Air Conditioner Test Report

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1.0 EXECUTIVE SUMMARY

1.1 Introduction

SCE and other utilities have been having occurrences of delayed voltage recovery following faults on the electrical system. Under normal conditions, voltage recovers to nominal levels in less than one second after the fault is cleared. In several cases in the past few years, voltage recovery has been delayed for over 30 seconds after normal fault clearing in some substations, especially when the air temperature and electrical system loading was high. This delayed voltage recovery is being attributed to stalling of air conditioner units. Delayed voltage recovery may lead to a system voltage collapse in the worst case.

This delayed undervoltage recovery behavior has been seen in the SCE system since 1989 but has not caused serious problems. In recent years, these delayed undervoltage recovery events have been increasing. During the summer of 2006, SCE experienced 36 delayed voltage recovery events. In some cases, these delayed voltage recoveries are out of compliance with the WECC supply voltage limit, which dictates that voltage should not be more than 20% below nominal for more than 20 cycles.

SCE customers are also affected by the delayed voltage recovery. This causes SCE customers inconvenience and potential loss of business when these events arise. Although there is no indication of an imminent total system voltage collapse at this time, SCE is approaching this problem in a conservative way by studying the phenomenon and exploring potential solutions.

1.2 Work Performed

SCE began air conditioner testing in 2005 to determine how the units would respond when exposed to various under-voltage transient conditions. The test results help SCE to properly model the electrical system and determine possible solutions. SCE tested ten (10) air conditioner units, in its Pomona Electric Vehicle Technical Center (EVTC), typically found in the service territory. The diversity of the tested air conditioner units included sizes (tonnage), compressor technology (reciprocating and scroll), refrigerant technology (R22 and R-410A), vintage (new and old), and efficiencies (10 thru 13 SEER).

The ten (10) air conditioner units were tested under different undervoltage transients including the *Long Notch, Delayed Recovery* and *Circuit Breaker Clearing* type of transient. The *Long Notch* transient (drop in voltage that was held for 30 seconds) was used to establish the threshold voltage where the air conditioner compressor stalled. The *Delayed Recovery* transient (drop in voltage followed by a 30 seconds recovery to nominal voltage) simulates the typical delayed voltage recovery event observed in SCE system. The *Circuit Breaker* transient (short duration drop in voltage held for 3, 6, 9, and 12 cycles) simulates the typical transient generated by the tripping and reclosing of circuit breakers commonly used in the SCE system.

In addition, SCE performed additional testing on the air conditioners for the WECC Load Modeling Task Force which included frequency oscillations, voltage oscillations, and different arrangements of undervoltage transients. The WECC is currently developing software models to simulate air conditioners in power system analysis programs. Current models do not properly

simulate stalling air conditioner behavior during undervoltage transients. SCE developed the Air Conditioner Testing Procedures for the testing of air conditioners with input from EPRI Solutions and Bonneville Power Administration (BPA). These procedures were used by EPRI Solutions (under contract with APS) and BPA. Together SCE, BPA, and EPRI Solutions will test more than 40 residential air conditioners and share the test data under the umbrella of the WECC Load Modeling Task Force. The detailed test procedures are attached to this report as Appendix #1.

1.3 Testing Results

This summary section contains the testing results for the air conditioning units when exposed to the *delayed recovery* type of transients, similar to that observed during the delayed voltage recovery events at SCE.

1.3.1 Stall Voltage

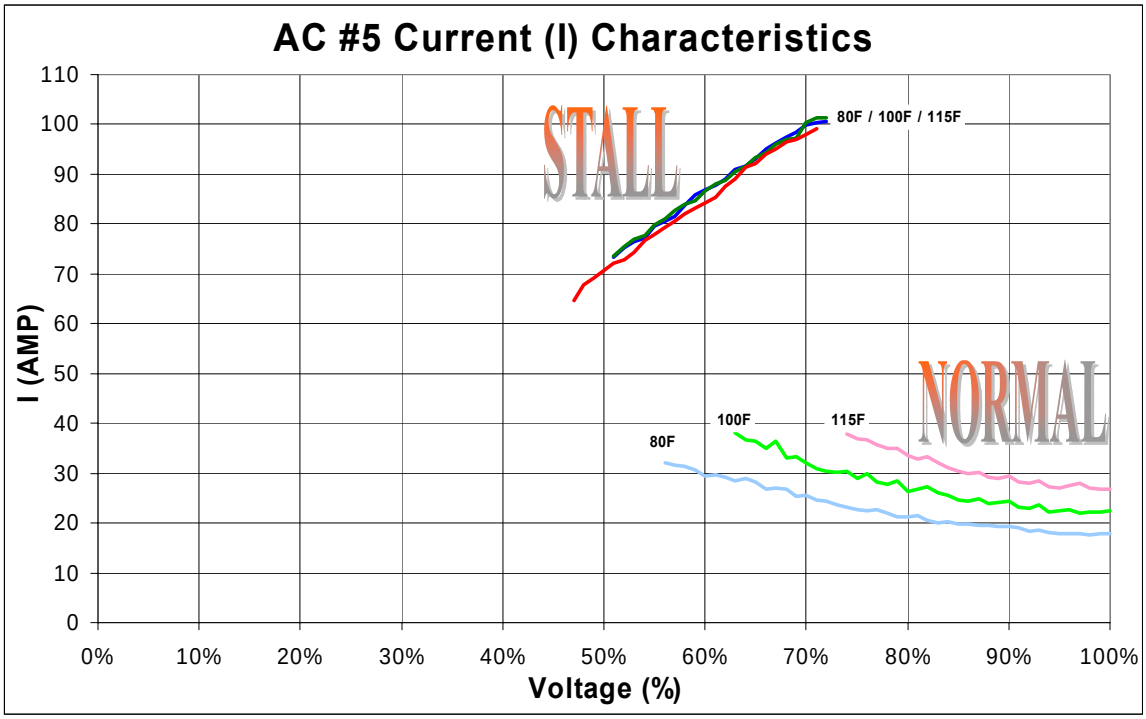
The ten tested air conditioning units had similar stalling voltages within ±5% (voltage level where compressor ceased to turn) at each of the tested temperatures. These voltages varied with the outdoor air temperature that the compressor and condensing coils were subjected to. The stall response time (time it takes the air conditioner compressor to stop turning) on the tested air conditioners was approximately 6 cycles after the under-voltage condition occurred. Test results indicated that the stalling voltage average at 80 °F is 61%, at 100 °F is 65%, and at 115 °F is 69%. Table 1 indicates the stalling windows (voltages between the stall threshold voltage and the contactor dropout voltage) for the ten tested air conditioner units when exposed to the *delayed recovery* type of transients. Air conditioner unit #10 did not stall at 80 °F and it operated down to the voltage where the contactor opened without stalling. Opening of the contactor did not prevent the air conditioner units from stalling; it just delayed stalling until the contactor reclosed (see more details in 1.3.4)

	Stall Window (80°F)		Stall Window (100°F)		Stall Window (115°F)	
	Stall Threshold	Contactor Dropout	Stall Threshold	Contactor Dropout	Stall Threshold	Contactor Dropout
AC #1	64%	50%	66%	50%	68%	50%
AC #2	56%	50%	61%	50%	66%	50%
AC #3	59%	35%	67%	35%	73%	35%
AC #4	62%	50%	67%	50%	75%	50%
AC #5	57%	50%	62%	50%	67%	45%
AC #6	59%	45%	64%	40%	68%	40%
AC #7	57%	50%	61%	50%	67%	50%
AC #8	64%	45%	67%	55%	69%	50%
AC #9	67%	55%	70%	55%	73%	55%
AC #10	none	45%	64%	50%	68%	55%

Table 1 – Stall Window

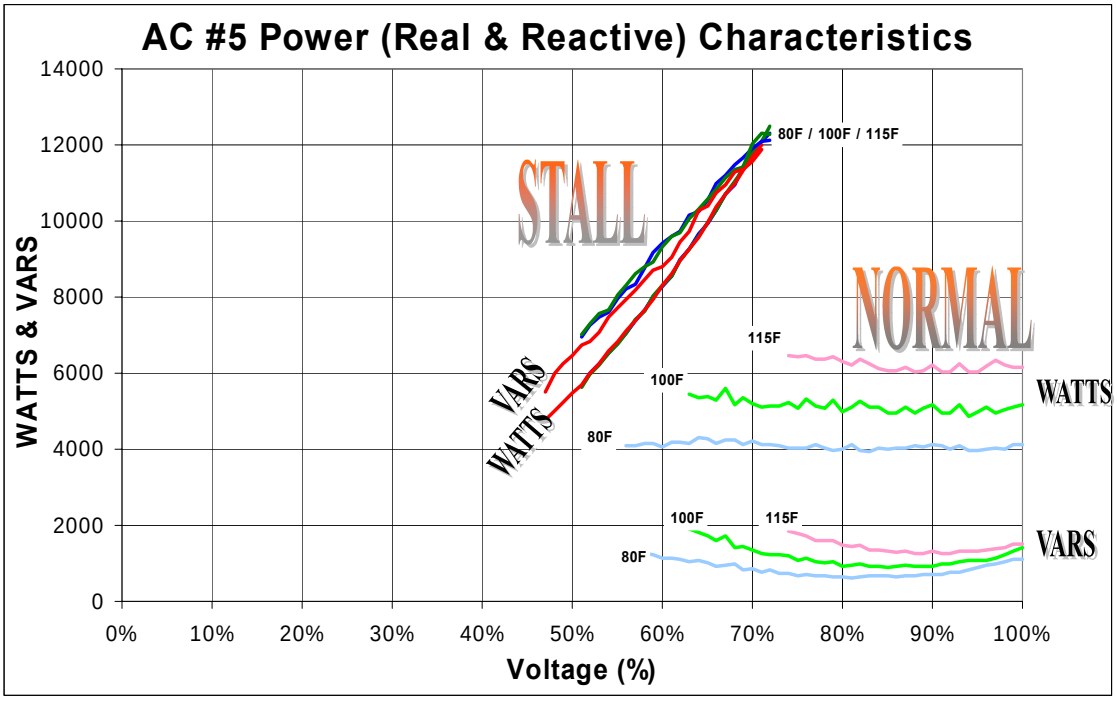
The major influence on the three stall parameters, current (I_{STALL}) and real power (P_{STALL}) and reactive power (Q_{STALL}), was the supply voltage. The higher the terminal voltage when the stall occurs, the higher the stall parameter values. The values of these parameters were also proportional to the unit size.

