser Air Exit Temperature			
57		Mean	°C	40.809

Item	Description		Units	Test Results
58		Maximum Variation	°C	0.028
	Suction Line Pressure			
59		Mean	kPa	1113.017
60		Maximum Variation	kPa	139.804
	Suction Line Temperature			
61		Mean	°C	40.331
62		Maximum Variation	°C	6.800
	Discharge Line Pressure			
63		Mean	kPa	3799.182
64		Maximum Variation	kPa	1145.916
	Discharge Line Temperature			
65		Mean	°C	97.424
66		Maximum Variation	°C	14.600
	Liquid Line Pressure			
67		Mean	kPa	3591.973
68		Maximum Variation	kPa	1108.887
	Liquid Line Temperature			
69		Mean	°C	53.589
70		Maximum Variation	°C	12.900
	Vapour Line Pressure			
71		Mean	kPa	1564.016
72		Maximum Variation	kPa	267.174
	Vapour Line Temperature			
73		Mean	°C	27.792
74		Maximum Variation	°C	6.000

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%)
12	Inverter setting/Compressor Speed			Not applicable
13	Date of test			14/04/2022

Item	Description		Units	Test Results
14	Test officer			Ian Nankivell
15	Test mode			Cooling
16	Test type			Cooling Capacity
17	Nominal test condition			T3
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	29
28		Mean	°C	28.140
29		Maximum Variation from Setpoint	°C	5.189
	Indoor Room Humidity			
30		Target	%	38
31		Mean	%	41.439
32		Maximum Variation from Setpoint	%	10.400
	Outdoor Room Temperature			
33		Target	°C	46
34		Mean	°C	45.656
35		Maximum Variation from Setpoint	°C	5.838
	Indoor Room Total Cooling Capacity			
36		Mean	W	3113.996
37		Maximum Variation	W	1663.153
	Indoor Room Sensible Cooling Capacity			
38		Mean	W	2442.987
39		Maximum Variation	W	1587.982
	Indoor Room Latent Cooling Capacity			
40		Mean	W	671.009
41		Maximum Variation	W	642.995
	Supply Voltage L1-N / L2-N / L3-N			
42		Mean	V	233.434 / 0 / 0

Item	Description		Units	Test Results
43		Maximum Variation	V	6.22 / 0 / 0
	Supply Power L1-N / L2-N / L3-N			
44		Mean	V	2880.178 / 0 / 0
45		Maximum Variation	V	649.696 / 0 / 0
	Energy Efficiency Ratio (EER) or Coefficient of Performance (CoP)			
46		Mean	kW/kW	1.083
47		Maximum Variation	kW/kW	0.469
	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	27.279
52		Maximum Variation	°C	4.692
	Evaporator Air Exit Temperature			
53		Mean	°C	23.028
54		Maximum Variation	°C	6.765
	Condenser Air Entry Temperature			
55		Mean	°C	39.690
56		Maximum Variation	°C	4.579
	Condenser Air Exit Temperature			
57		Mean	°C	40.809
58		Maximum Variation	°C	0.027
	Suction Line Pressure			
59		Mean	kPa	868.961
60		Maximum Variation	kPa	67.532
	Suction Line Temperature			
61		Mean	°C	42.605
62		Maximum Variation	°C	6.600
	Discharge Line Pressure			
63		Mean	kPa	3385.304
64		Maximum Variation	kPa	787.920
	Discharge Line Temperature			
65		Mean	°C	106.408
66		Maximum Variation	°C	13.400
	Liquid Line Pressure			
67		Mean	kPa	3189.502
68		Maximum Variation	kPa	773.287

Item	Description		Units	Test Results
	Liquid Line Temperature			
69		Mean	°C	51.202
70		Maximum Variation	°C	9.900
	Vapour Line Pressure			
71		Mean	kPa	1391.168
72		Maximum Variation	kPa	167.353
	Vapour Line Temperature			
73		Mean	°C	25.135
74		Maximum Variation	°C	4.500