Graph 1 below indicates the typical current (I) behavior of an air conditioner unit when exposed to the *delayed recovery* type of transient. The normal running current (I_{FLA}) is approximately 17, 22, and 27 Amps at nominal voltage (100% or 240 V) for the three simulated outdoor temperatures 80, 100, 115 °F respectively. The normal running current was found to be inversely proportional to the supply voltage, the lower the voltage the higher the normal running current. This behavior continues down to where the unit starts stalling (stalling threshold voltage). The current jumped from as low as 17 Amps (at nominal voltage and 80 °F) to 100 Amps (at 70% applied voltage) when the unit stalled. The stall current (I_{STALL}) was found to be directly proportional to the applied voltage, the higher the voltage applied to the compressor terminals during the stall the higher the stall current (blue, green, and red plot lines). This behavior continues down to where the contactor drops out (contactor drop out voltage).



Graph 1 – Stall Current

Graph 2 indicates the typical power (real P and reactive Q) behavior of an air conditioner unit when exposed to the *delayed recovery* type of transient. The normal running real power (P) is approximately 4000, 5000, and 6000 Watts and the normal running reactive power (Q) is approximately 900, 1100, and 1300 VARs at nominal voltage (100% or 240 V) for the three simulated outdoor temperatures 80, 100, 115 °F respectively. The normal real power (NORMAL WATTS plot line) did not change significantly when the applied voltage decreased all the way down until the unit stall point. The normal reactive power (NORMAL VARS plot line) was found to be inversely proportional to the applied voltage down to approximately 85% then started being proportional to the applied voltage until the unit stalled (stall threshold voltage). The real power jumped from 4000 Watts (at nominal voltage and 80 °F) to as high as 12,000 Watts (at 70% applied voltage) when the unit stalled. The reactive power jumped from 900 VARs (at nominal voltage and 80 °F) to as high as 12,000 VARs (at 70% applied voltage) when the unit stalled. When stalled, both the real and reactive powers were found to be directly proportional to the applied voltage, the higher the voltage the higher the Watts and VARs. This behavior continues down to where the contactor drops out (contactor drop out voltage).



Graph 2 – Stall Real and Reactive Power

1.3.2 Metering Devices

Air conditioner systems usually use either thermostatic expansion valves (TXV) or orifice metering devices to control the proper flow of refrigerant in the high-pressure side of the cooling coil (indoor coil). Controlling the proper flow of refrigerant in the high-pressure side is critical because too much flow can cause the cooling coil to freeze and therefore not produce any cooling. The orifice-metering device has a unique advantage that is brings the pressure quickly into equalization after the compressor shuts down. The TXV helps the cooling coil maintain proper flow using a sophisticated feedback system but pressure equalization is achieved at a much slower rate (1 to 2 minutes) than the orifice. The TXV helps the cooling coil have the proper flow when the system is undercharged, maintaining its efficiency. It offers no improvement when the system is overcharged. Since TXVs are commonly used in new air conditioner installations, most of the air conditioner units tested had TXV valves.

When stalled, the compressor ceases to turn and therefore does not generate pressure. The high-pressure (liquid line) and low-pressure (vapor line) need to equalize in order for the compressors to restart smoothly. Most air conditioners rely on thermostats (which commonly have a 5 minutes delay) to avoid short cycling which allows pressure equalization before a restart is attempted.

Most of the tested air conditioner units with scroll compressors went into IDLE (drawing the same running amps without producing any cooling) or NO-LOAD (drawing about ½ the running amps without producing any cooling) condition after a *circuit breaker clearing* generated type of transient. It seems that some mechanical device prevented them from restarting normally. We opened a scroll compressor and found a pressure relief valve between the high pressure and low-pressure chambers.

This valve is designed to prevent too much pressure from building up in the high-pressure side, releasing it into the low-pressure chamber. This valve may have stuck open when the compressor went into either IDLE or NO-LOAD condition because the unit draws current but no pressure is built up, and no cooling is produced. The air conditioner unit had to be turned off and then back on again to resume normal running condition.

Graph 3 – Pressure Relief Valve

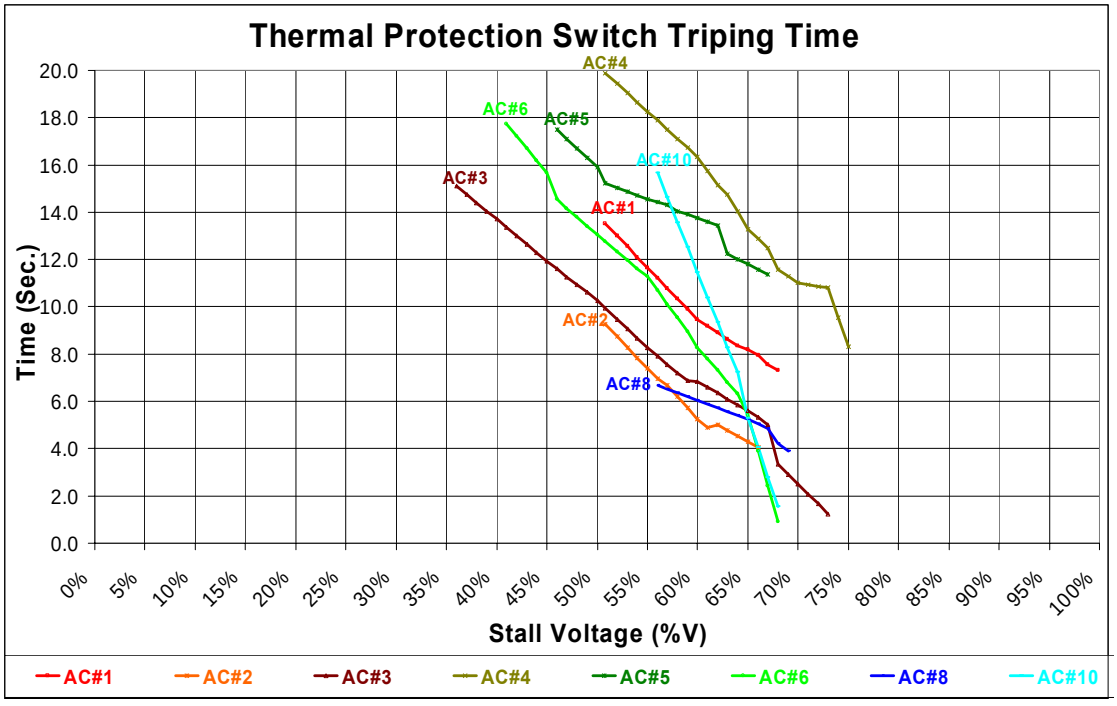
Some air conditioner units have high-pressure and low-pressure switches that are in series with the thermostat circuit to protect the compressor from harmful high-pressure conditions. One of the units (air conditioner unit #5) shut itself down under normal running conditions (at nominal voltage) due to high pressure when the outdoor temperature reached 120°F. This indicated that this particular air conditioner unit, under normal charging conditions, would not work properly at in areas where the temperature reaches 120°F.

1.3.3 Thermal Protection Switch

All of the tested air conditioning units' compressors have a thermal protection switch that opens to protect the motor from overheating due to extended stall currents. Without the thermal protection switch, the motor might overheat and fail when high currents are present for long periods. When exposed to the *delayed recovery* type of transients, most of the tested air conditioner compressors (except A/C #7) stalled for as short as 1.0 second and as long as 20 seconds before the thermal protection switch opened to protect the compressor (as seen in Graph 2). Air conditioner unit #7 stalled for as long as 11.6 seconds without opening the thermal protection switch during the 30

second transient. In this unit, when the voltage rose above 162 V, the compressor resumed normal running condition. Air conditioner unit #9's (used unit) thermal protection switch opened only at the higher test temperatures (100 °F and 115 °F) and only after the compressor stalled for more than 12 seconds. Air conditioner unit #10's thermal protection switch opened only at the highest test temperature (115 °F). All the units restarted normally after the thermal protection switch reclosed except for air conditioner units #6 and #8. These two units needed to be turned off and then on again in order to run normally.

Graph 4 shows the thermal protection switch average tripping time versus the stall voltage for each of the tested air conditioner units except for #7 and #9. Each air conditioner unit had similar linear thermal protection switch tripping time slopes at the three tested temperatures except for unit # 9, which behaved differently for each of the three tested temperatures. The thermal protection tripping time was found to be inversely proportional to the sag voltage, the lower the voltage the longer the thermal protection switch tripping time. The thermal protection tripping time can be as short as 1.0 second and as long as 20 seconds as shown in graph below. The right end of each plot is where the unit started stalling (stall threshold) and the left end is where the contactor opens (contactor dropout voltage).



Graph 4 – Thermal Protection Switch Tripping Time

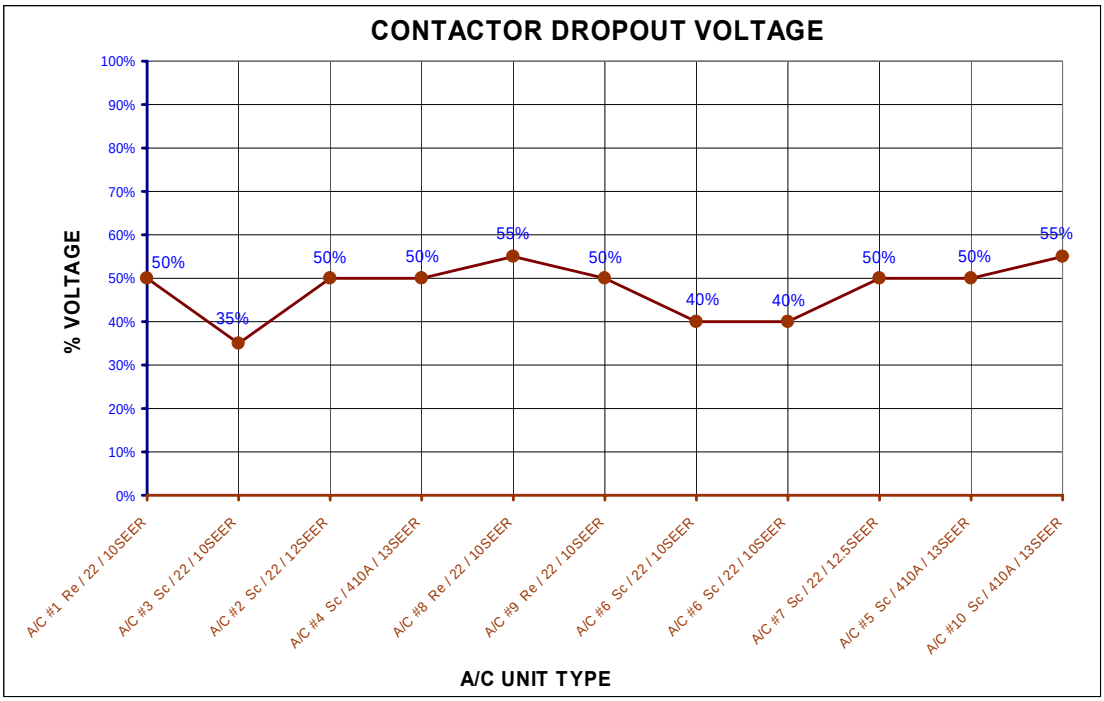
Table 2 indicates the stalling window (between the stall threshold voltage and contactor dropout voltage). The thermal protection switch (TPS) tripping time for each of the tested units can be calculated with the t_{TPS} formula shown below.

$t_{TPS} = (m * V) + \varphi$									
	Stall Window (80°F)		Stall Window (100°F)		Stall Window (115°F)		Slope (m)	Constant (φ)	
	High	Low	High	Low	High	Low			
AC #1	64%	51%	66%	51%	68%	51%	-44.0000	35.8667	
AC #2	56%	51%	61%	51%	66%	51%	-31.2333	24.5817	
AC #3	59%	36%	67%	36%	73%	36%	-31.6667	25.8500	
AC #4	62%	51%	67%	51%	75%	51%	-49.6667	46.1333	
AC #5	57%	51%	62%	51%	67%	46%	-27.3333	30.1500	
AC #6	59%	46%	64%	41%	68%	41%	-47.8718	36.9962	
AC #7	57%	51%	61%	51%	67%	51%	-68.3333	49.0500	
AC #8	64%	46%	67%	56%	69%	51%	-22.7500	20.0442	
AC #9	67%	56%	70%	56%	73%	56%	-67.0000	44.1500	@ 80°F
							-62.3077	46.3846	@ 100°F
							-26.0000	22.9000	@ 115°F
AC #10	none	46%	64%	51%	68%	56%	-105.5208	74.7625	

Table 2 – Stall Calculation

1.3.4 Contactor Dropout

All the tested air conditioners have a main power contact relay (called the contactor) that has a 24 VAC coil connected in series with the thermostat contact. All of the contactors were found to have a quick response time (2 cycles to open/close when voltage is applied). These units use standard contactors (off the shelf type) which were not specifically designed for air conditioner use. From the tests, the contactor dropout voltage varied from about 55% down to 35% as seen in the Graph 5. This means that when the supply voltage goes below these values (below brown line on the graph below) the contactor will open tripping off the compressor. While the contactor is open, the compressor is off, but as soon as it recloses, the air conditioner compressor stalls when exposed to the *delayed recovery* type of transient.



Graph 5 – Contactor Dropout Voltage

Opening the contactor did not prevent the air conditioner units from stalling; it just delayed it until the supply voltage reaches the contactor threshold voltage. Table 3 indicates the maximum stalling times after the contactor recloses for all of the tested air conditioner units. This maximum time is when the voltage at the compressor is just above the contactor dropout voltage.

	Contactor Dropout Voltage (%)	Max. Stall Time After Contactor Reclosed (sec.)
A/C #1 Re / 22 / 10SEER	50%	11.5
A/C #3 Sc / 22 / 10SEER	35%	11.8
A/C #2 Sc / 22 / 12SEER	50%	5.5
A/C #4 Sc / 410A / 13SEER	50%	15.9
A/C #8 Re / 22 / 10SEER	55%	5.6
A/C #9 Re / 22 / 10SEER	50%	11.2
A/C #6 Sc / 22 / 10SEER	40%	11.4
A/C #6-OC Sc / 22 / 10SEER	40%	8.1
A/C #7 Sc / 22 / 12.5SEER	50%	6.4
A/C #5 Sc / 410A / 13SEER	50%	8.1
A/C #10 Sc / 410A / 13SEER	55%	6.6

Table 3 –Stalling Time after Contactor Reclosed

2.0 OBJECTIVE

SCE and other utilities have had several occurrences of delayed voltage recovery following faults on the electrical system. Under normal conditions, voltage recovers to normal levels in less than one second after the fault is cleared. In several cases in the past few years, voltage recovery has been delayed for over 30 seconds after normal fault clearing in the Valley Substation area. This delayed voltage recovery is being attributed to stalling of air conditioner units. Testing of air conditioner units is being conducted to determine how they behave when exposed to various under-voltage conditions. These test results will help to properly model the electrical system and determine possible solutions to this problem.

The objective of this testing is to investigate the air conditioner's response to different under-voltage transient conditions, especially under the *delayed recovery* type of transient. SCE has tested ten air conditioner units typically found in the service territory. The diversity of the tested air conditioner units included size (tonnage), compressor technology (reciprocating and scroll), refrigerant technology (R22 and R-410A), vintage (new and old), and efficiency (10 thru 13 SEER) as seen in Table 4. The test results will help to properly model the electrical system and determine possible solutions to events.

A/C #	Mfg	Condenser Unit	Ton	Comp.	Refrig.	SEER	Vintage
1	Carrier	38CKS036	3	Re	22	10	New
3	Rheem	RAKB036-JAZ	3	Sc	22	10	New
2	Carrier	38BRG036300	3	Sc	22	12	New
4	Carrier	38TXA036-30	3	Sc	410A	13	New
8	Goodman	CLK048	4	Re	22	10	New
9	Day & Night	5680J048	4	Re	22	10	Used
6	Rheem	RAB048-JAZ	4	Sc	22	10	New
6	Rheem (Over-Charged)	RAB048-JAZ	4	Sc	22	10	New
7	Carrier	38TRA-048	4	Sc	22	12.5	New
5	Coleman	AC3B048F1A	4	Sc	410A	13	New
10	Carrier	38TXA060-31	5	Sc	410A	13	New

Table 4 – Tested Air Conditioner Units

The same indoor unit (air handler) was used for all the tests except for the cooling coil, which was replaced, depending on the system tonnage. Three different cooling coils were used for the three different systems tonnages (3, 4, and 5-tons). The air handler's fan speed was adjusted for the three different system tonnages. Different air conditioner system piping was used for the different refrigerants.

The test procedures described in section 3.0 were performed for each air conditioner unit. Each unit test is composed of fifteen sub-tests from which SCE has analyzed the first five. Others are reviewing the remaining test results.

2.1. Measurements

The air conditioner instrumentation provided four voltages (V_1, V_2, V_3, and V_4) and four currents (I_1, I_2, I_3, and I_4) as noted in Table 5. The voltages and currents were captured at the condenser unit (outdoor unit). In addition to the voltages and currents required above, the real power (W) and apparent power (VA) are also computed (see Table 6). The Yokogawa Power Analyzer can mathematically calculate real, apparent powers and frequency.

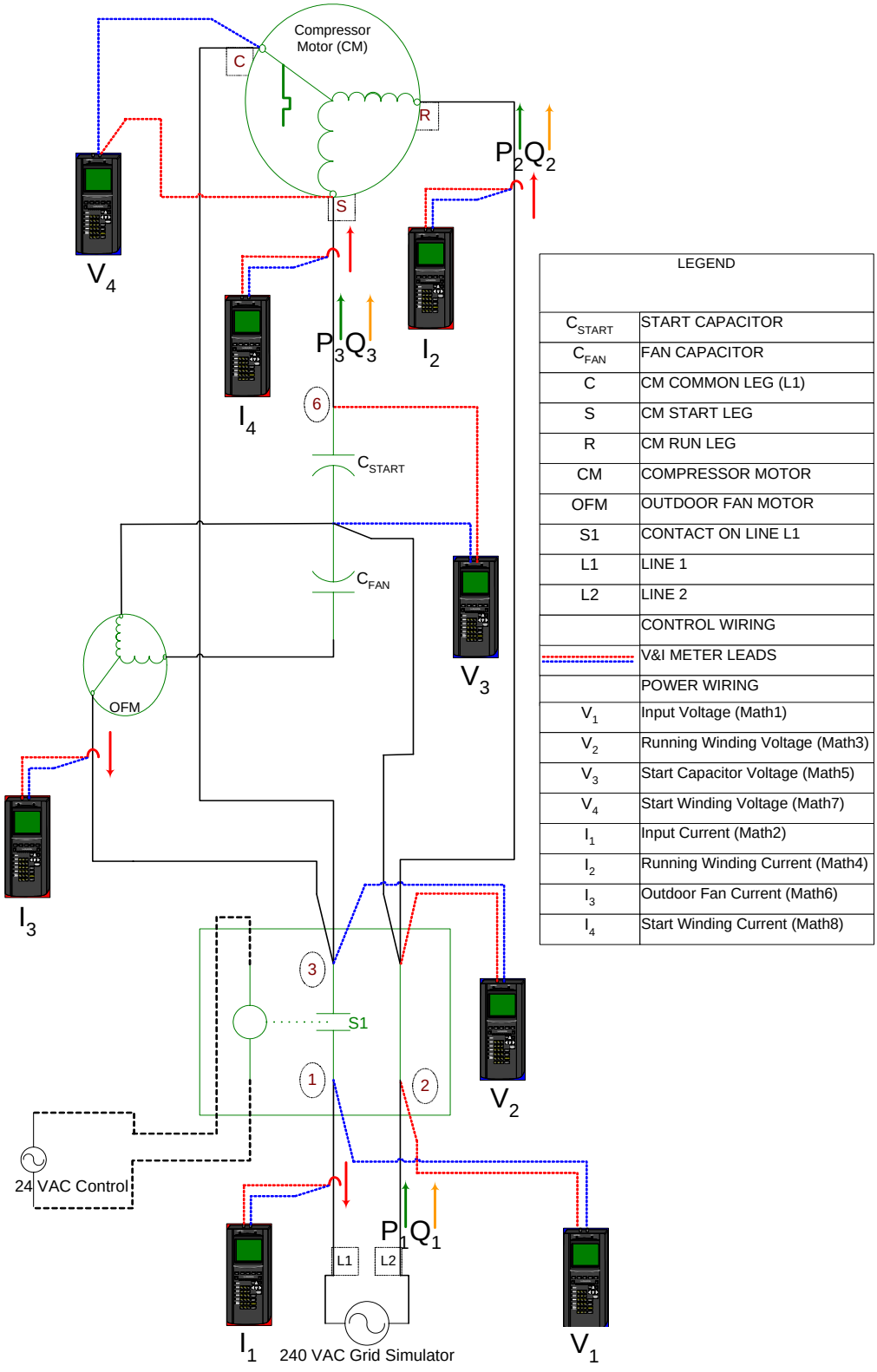
TAG	DESCRIPTION	Yokogawa	
		MATH	EXPRESSION
V_1	Input Voltage	1	Trend(C1)
V_2	Compressor Motor Running Winding Voltage	3	Trend(C3)
V_3	Capacitor Voltage	5	Trend(C5)
V_4	Compressor Motor Start Winding Voltage	7	Trend(C7)
I_1	Input Current	2	Trend(C2)
I_2	Compressor Motor Running Winding Current	4	Trend(C4)
I_3	Fan Motor Current	6	Trend(C6)
I_4	Compressor Motor Start Winding Current	8	Trend(C8)

Table 5 – Yokogawa Voltage and Current Points

Tag	Description	Yokogawa	
		MATH	EXPRESSION
W_1	Total Real Power	9	Trend(C1*C2)
W_2	Compressor Motor Running Winding Real Power	11	Trend(C3*C4)
W_3	Compressor Motor Start Winding Real Power	13	Trend(C7*C8)
F	Frequency	15	Trendf(C1)
VA_1	Total Apparent Power	10	Trend(C1)*Trend(C2)
VA_2	Compressor Motor Running Winding Apparent Power	12	Trend(C3)*Trend(C4)
VA_3	Compressor Motor Start Apparent Power	14	Trend(C7)*Trend(C8)

Table 6 – Yokogawa Real and Apparent Power Points

All of these voltages, currents, real power, apparent power, and frequency measurements are synchronized. A macro was created to filter the data and calculate the reactive power (VARs) and power factor (PF).