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			15/04/2022
14	Test officer			Ian Nankivell
15	Test mode			Cooling
16	Test type			Cooling Capacity
17	Nominal test condition			T3
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			

Item	Description		Units	Test Results
27		Target	°C	29
28		Mean	°C	29.119
29		Maximum Variation from Setpoint	°C	5.849
	Indoor Room Humidity			
30		Target	%	38
31		Mean	%	42.207
32		Maximum Variation from Setpoint	%	8.935
	Outdoor Room Temperature			
33		Target	°C	46
34		Mean	°C	45.980
35		Maximum Variation from Setpoint	°C	3.755
	Indoor Room Total Cooling Capacity			
36		Mean	W	2923.228
37		Maximum Variation	W	16430.286
	Indoor Room Sensible Cooling Capacity			
38		Mean	W	2091.215
39		Maximum Variation	W	4574.926
	Indoor Room Latent Cooling Capacity			
40		Mean	W	832.014
41		Maximum Variation	W	13735.842
	Supply Voltage L1-N / L2-N / L3-N			
42		Mean	V	227.734 / 0 / 0
43		Maximum Variation	V	242.13 / 0 / 0
	Supply Power L1-N / L2-N / L3-N			
44		Mean	V	1511.605 / 0 / 0
45		Maximum Variation	V	3639.907 / 0 / 0
	Energy Efficiency Ratio (EER) or Coefficient of Performance (CoP)			
46		Mean	kW/kW	3.083
47		Maximum Variation	kW/kW	101.901
	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	27.772

Item	Description		Units	Test Results
52		Maximum Variation	°C	9.601
	Evaporator Air Exit Temperature			
53		Mean	°C	24.135
54		Maximum Variation	°C	15.355
	Condenser Air Entry Temperature			
55		Mean	°C	34.182
56		Maximum Variation	°C	12.494
	Condenser Air Exit Temperature			
57		Mean	°C	38.339
58		Maximum Variation	°C	8.568
	Suction Line Pressure			
59		Mean	kPa	1552.772
60		Maximum Variation	kPa	1123.589
	Suction Line Temperature			
61		Mean	°C	50.352
62		Maximum Variation	°C	25.100
	Discharge Line Pressure			
63		Mean	kPa	3175.439
64		Maximum Variation	kPa	2184.248
	Discharge Line Temperature			
65		Mean	°C	75.895
66		Maximum Variation	°C	56.400
	Liquid Line Pressure			
67		Mean	kPa	3150.046
68		Maximum Variation	kPa	1969.423
	Liquid Line Temperature			
69		Mean	°C	47.188
70		Maximum Variation	°C	21.900
	Vapour Line Pressure			
71		Mean	kPa	1782.257
72		Maximum Variation	kPa	728.357
	Vapour Line Temperature			
73		Mean	°C	33.077
74		Maximum Variation	°C	16.700

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			23/03/2022
14	Test officer			Ian Nankivell
15	Test mode			Cooling
16	Test type			Cooling Capacity
17	Nominal test condition			T3
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	29
28		Mean	°C	28.996
29		Maximum Variation from Setpoint	°C	0.261
	Indoor Room Humidity			
30		Target	%	38
31		Mean	%	44.370
32		Maximum Variation from Setpoint	%	6.689

Item	Description		Units	Test Results
	Outdoor Room Temperature			
33		Target	°C	46
34		Mean	°C	45.867
35		Maximum Variation from Setpoint	°C	0.680
	Indoor Room Total Cooling Capacity			
36		Mean	W	3481.927
37		Maximum Variation	W	363.069
	Indoor Room Sensible Cooling Capacity			
38		Mean	W	2823.223
39		Maximum Variation	W	378.399
	Indoor Room Latent Cooling Capacity			
40		Mean	W	658.703
41		Maximum Variation	W	280.888
	Supply Voltage L1-N / L2-N / L3-N			
42		Mean	V	230.149 / 0 / 0
43		Maximum Variation	V	10.21 / 0 / 0
	Supply Power L1-N / L2-N / L3-N			
44		Mean	V	3175.21 / 0 / 0
45		Maximum Variation	V	93.487 / 0 / 0
	Energy Efficiency Ratio (EER) or Coefficient of Performance (CoP)			
46		Mean	kW/kW	1.097
47		Maximum Variation	kW/kW	0.127
	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	27.188
52		Maximum Variation	°C	0.425
	Evaporator Air Exit Temperature			
53		Mean	°C	22.278
54		Maximum Variation	°C	0.818
	Condenser Air Entry Temperature			
55		Mean	°C	40.771
56		Maximum Variation	°C	0.726