LEGEND	
C_{START}	START CAPACITOR
C_{FAN}	FAN CAPACITOR
C	CM COMMON LEG (L1)
S	CM START LEG
R	CM RUN LEG
CM	COMPRESSOR MOTOR
OFM	OUTDOOR FAN MOTOR
S1	CONTACT ON LINE L1
L1	LINE 1
L2	LINE 2
	CONTROL WIRING
	V&I METER LEADS
	POWER WIRING
V_1	Input Voltage (Math1)
V_2	Running Winding Voltage (Math3)
V_3	Start Capacitor Voltage (Math5)
V_4	Start Winding Voltage (Math7)
I_1	Input Current (Math2)
I_2	Running Winding Current (Math4)
I_3	Outdoor Fan Current (Math6)
I_4	Start Winding Current (Math8)

Figure 6 – Typical Air Conditioner Diagram

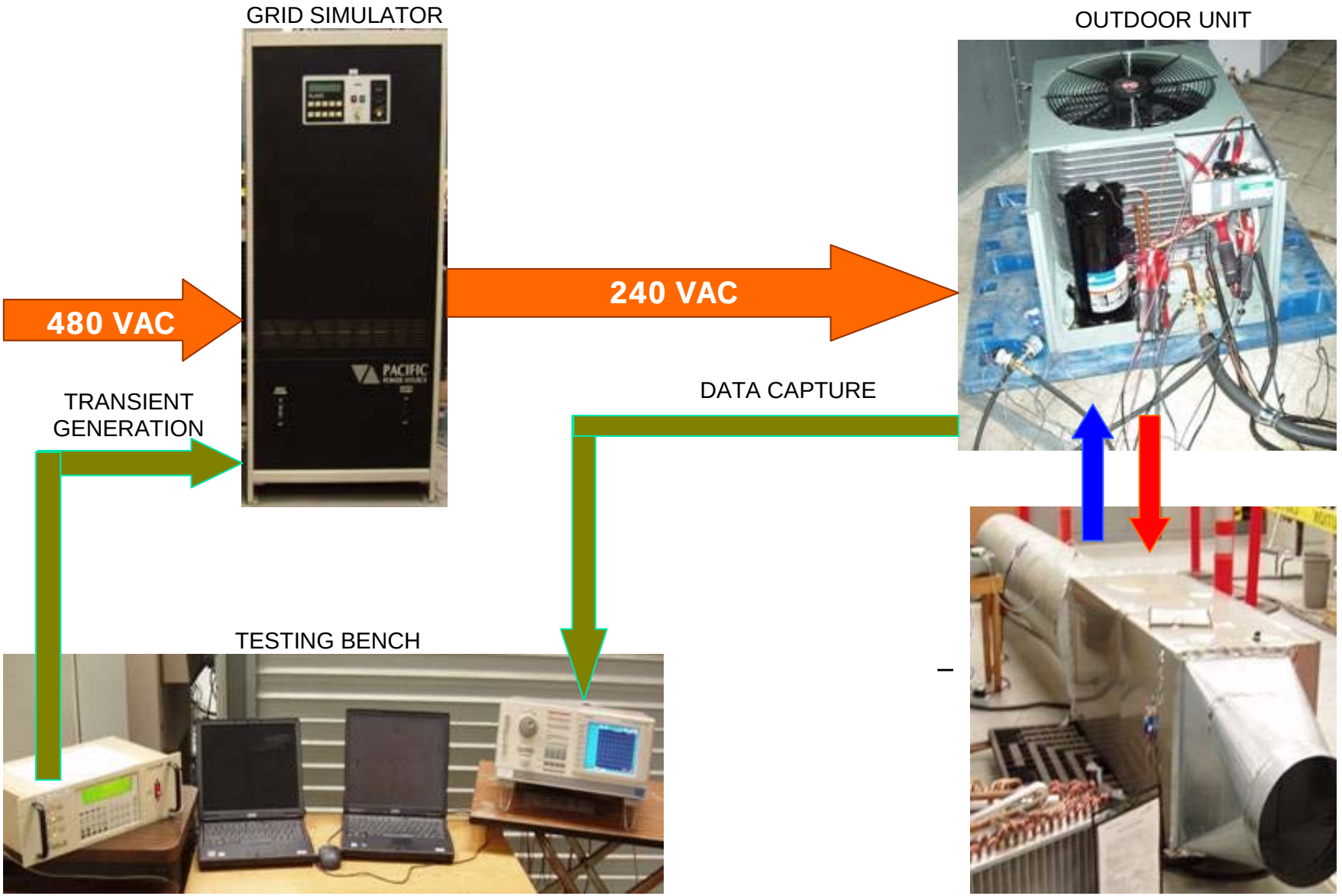


Figure 7 – Testing Layout Diagram

3.0 AIR CONDITIONER TEST TRANSIENT

This test report is focused mainly on the response of the air conditioner units to three different types of transients the *Long Notch*, the *Delayed Recovery* and *Circuit Breaker Clearing* type of transients. Other tests were also performed for the WECC Load Modeling Task Force, which included voltage oscillations, frequency oscillations, circuit breaker clearing transients with different voltage recoveries, and tests with the contactor bypassed. The detailed test procedure can be found in APPENDIX # 1.

3.1 Long Notch Type of Transient

The *Long Notch* type of transient was used to determine both the stalling threshold voltage and the contactor dropout voltage. This information was later used to implement the other two types of transients, the *Delayed Recovery* and the *Circuit Breaker Clearing*.

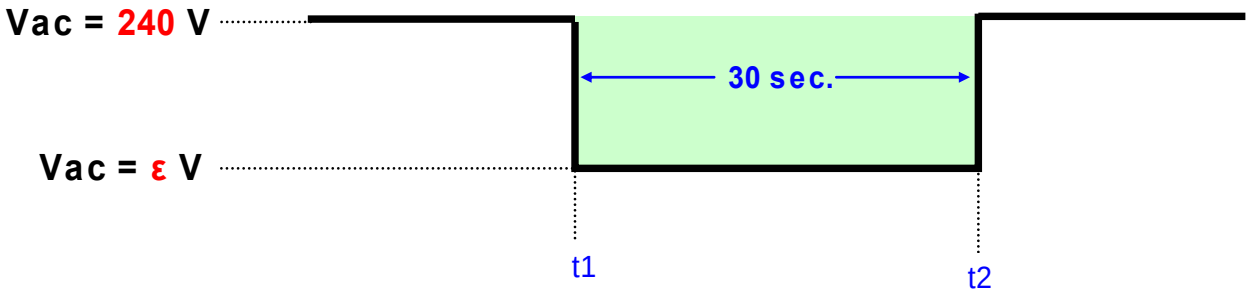


Figure 8

3.2 Delayed Recovery Type of Transient

The *Delayed Recovery* type of transient was used to determine the air conditioners' response to a delayed voltage recovery event in the electrical grid. A 30 second ramp up recovery time was used because this is similar to the transients observed in our system.

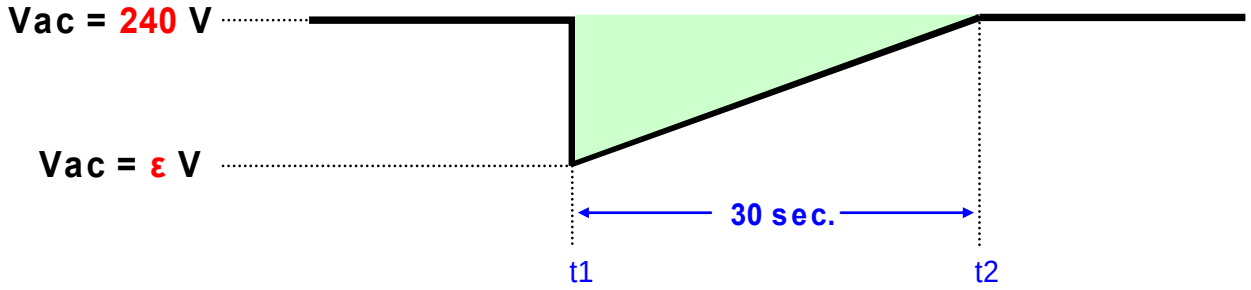


Figure 9

3.3 Circuit Breaker Clearing Type of Transient

The *Circuit Breaker Clearing* type of transients was used to determine the air conditioners response to short interruptions caused by the opening and reclosing of circuit breakers. Transients of 3, 6, 9, and 12 cycles were used because these are the switching times of circuit breakers commonly used on the SCE electrical system.

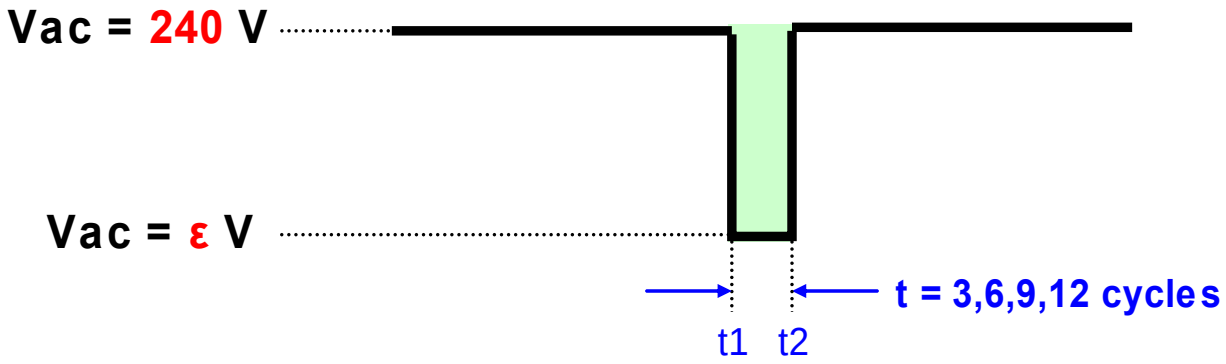


Figure 10

4.0 A/C #1 - TEST RESULTS

The air conditioner's compressor stalled when the voltage was in the stalling window (between the stall threshold voltage and contactor dropout voltage) when exposed to any of the three transients. This air conditioner unit stalled, drawing approximately 48 Amps at 129 VAC, for 21.5 seconds before the thermal protection switch opened to protect the compressor when exposed to the *long notch* type of transients. This air conditioner unit stalled, drawing approximately 62 Amps at 175 VAC, for as long as 12.5 seconds before the thermal protection switch opened to protect the compressor when exposed to the *delayed recovery* type of transients. It stalled, drawing approximately 94 Amps at 235 VAC, for as long as 2.9 seconds before the thermal protection switch opened, when exposed to the *circuit breaker clearing* type of transients. Opening the contactor did not help in preventing the compressor from stalling, it just delayed the stall until the contactor reclosed. The good thing about this air conditioner unit is that it restarted normally after any stall. The power contactor drop out voltage was 50%.

4.1 SYSTEM SPECIFICATIONS

The tested air conditioner system has the following specifications:

MAIN SYSTEM	
Manufacturer	Carrier
Condenser Unit	38CKS036
Evaporator Coil	CK3BA036
Size (Tons)	3
Compressor Type	Reciprocating
Refrigerant	R-22
SEER	10
Condition	New
Unit Cost	$670.00

COMPRESSOR	
Manufacturer	Bristol
Model	739024-1602-00
Type	Reciprocating
FLA (AMPS)	16
LRA (AMPS)	82
Phase	1
Refrigerant	R22
Charge (LBS)	4.6
Voltage (V)	230/208
PMAX High (PSI)	-
PMAXLow (PSI)	-

FAN MOTOR	
Manufacturer	GE
Model	5KCP39EGS070S
Voltage (V)	208/230
Current (I)	1.4
Power (HP)	0.25
RPM	1100
FLA (AMPS)	1.4

CONTACTOR	
Manufacturer	Product Unlimited
Model	HN51KC024
Rating (V)	240/277
FLA (AMPS)	30
LRA (AMPS)	150
Resistance	40

CAPACITOR	
Manufacturer	GE
Model	HC98JA046D
Rating (V)	370
Capacitance (µF)	45

4.2 TEST PARAMETERS

The test parameters for this unit were not captured. The performance parameter table can be found in APPENDIX #2 -- Attachment # 1

	80°F	100°F	115°F
T_{INLET} (°C)	-	-	-
T_{OUTLET} (°C)	-	-	-
$T_{COMP.\ AMB.}$ (°C)	-	-	-
T_{CASE} (°C)	-	-	-
T_{GAS} (°C)	-	-	-
T_{LIQ} (°C)	-	-	-
R_{FLOW} (Kcfm)	-	-	-
P_{LOW} (PSI)	-	-	-
P_{HIGH} (PSI)	-	-	-
$I_{RUNNING}$ (A)	14.0	16.0	17.0
$W_{RUNNING}$ (W)	3100.0	3500.0	3800.0
$VAR_{RUNNING}$ (VAR)	1300.0	1300.0	1300.0

4.3 INRUSH TEST RESULTS

This air conditioner system took approximately 10 cycles to come to normal steady running state, from which 9 cycles exhibited LOCKED-ROTOR characteristics. The data below was recorded for the air conditioner system.

Inrush	
V_{INRUSH}	233 VAC
I_{INRUSH}	97 A
W_{INRUSH}	16,300 W
VAR_{INRUSH}	15,700 VAR
t	10 cycles

4.4 POWER CONTACTOR TEST RESULTS

The power contactor opened at 50% voltage sag. In general, opening the contactor did not prevent the compressor from stalling; it just delayed the stalling until the contactor reclosed. The compressor had the following responses right after the contactor reclosed:

- *Long Notch* type of transients
  - The compressor stalled, drawing approximately 94 Amps at 233 VAC, right after the contactor reclosed for as long as 3.0 seconds before the thermal protection switch opened to protect the compressor.
- *Delayed Recovery* type of transient
  - The compressor stalled, drawing approximately 64 Amps at 176 VAC, right after contactor reclosed for as long as 11.5 seconds before the thermal protection switch opened to protect the compressor.

- *Circuit Breaker Clearing* type of transients
  - The compressor stalled, drawing approximately 94 Amps at 233 VAC, right after the contactor reclosed for as long as 2.9 seconds before the thermal protection switch opened to protect the compressor.

4.5 *30-SECOND LONG NOTCH* TYPE OF TRANSIENT TEST RESULTS

This compressor has the following threshold voltages 60% at 80 °F, 67% at 100 °F and 115 °F when exposed to the *long notch* type of transients. Therefore, the stalling windows for this compressor are the following: 60% to 50% at 80 °F, 67% to 50% at 100 °F, and 67% to 50% at 115 °F. The thermal protection switch opened after each stall to protect the compressor. The compressor stalled in the stalling window, drawing approximately 48 Amps at 129 VAC, for as long as 21.5 seconds before the thermal protection switch opened to protect the compressor. If the power contactor opened and then reclosed, the compressor stalled drawing approximately 94 Amps at 235 VAC, for as long as 3.0 seconds before the thermal protection opened to protect the compressor. The following are the detail responses of the compressor for each of the temperatures:

- °At 80 °F
  - The compressors stalled, drawing approximately 48 Amps at 129 VAC, for as long as 16.9 seconds before the thermal protection switch opened to protect the compressor.
  - If the power contactor opened and then reclosed, the compressor stalled for as long as 3.0 seconds, drawing approximately 94 Amps at 237 VAC, characteristics before the thermal protection opened to protect the compressor
- At 100 °F.
  - The compressor stalled, drawing approximately 48 Amps at 129 VAC, for as long as 21.5 seconds before the thermal protection switch opened to protect the compressor.
  - If the power contactor opened and then reclosed, the compressor stalled for as long as 3.0 seconds, drawing approximately 94 Amps at 235 VAC, before the thermal protection opened to protect the compressor.
- At 115 °F
  - The compressor stalled, drawing approximately 48 Amps at 130 VAC, for as long as 17.9 seconds before the thermal protection switch opened to protect the compressor.
  - If the power contactor opened and then reclosed, the compressor stalled for as long as 3.0 seconds, drawing approximately 94 Amps at 237 VAC, before the thermal protection switch opened to protect the compressor.

4.6 *DELAYED RECOVERY* TYPE OF TRANSIENT TEST RESULTS

This compressor has the following stall threshold voltages 64% at 80 °F, 65% at 100 °F, and 68% at 115 °F when exposed to the *delayed recovery* type of transient. Therefore, the stalling windows for this compressor are the following: 65% to 50% at 80 °F, 67% to 50% at 100 °F, and 68% to 50% at 115 °F. The thermal protection switch opened after each stall to protect the compressor. The compressor stalled in the stalling window, drawing approximately 62 Amps at 175 VAC, for as long as 12.5 seconds before the thermal protection switch opened to protect the compressor. If the power contactor opened and then reclosed, the compressor stalled, drawing approximately 63 Amps at 178 VAC, for as long as 11.5 seconds before the thermal protection opened to protect the

compressor. The following are the detail responses of the compressor for each of the temperatures:

- At 80 °F
  - The compressor stalled, drawing approximately 61 Amps at 170 VAC, for as long as 10.9 seconds before the thermal protection switch opened to protect the compressor.
  - If the power contactor opened and then reclosed, the compressor stalled, drawing approximately 62 Amps at 176 VAC, for as long as 10 seconds before the thermal protection switch opened to protect the compressor.
- At 100 °F
  - The compressor stalled, drawing approximately 62 Amps at 173 VAC, for as long as 11.6 seconds before thermal protection switch opened to protect the compressor.
  - If the power contactor opened and then reclosed, the compressor stalled, drawing approximately 62 Amps at 175 VAC, for as long as 11.0 seconds before the thermal protection opened to protect the compressor.
- At 115 °F
  - The compressor stalled, drawing approximately 62 Amps at 175 VAC, for as long as 12.5 seconds before thermal protection switch opened to protect the compressor .
  - If the power contactor opened and then reclosed, the unit stalled, drawing approximately 63 Amps at 178 VAC, for as long as 11.5 seconds before the thermal protection opened to protect the compressor.

4.7 *CIRCUIT BREAKER CLEARING* TYPE OF TRANSIENT TEST RESULTS

This compressor has the following threshold voltages 63% at 80 °F, 64% at 100 °F, and 66% at 115 °F when exposed to the *circuit breaker clearing* type of transients. Therefore, the stalling windows are the following: 63% to 50% at 80 °F, 64% to 50% at 100 °F, and 66% to 50% at 115 °F. The thermal protection switch opened after each stall to protect the compressor. The compressor stalled in the stalling window, drawing approximately 94 Amps at 235 VAC, for as long as 2.8 seconds before the thermal protection switch opened to protect the compressor. If the power contactor opened and then reclosed, the compressor stalled, drawing approximately 94 Amps at 235 VAC, for as long as 2.8 seconds before the thermal protection opened to protect the compressor. The following are the detail responses of the compressor for each of the temperatures:

- At 80 °F
  - The compressor stalled, drawing approximately 95 Amps at 235 VAC, for as long as 2.8 seconds before the thermal protection switch opened to protect the compressor.
  - If the power contactor opened and then reclosed, the compressor stalled, drawing approximately 94 Amps at 235 VAC, for as long as 2.8 seconds before the thermal protection switch opened to protect the compressor.
- At 100 °F
  - The compressor stalled, drawing approximately 94 Amps at 234 VAC, for as long as 2.8 seconds before the thermal protection switch opened to protect the compressor.
  - If the power contactor opened and then reclosed, the compressor stalled, drawing approximately 94 Amps at 235 VAC, for as long as 2.9 seconds before the thermal protection switch opened to protect the compressor.
- At 115 °F
  - The compressor stalled, drawing approximately 94 Amps at 235 VAC, for as long as 2.9 seconds before the thermal protection switch opened to protect the compressor.