Item	Description		Units	Test Results
	Condenser Air Exit Temperature			
57		Mean	°C	40.810
58		Maximum Variation	°C	0.014
	Suction Line Pressure			
59		Mean	kPa	942.165
60		Maximum Variation	kPa	28.030
	Suction Line Temperature			
61		Mean	°C	42.377
62		Maximum Variation	°C	0.800
	Discharge Line Pressure			
63		Mean	kPa	3804.658
64		Maximum Variation	kPa	120.225
	Discharge Line Temperature			
65		Mean	°C	106.979
66		Maximum Variation	°C	1.300
	Liquid Line Pressure			
67		Mean	kPa	2090.518
68		Maximum Variation	kPa	17.656
	Liquid Line Temperature			
69		Mean	°C	50.836
70		Maximum Variation	°C	1.300
	Vapour Line Pressure			
71		Mean	kPa	2115.691
72		Maximum Variation	kPa	16.969
	Vapour Line Temperature			
73		Mean	°C	23.338
74		Maximum Variation	°C	0.900

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

Item	Description		Units	Test Results
10	Refrigerant			R410a
11	Refrigerant charge		kg	1.92kg (60%)
12	Inverter setting/Compressor Speed			Not applicable
13	Date of test			14/04/2022
14	Test officer			Ian Nankivell
15	Test mode			Cooling
16	Test type			Cooling Capacity
17	Nominal test condition			T3
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	29
28		Mean	°C	28.974
29		Maximum Variation from Setpoint	°C	2.059
	Indoor Room Humidity			
30		Target	%	38
31		Mean	%	40.545
32		Maximum Variation from Setpoint	%	4.979
	Outdoor Room Temperature			
33		Target	°C	46
34		Mean	°C	45.839
35		Maximum Variation from Setpoint	°C	3.051
	Indoor Room Total Cooling Capacity			
36		Mean	W	3090.276
37		Maximum Variation	W	1624.266
	Indoor Room Sensible Cooling Capacity			
38		Mean	W	2415.682
39		Maximum Variation	W	1523.298
	Indoor Room Latent Cooling Capacity			

Item	Description		Units	Test Results
40		Mean	W	674.594
41		Maximum Variation	W	647.883
	Supply Voltage L1-N / L2-N / L3-N			
42		Mean	V	233.789 / 0 / 0
43		Maximum Variation	V	3.779 / 0 / 0
	Supply Power L1-N / L2-N / L3-N			
44		Mean	V	2883.125 / 0 / 0
45		Maximum Variation	V	649.696 / 0 / 0
	Energy Efficiency Ratio (EER) or Coefficient of Performance (CoP)			
46		Mean	kW/kW	1.073
47		Maximum Variation	kW/kW	0.469
	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	27.240
52		Maximum Variation	°C	4.777
	Evaporator Air Exit Temperature			
53		Mean	°C	23.037
54		Maximum Variation	°C	6.686
	Condenser Air Entry Temperature			
55		Mean	°C	39.681
56		Maximum Variation	°C	4.498
	Condenser Air Exit Temperature			
57		Mean	°C	40.809
58		Maximum Variation	°C	0.027
	Suction Line Pressure			
59		Mean	kPa	869.551
60		Maximum Variation	kPa	62.036
	Suction Line Temperature			
61		Mean	°C	42.552
62		Maximum Variation	°C	6.600
	Discharge Line Pressure			
63		Mean	kPa	3384.403
64		Maximum Variation	kPa	787.920
	Discharge Line Temperature			