- If the power contactor opened and then reclosed, the unit stalled, drawing approximately 94 Amps at 235 VAC, for as long as 2.8 seconds before the thermal protection switch opened to protect the compressor.

5.0 A/C #2 - TEST RESULTS

The air conditioner's compressor stalled when the voltage was in the stalling window (between the stall threshold voltage and contactor dropout voltage) when exposed to the *long notch* and *delayed recovery* type of transients. This compressor stalled, drawing approximately 47 Amps at 127 VAC, for as long as 20.2 seconds before the thermal protection switch opened to protect the compressor, when exposed to the *long notch* type of transients. This compressor stalled, drawing approximately 56 Amps at 152 VAC, for as long as 7.7 seconds before the thermal protection switch opened to protect the compressor, when exposed to the *delayed recovery* type of transients. This compressor did not stalled when exposed to the *circuit breaker clearing* type of transients; therefore, this unit is not sensitive to circuit breaker clearing type of transients except when they go below the contactor dropout voltage. Opening the contactor did not help to prevent the compressor from stalling, it just delayed stalling except for the *long notch* type of transient where it did not stall at all. The good thing about this air conditioner unit is that it restarts normally after any stall. The power contactor drop out voltage is 50%.

5.1 SYSTEM SPECIFICATIONS

The tested air conditioner system has the following specifications:

MAIN SYSTEM	
Manufacturer	Carrier
Condenser Unit	38BRG036300
Evaporator Coil	CK3BA036
Size (Tons)	3
Compressor Type	Scroll
Refrigerant	R-22
SEER	12
Condition	New
Unit Cost	$1,068.00

COMPRESSOR	
Manufacturer	Copeland
Model	ZR34K3-PFV-130
Type	Scroll
FLA (AMPS)	17.6
LRA (AMPS)	88
Phase	1
Refrigerant	R22
Charge (LBS)	6.5
Voltage (V)	230/208
PMAX High (PSI)	398.8
PMAXLow (PSI)	290

FAN MOTOR	
Manufacturer	GE
Model	5KCP39GFSS166S
Voltage (V)	208/230
Current (I)	0.95
Power (HP)	0.2
RPM	825
FLA (AMPS)	1.1

CONTACTOR	
Manufacturer	Product Unlimited
Model	HN51KC024
Rating (V)	240/277
FLA (AMPS)	30
LRA (AMPS)	150
Resistance	40

CAPACITOR	
Manufacturer	Aurora
Model	PRCD 5575
Rating (V)	370
Capacitance (µF)	75

5.2 TEST PARAMETERS

This air conditioner unit has the following testing parameters.

	80°F	100°F	115°F
T_{INLET} (°C)	22.6	23.1	22.9
T_{OUTLET} (°C)	10.9	11.8	12.5
$T_{COMP.\ AMB.}$ (°C)	27.4	39.2	47.0
T_{CASE} (°C)	78.0	89.9	100.7
T_{GAS} (°C)	-	-	-
T_{LIQ} (°C)	-	-	-
R_{FLOW} (Kcfm)	1.3	1.6	1.4
P_{LOW} (PSI)	54.0	66.3	72.6
P_{HIGH} (PSI)	199.4	261.6	317.5
$I_{RUNNING}$ (A)	12.0	15.0	17.0
$W_{RUNNING}$ (W)	2608.0	3164.0	3884.0
$VAR_{RUNNING}$ (VAR)	823.0	850.0	888.0

A more detail performance parameter table can be found in APPENDIX #2 -- Attachment # 2

5.3 INRUSH TEST RESULTS

This air conditioner unit took approximately 14 cycles to come to normal running state. The data below was recorded for the whole air conditioner system.

Inrush	
V_{INRUSH}	227 VAC
I_{INRUSH}	99 A
W_{INRUSH}	16,000 W
VAR_{INRUSH}	15,700 VAR
t	14 cycles

5.4 POWER CONTACTOR TEST RESULTS

The power contactor opened at 50% voltage sag. In general, opening the contactor did not prevent the compressor from stalling; it just delayed the stalling until the contactor reclosed except when exposed to *long notch* type of transients. The compressor had the following responses right after the contactor reclosed:

- *Long notch* type of transients
  - The compressor never stalled after the power contactor reclosed.
- *Delayed Recovery* type of transient

- The compressor stalled, drawing approximately 61 Amps at 165 VAC, right after the contactor reclosed for as long as 5.5 seconds before the thermal protection switch opened to protect the compressor.

♦ *Circuit Breaker Clearing* type of transients
- The compressor stalled, drawing approximately 90 Amps at 228 VAC, right after the contactor reclosed for as long as 0.3 seconds before resuming the normal running mode.

5.5 *30-SECOND LONG NOTCH* TYPE OF TRANSIENT TEST RESULTS

This unit has the following threshold voltages 58% at 80 °F, 63% at 100 °F, and 68% at 115 °F when exposed to the *long notch* type of transients. Therefore, the stalling windows are the following: 58% to 50% at 80 °F, 63% to 50% at 100 °F, and 68% to 50% at 115 °F. The thermal protection switch opened after each stall to protect the unit. The unit stalled in the stalling window, drawing approximately 47 Amps at 127 VAC, for as long as 20.2 seconds before the thermal protection switch opened to protect the unit. If the power contactor opened and then reclosed, the compressor would return to the normal running mode. The following are the details for each of the temperatures:

♦ At 80 °F
- The compressor stalled, drawing approximately 47 Amps at 127 VAC, for as long as 20.2 seconds before the thermal protection switch opens to protect the compressor.
- If the power contactor opened and reclosed, the compressor resumed normal running mode.

♦ At 100 °F
- The compressor stalled, drawing approximately 47 Amps at 127 VAC, for as long as 17.0 seconds before the thermal protection switch opened to protect the compressor.
- If the power contactor opened and then reclosed, the compressor resumed the normal running mode.

♦ At 115 °F
- The compressor stalled, drawing approximately 47 Amps at 127 VAC, for as long as 14.7 seconds before the thermal protection switch opened to protect the compressor.
- If the power contactor opened and then reclosed, the compressor resumed the normal running mode.

5.6 *DELAYED RECOVERY* TYPE OF TRANSIENT TEST RESULTS

This unit has the following threshold voltages 55% at 80 °F, 60% at 100 °F, and 65% at 115 °F when exposed to the *delayed recovery* type of transient. Therefore, the stalling windows are the following: 55% to 50% at 80 °F, 60% to 50% at 100 °F, and 65% to 50% at 115 °F. The thermal protection switch opened after each stall to protect the unit. The compressor stalled in the stalling window, drawing approximately 56 Amps at 152 VAC, for as long as 7.7 seconds before the thermal protection switch opened to protect the compressor. If the power contactor opened and then reclosed, the compressor stalled, drawing approximately 61 Amps at 165 VAC, for as long as 5.5 seconds before the thermal protection switch opened to protect it. The following are the details for each of the temperatures:

♦ At 80 °F
- The compressor stalled, drawing approximately 55 Amps at 148 VAC, for as long as 6.9 seconds before the thermal protection switch opened to protect the compressor.

- If the power contactor opened and then reclosed, the compressor stalled, drawing approximately 59 Amps at 160 VAC, for as long as 5.2 seconds before the thermal protection opened to protect the compressor.

♦ At 100 °F
- The compressor stalled, drawing approximately 56 Amps at 152 VAC, for as long as 7.7 seconds before the thermal protection switch opened to protect the compressor.
- If the power contactor opened and then reclosed, the compressor stalled, drawing approximately 60 Amps at 161 VAC, for as long as 5.4 seconds before the thermal protection switch opened to protect the compressor.

♦ At 115 °F
- The compressor stalled, drawing approximately 56 Amps at 154 VAC, for as long as 7.6 seconds before the thermal protection switch opened to protect the compressor.
- If the power contactor opened and then reclosed, the compressor stalled, drawing approximately 61 Amps at 165 VAC, for as long as 5.5 seconds before the thermal protection switch opened to protect the compressor.

5.7 *CIRCUIT BREAKER CLEARING* TYPE OF TRANSIENT TEST RESULTS

This unit did not stall when exposed to the *Circuit Breaker Clearing* type of transients except when the contactor opened. Then it stalled when the contactor reclosed, drawing approximately 90 Amps at 228 VAC,

6.0 A/C #3 - TEST RESULTS

The air conditioner's compressor stalled when the voltage was in the stalling window (between the stall threshold voltage and contactor dropout voltage) when exposed to any of the three test transients. This compressor stalled, drawing approximately 57 Amps at 138 VAC, for as long as 13.5 seconds before the thermal protection switch opened to protect the compressor, when exposed to the *long notch* type of transients in the stalling window. It stalled, drawing approximately 62 Amps at 156 VAC, for as long as 14.2 seconds before the thermal protection switch opened to protect the compressor, when exposed to the *delayed recovery* type of transients. It stalled, drawing approximately 101 Amps at 227 VAC, for as long as 0.5 seconds then unit restart normally or went into NO-LOAD condition, when exposed to *circuit breaker clearing* type of transients. Opening the contactor did not help to prevent the compressor from stalling, it just delayed it. If the power contactor opened and then reclosed, the compressor stalled for as long as 12.7 seconds before the thermal protection switch opened to protect it except when exposed to the *long notch* type of transients where it returned to normal running mode. If the unit did not restart normally or went into the NO-LOAD condition, then the compressor needed to be turned off and then on again in order to restart normally. At the NO-LOAD condition, the compressor consumed ½ of the normal running power but without producing any cooling. At high temperatures, the compressor is sensitive to the *circuit breaker clearing* type of transients where most of the tests end up in the NO-LOAD condition. The power contactor drop out voltage is 35%.

6.1 SYSTEM SPECIFICATIONS

The tested air conditioner system has the following specifications:

MAIN SYSTEM	
Manufacturer	Rheem
Condenser Unit	RAKB036-JAZ
Evaporator Coil	CK3BA036
Size (Tons)	3
Compressor Type	Scroll
Refrigerant	R-22
SEER	10
Condition	New
Unit Cost	$925.00

COMPRESSOR	
Manufacturer	Copeland
Model	ZR36X3-PFV-230
Type	Scroll
FLA (AMPS)	19
LRA (AMPS)	95
Phase	1
Refrigerant	R22
Charge (LBS)	4.9
Voltage (V)	230/208
PMAX High (PSI)	398.8
PMAXLow (PSI)	290

FAN MOTOR	
Manufacturer	Emerson
Model	K55HXKYH-9836
Voltage (V)	208/230
Current (I)	1.3
Power (HP)	0.2
RPM	1075
FLA (AMPS)	1.3

CONTACTOR	
Manufacturer	Cutler-Hammer
Model	C25CNY3T
Rating (V)	240/277
FLA (AMPS)	25
LRA (AMPS)	150
Resistance	30

CAPACITOR	
Manufacturer	Digital Tech
Model	43-101665-14
Rating (V)	370
Capacitance (µF)	50

6.2 TEST PARAMETERS

This air conditioner unit has the following testing parameters.

	80°F	100°F	115°F
T_{INLET} (°C)	22.5	23.7	24.7
T_{OUTLET} (°C)	9.1	11.0	12.9
$T_{COMP.\ AMB.}$ (°C)	26.3	38.5	46.7
T_{CASE} (°C)	67.4	82.2	92.5
T_{GAS} (°C)	-	-	-
T_{LIQ} (°C)	-	-	-
R_{FLOW} (Kcfm)	1.4	1.3	1.3
P_{LOW} (PSI)	62.8	68.1	359.6
P_{HIGH} (PSI)	224.6	300.2	73.7
$I_{RUNNING}$ (A)	14.0	17.0	20.0
$W_{RUNNING}$ (W)	3152.0	3911.0	4583.0
$VAR_{RUNNING}$ (VAR)	1200.0	1250.0	1348.0

A more detail internal performance parameter table can be found in APPENDIX #2 -- Attachment # 3.

6.3 INRUSH TEST RESULTS

This air conditioner unit took approximately 13 cycles to come to the normal steady running state. The data below was recorded for the whole air conditioner system.

Inrush	
V_{INRUSH}	226 VAC
I_{INRUSH}	106 A
W_{INRUSH}	17,200 W
VAR_{INRUSH}	16,800 VAR
t	13 cycles

6.4 POWER CONTACTOR TEST RESULTS

The power contactor opened with a 35% voltage sag. The compressor, at times, goes into a NO-LOAD condition. The compressor had the following responses right after the contactor reclosed:

- *Long notch* type of transient
  - The compressor never stalled after the power contactor reclosed.
- *Delayed Recovery* type of transient
  - The compressor stalled, drawing approximately 62 Amps at 154 VAC, for as long as 13 seconds before the thermal protection switch opened to protect the compressor.
- *Circuit Breaker Clearing* type of transient

- At times the compressor stalled, drawing approximately 102 Amps at 226 VAC, for less than 0.4 seconds right after the power contactor reclosed then return to the normal running mode.
- At times the compressor stalled, drawing approximately 101 Amps at 227 VAC, for less than 0.4 seconds right after the power contactor reclosed then went into a NO-LOAD condition.
- At times the compressor stalled, drawing approximately 102 Amps at 226 VAC, for less than 1 second right after the power contactor reclosed causing the thermal protection switch to open to protect the compressor. The compressor did not go into a NO-LOAD condition.
- At times the compressor returned to the normal running mode after the contactor reclosed.

6.5 *30-SECOND LONG NOTCH* TYPE OF TRANSIENT TEST RESULTS

This unit has the following threshold voltages 60% at 80 °F, 65% at 100 °F, and 70% at 115 °F when exposed to the *long notch* type of transients. Therefore, the stalling windows are the following: 60% to 35% at 80 °F, 65% to 35% at 100 °F, and 70% to 35% at 115 °F. The thermal protection switch opened to protect the compressor. The compressor did not always restarted normally after the thermal protection switch reclosed and at times it went into the NO-LOAD condition. The compressor needed to be turned off and then on again in order to restart normally. The unit stalled in the stalling window, drawing approximately 57 Amps at 138 VAC, for as long as 13.5 seconds before the thermal protection switch opened to protect the compressor. Sometimes the compressor stalled, drawing approximately 46 Amps at 114 VAC, for the complete transient period without opening the thermal protection switch. If the power contactor opened and then reclosed, the compressor returned to the normal running mode. The following are the details for each of the temperatures:

- At 80 °F
  - At times the compressor stalled, drawing approximately 57 Amps at 138 VAC, for as long as 13.5 seconds before the thermal protection switch opened to protect the compressor.
  - At times the compressor stalled, drawing approximately 61 Amps at 126 VAC through the complete transient period and then the thermal protection switch opened when the voltage returned to normal at the end of the transient. The unit did not restart normally.
  - At times it stalled, drawing approximately 46 Amps at 114 VAC, for the complete transient period and then returned to the normal running mode.
  - If the power contactor opened and then reclosed, the compressor returned to the normal running mode.
- At 100 °F
  - At times the compressor stalled, drawing approximately 57 Amps at 138 VAC, for as long as 13.1 seconds before the thermal protection switch opened to protect the compressor.
  - At times, the compressor stalled, drawing approximately 51 Amps at 125 VAC, for as long as 1.1 seconds and then went into the NO-LOAD condition.
  - At times the compressor stalled, drawing approximately 46 Amps at 115 VAC through the complete transient period and the returned to the normal running mode.
  - If the power contactor opened and then reclosed, the compressor returned to the normal running mode.
- At 115 °F
  - At times the compressor stalled, drawing approximately 61 Amps at 149 VAC, for as long as 6.5 seconds before the thermal protection switch opened. When the thermal switch

reclosed the unit stalled for a second time for as long as 4.6 seconds before the thermal protection switch opened again to protect the compressor.

- At times the compressor stalled, drawing approximately 45 Amps at 114 VAC, for the transient period and then returned to the normal running mode.
- If the power contactor opened and then reclosed, the unit returned to the normal running mode.

6.6 *DELAYED RECOVERY* TYPE OF TRANSIENT TEST RESULTS

This compressor has the following threshold voltages 55% at 80 °F, 60% at 100 °F, and 65% at 115 °F when exposed to the *delayed recovery* type of transient. Therefore, the stalling windows are the following: 55% to 35% at 80 °F, 60% to 35% at 100 °F, and 65% to 35% at 115 °F. The thermal protection switch opened after each stall to protect the compressor. The compressor stalled in the stalling window, drawing approximately 62 Amps at 156 VAC, for as long as 14.2 seconds before the thermal protection switch opened to protect the compressor. If the power contactor opened and then reclosed, the compressor stalled, drawing approximately 63 Amps at 157 VAC, for as long as 9.1 seconds before the thermal protection switch opened to protect the compressor. Opening the contactor did not help in preventing the compressor from stalling, it just delayed it. In general, the unit restarted normally after any stalling except in one case where it went into the NO-LOAD condition. The following are the details for each of the temperatures:

- At 80 °F
  - The compressor stalled, drawing approximately 62 Amps at 156 VAC, for as long as 14.2 seconds before the thermal protection switch opened to protect the compressor.
  - If the power contactor opened and then reclosed, the compressor stalled, drawing approximately 63 Amps at 157 VAC, for as long as 9.1 seconds before the thermal protection switch opened to protect the compressor.
- At 100 °F
  - The compressor stalled, drawing approximately 61 Amps at 153 VAC, for as long as 12.2 seconds before the thermal protection switch opened to protect the compressor.
  - In one test, the compressor stalled, drawing approximately 57 Amps at 137 VAC, for as long as 0.8 seconds before the thermal protection switch opened. When the thermal protection switch closed, the unit went into NO-LOAD condition.
- At 115 °F
  - The compressor stalled, drawing approximately 60 Amps at 154 VAC, for as long as 12.9 seconds before the thermal protection switch opened to protect the compressor.
  - If the power contactor opened and then reclosed, the compressor stalled, drawing approximately 63 Amps at 159 VAC, for as long as 8.8 seconds before the thermal protection opened to protect the compressor.

6.7 *CIRCUIT BREAKER CLEARING* TYPE OF TRANSIENT TEST RESULTS

This unit had the following threshold voltages 50% at 80 °F, 60% at 100 °F, and 65% at 115 °F when exposed to the *circuit breaker clearing* type of transients. Therefore, the stalling windows are the following: 50% to 35% at 80 °F, 60% to 35% at 100 °F, and 65% to 35% at 115 °F. The thermal protection switch rarely opened after stalling to protect the compressor. The unit stalled in the stalling window, drawing approximately 101 Amps at 227 VAC, for as long as 0.5 seconds

before return to the normal running state or the NO-LOAD condition. If the power contactor opened and then reclosed the compressor stalled, drawing approximately 102 Amps at 227 VAC, long as 0.5 seconds. Then it either resumed the normal running state or went into the NO-LOAD condition. Opening the contactor did not prevent the compressor from stalling, it just delayed it. The following are the details for each of the temperatures:

- At 80 °F
  - The compressor stalled, drawing approximately 101 Amps at 227 VAC, for as long as 0.5 seconds before it returned to the normal running mode.
  - If the power contactor opened and then reclosed, the compressor stalled, drawing approximately 102 Amps at 227 VAC, for as long as 0.5 seconds. Then it either the thermal protection switch opened or it went into the NO-LOAD condition. In both cases, the compressor did not restart normally.
- At 100 °F
  - At times the compressor stalled, drawing approximately 102 Amps at 226 VAC, for as long as 0.5 seconds before it returned to the normal running state.
  - At times the compressor stalled, drawing approximately 103 Amps at 227 VAC, for as long as 0.4 seconds before it went into the NO-LOAD condition.
  - If the power contactor opens and then recloses, the unit stalled for as long as 0.3 seconds , drawing approximately 101 Amps at 226 VAC. It then went into the NO-LOAD condition.
- At 115 °F
  - Usually the compressor stalled, drawing approximately 102 Amps at 226 VAC, for as long as 0.5 seconds and then went into the NO-LOAD condition.
  - At times the unit stalled, drawing approximately 102 Amps at 226 VAC, for as long as 0.5 seconds before it returned to the normal running mode.
  - If the power contactor opened and then reclosed, the compressor stalled for as long as 0.4 seconds, drawing approximately 103 Amps at 227 VAC. Then either the unit returned to the normal running state or it went into the NO-LOAD condition.