Item	Description		Units	Test Results
65		Mean	°C	106.389
66		Maximum Variation	°C	13.400
	Liquid Line Pressure			
67		Mean	kPa	3189.254
68		Maximum Variation	kPa	773.287
	Liquid Line Temperature			
69		Mean	°C	51.152
70		Maximum Variation	°C	9.900
	Vapour Line Pressure			
71		Mean	kPa	1392.882
72		Maximum Variation	kPa	161.514
	Vapour Line Temperature			
73		Mean	°C	25.179
74		Maximum Variation	°C	4.400

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			11/03/2022
14	Test officer			Ian Nankivell
15	Test mode			Cooling
16	Test type			Cooling Capacity
17	Nominal test condition			T3
18	Test room type indoor equipment			Calorimeter
19	Test room type outdoor equipment			Calorimeter

Item	Description		Units	Test Results
20	Test standard(s)			AS/NZS3823.1.2:2012
21	Fan speed settings, indoor			High

Item	Description		Units	Test Results
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	29
28		Mean	°C	27.933
29		Maximum Variation from Setpoint	°C	2.918
	Indoor Room Humidity			
30		Target	%	38
31		Mean	%	68.270
32		Maximum Variation from Setpoint	%	36.982
	Outdoor Room Temperature			
33		Target	°C	46
34		Mean	°C	41.743
35		Maximum Variation from Setpoint	°C	5.388
	Indoor Room Total Cooling Capacity			
36		Mean	W	5372.899
37		Maximum Variation	W	6284.350
	Indoor Room Sensible Cooling Capacity			
38		Mean	W	4742.886
39		Maximum Variation	W	5227.871
	Indoor Room Latent Cooling Capacity			
40		Mean	W	630.013
41		Maximum Variation	W	2937.366
	Supply Voltage L1-N / L2-N / L3-N			
42		Mean	V	230.559 / 0 / 0
43		Maximum Variation	V	14.201 / 0 / 0
	Supply Power L1-N / L2-N / L3-N			

Item	Description		Units	Test Results
44		Mean	V	2791.158 / 0 / 0
45		Maximum Variation	V	3639.63 / 0 / 0
	Energy Efficiency Ratio (EER) or Coefficient of Performance (CoP)			
46		Mean	kW/kW	2.309
47		Maximum Variation	kW/kW	37.227
	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	22.228
52		Maximum Variation	°C	13.749
	Evaporator Air Exit Temperature			
53		Mean	°C	14.012
54		Maximum Variation	°C	14.990
	Condenser Air Entry Temperature			
55		Mean	°C	32.035
56		Maximum Variation	°C	21.328
	Condenser Air Exit Temperature			
57		Mean	°C	37.497
58		Maximum Variation	°C	20.269
	Suction Line Pressure			
59		Mean	kPa	1143.768
60		Maximum Variation	kPa	1196.479
	Suction Line Temperature			
61		Mean	°C	31.776
62		Maximum Variation	°C	32.300
	Discharge Line Pressure			
63		Mean	kPa	3637.993
64		Maximum Variation	kPa	2142.478
	Discharge Line Temperature			
65		Mean	°C	81.605
66		Maximum Variation	°C	67.200

	Liquid Line Pressure			
67		Mean	kPa	3434.219
68		Maximum Variation	kPa	2082.228
	Liquid Line Temperature			
69		Mean	°C	40.971
70		Maximum Variation	°C	27.500
	Vapour Line Pressure			
Item	**Description**		**Units**	**Test Results**
71		Mean	kPa	1596.647
72		Maximum Variation	kPa	785.310
	Vapour Line Temperature			
73		Mean	°C	23.357
74		Maximum Variation	°C	22.700

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. They will provide a heat load in equilibrium with the device so as the maintain the required 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.