7.0 A/C #4 - TEST RESULTS

The air conditioner's compressor stalled when the voltage was in the stalling window (between the stall threshold voltage and contactor dropout voltage) when exposed to any of the three test transients. When exposed to the *long notch* type of transients in the stalling window, this compressor stalled, drawing approximately 44 Amps at 140 VAC, for as long as 28.2 seconds before the thermal protection switch opened to protect the compressor but sometimes it stalled for the complete 30 second transient period without opening the thermal protection switch. At times, the compressor stalled for a short period of time (1.0 second) then went into the NO-LOAD condition. The compressor stalled, drawing approximately 60 Amps at 195 VAC, for as long as 19.6 seconds before the thermal protection switch opened to protect the compressor, when exposed to the *delayed recovery* type of transient. It stalled, drawing approximately 82 Amps at 229 VAC, for as long as 0.5 seconds then the compressor either returned to normal running mode or went into the NO-LOAD condition, when exposed to the *circuit breaker clearing* type of transients. In general, opening the contactor did not prevent the compressor from stalling; it just delayed it except when exposed to the *long notch* transient where it resumed normal running mode. If the power contactor opened and then reclosed, the compressor stalled for as long as 21.0 seconds before the thermal protection switch opened to protect it except when exposed to the *long notch* type of transients where it resumed the normal running mode. When the contactor opened under the *circuit breaker clearing* type of transients, the compressor stalled for as long as 0.5 second then usually went into the NO-LOAD condition. If the unit did not restart normally or went into the NO-LOAD condition, then the compressor needed to be turned off and then on again in order to restart normally. The compressor in the NO-LOAD condition consumed ½ of the normal running power but without producing any work (cooling). At high temperatures, the compressor is more sensitive to the *circuit breaker clearing* type of transients where most of the tests end up in the NO-LOAD condition. The power contactor drop out voltage is 55%.

7.1 SYSTEM SPECIFICATIONS

The tested air conditioner system has the following specifications:

MAIN SYSTEM	
Manufacturer	Carrier
Condenser Unit	38TXA036-30
Evaporator Coil	CK3BA036
Size (Tons)	3
Compressor Type	Scroll
Refrigerant	R-410A
SEER	13
Condition	New
Unit Cost	$1,687.00

COMPRESSOR	
Manufacturer	Copeland
Model	ZP31K5-PFV-130
Type	Scroll
FLA (AMPS)	16.7
LRA (AMPS)	79
Phase	1
Refrigerant	R410A
Charge (LBS)	6.88
Voltage (V)	230/208
PMAX High (PSI)	623.7
PMAXLow (PSI)	406.1

FAN MOTOR	
Manufacturer	GE
Model	5KCP39GF
Voltage (V)	208/230
Current (I)	0.95
Power (HP)	0.2
RPM	825
FLA (AMPS)	1.1

CONTACTOR	
Manufacturer	Product Unlimited
Model	HN51KC024
Rating (V)	240/277
FLA (AMPS)	30
LRA (AMPS)	160
Resistance	40

CAPACITOR	
Manufacturer	GE
Model	97F9969
Rating (V)	370
Capacitance (µF)	45

7.2 TEST PARAMETERS

This air conditioner unit has the following testing parameters.

	80°F	100°F	115°F
T_{INLET} (°C)	22.4	22.9	22.9
T_{OUTLET} (°C)	10.8	10.9	12.1
$T_{COMP.\ AMB.}$ (°C)	27.8	39.0	47.8
T_{CASE} (°C)	89.5	94.8	108.7
T_{GAS} (°C)	-	-	-
T_{LIQ} (°C)	-	-	-
R_{FLOW} (Kcfm)	1.6	1.2	1.2
P_{LOW} (PSI)	106.9	117.8	127.1
P_{HIGH} (PSI)	351.9	471.5	579.4
$I_{RUNNING}$ (A)	12.0	15.0	18.0
$W_{RUNNING}$ (W)	2763.0	3507.0	4272.0
$VAR_{RUNNING}$ (VAR)	647.0	700.0	846.0

A more detail internal performance parameter table can be found in APPENDIX #2 -- Attachment # 4.

7.3 INRUSH TEST RESULTS

It would take approximately 14 cycles to come to the normal steady running state. The data below was recorded for the whole air conditioner system.

Inrush	
V_{INRUSH}	228 VAC
I_{INRUSH}	84 A
W_{INRUSH}	14,400 W
VAR_{INRUSH}	13,100 VAR
t	14 cycles

7.4 POWER CONTACTOR TEST RESULTS

The power contactor opened with a 50% voltage sag. In one instance, the unit did not restart normally and needed to be turned off and then on again in order to return to the normal running mode. The compressor had the following responses right after contactor reclosed:

- *Long notch* type of transient
  - Never stalled after power contactor reclosed.
- *Delayed Recovery* type of transient
  - The compressor stalled, drawing approximately 62 Amps at 202 VAC, right after contactor reclosed for as long as 15.9 seconds before the thermal protection switch opened to protect the compressor.
  - Restarted normally after thermal protection switch reclosed except for one case where it did not restart normally and needed to be turned off and then on again in order to return to the normal running state.
- *Circuit Breaker Clearing* type of transient
  - At 80 °F
    - The compressor stalled, drawing approximately 84 Amps at 229 VAC, right after the contactor reclosed for as long as 1.4 seconds before it returned to the normal running mode.
  - At 100 °F
    - At times the compressor stalled, drawing approximately 85 Amps at 229 VAC right after the contactor reclosed for as long as 0.4 seconds before it went into the NO-LOAD condition.
    - At times the compressor returned to the normal running mode.
  - At 115 °F
    - At times the compressor stalled, drawing approximately 83 Amps at 229 VAC right after the contactor reclosed for as long as 0.4 seconds before it went into the NO-LOAD condition.
    - At times the compressor returned to the normal running mode.

7.5 *30-SECOND LONG NOTCH* TYPE OF TRANSIENT TEST RESULTS

This compressor has the following threshold voltages 62% at 80 °F, 68% at 100 °F, and 75% at 115 °F when exposed to the *long notch* type of transients. Therefore, the stalling windows are the

following: 62% to 50% at 80 °F, 68% to 50% at 100 °F, and 75% to 50% at 115 °F. The thermal protection switch opens to protect the compressor. The unit stalled in the stalling window, drawing approximately 44 Amps at 140 VAC, for as long as 28.2 seconds before the thermal protection switch opened to protect the compressor. At times, it also stalled for as long as 0.9 seconds before it went into the NO-LOAD condition. In this condition, the compressor will never restart normally, it will always consume ½ the normal running power but without producing any work (no cooling). If the power contactor opened and then reclosed the compressor did not return to the normal running state. The compressor needed to be turned off and then on again in order to restart normally. The following are the details for each of the temperatures:

- At 80 °F
  - At times the compressor stalled, drawing approximately 42 Amps at 128 VAC, for the complete transient period and then returned to the normal running state.
  - At times the compressor stalled, drawing approximately 44 Amps at 140 VAC, for as long as 28.2 seconds before the thermal protection switch opened to protect the compressor. The compressor did not restart normally.
  - If the power contactor opened and then reclosed, the compressor returned to normal running mode.
- At 100 °F
  - At times the compressor stalled, drawing approximately 51 Amps at 159 VAC, for as long as 0.9 seconds then went into the NO-LOAD condition.
  - At times the compressor stalled, drawing approximately 51 Amps at 151 VAC, for as long as 23.8 seconds before the thermal protection switch opened to protect the compressor.
  - At times the compressor stalled, drawing approximately 41 Amps at 126 VAC, for the complete transient period without opening the thermal protection switch.
  - If the power contactor opened and then reclosed, the compressor returned to normal running mode.
- At 115 °F
  - At times the compressor stalled, drawing approximately 56 Amps at 174 VAC, for as long as 1.0 second and then went into the NO-LOAD condition.
  - At times the compressor stalled, drawing approximately 49 Amps at 151 VAC, for as long as 16.5 seconds before the thermal protection switch opened to protect the compressor.
  - At times the compressor stalled, drawing approximately 40 Amps at 128 VAC, for the complete transient period without opening the thermal protection switch.
  - If the power contactor opened and then reclosed the unit returned to the normal running state.

7.6 *DELAYED RECOVERY* TYPE OF TRANSIENT TEST RESULTS

This compressor had the following threshold voltages 60% at 80 °F, 65% at 100 °F, and 75% at 115 °F when exposed to the *delayed recovery* type of transient. Therefore, the stalling windows are the following: 60% to 50% at 80 °F, 65% to 50% at 100 °F, and 75% to 50% at 115 °F. The thermal protection switch opened after each stall to protect the compressor. The unit stalled in the stalling window, drawing approximately 60 Amps at 195 VAC, for as long as 19.6 seconds before the thermal protection switch opened to protect the compressor. At high temperatures, this compressor at times did not restarted normally after the thermal protection switch reclosed. It needed to be turned off and then on again in order to restart normally. If the power contactor opened and then reclosed, the compressor stalled, drawing approximately 62 Amps at 200 VAC,

for as long as 15.9 seconds before the thermal protection switch opened to protect the compressor. The following are the details for each of the temperatures:

- At 80 °F
  - The compressor stalled, drawing approximately 58 Amps at 186 VAC, for as long as 16.8 seconds before the thermal protection switch opened to protect the compressor.
  - If the power contactor opened and then reclosed, the compressor stalled, drawing approximately 58 Amps at 185 VAC, for as long as 13.2 seconds before the thermal protection switch opened to protect the compressor. The compressor did not restart normally.
- At 100 °F
  - The compressor stalled, drawing approximately 60 Amps at 195 VAC, for as long as 19.6 seconds before the thermal protection switch opened to protect the compressor.
  - If the power contactor opened and then reclosed, the compressor stalled, drawing approximately 61 Amps at 194 VAC, for as long as 13.4 seconds before the thermal protection switch opened to protect the compressor.
- At 115 °F
  - At times the compressor stalled, drawing approximately 59 Amps at 193 VAC, for as long as 18.4 seconds before the thermal protection switch opened to protect the compressor.
  - At times the compressor stalled, drawing approximately 60 Amps at 191 VAC, for as long as 16.9 seconds before the thermal protection switch opened to protect the compressor. The compressor did not restart normally.
  - If the power contactor opened and then reclosed, the compressor stalled, drawing approximately 62 Amps at 200 VAC, for as long as 15.9 seconds before the thermal protection switch opened to protect the compressor.

7.7 *CIRCUIT BREAKER CLEARING* TYPE OF TRANSIENT TEST RESULTS

This compressor had the following threshold voltages 55% at 80 °F, 65% at 100 °F, and 70% at 115 °F when exposed to the *Circuit Breaker Clearing* type of transients. Therefore, the stalling windows are the following: 55% to 50% at 80 °F, 60% to 50% at 100 °F, and 70% to 50% at 115 °F. At times the thermal protection switch opened after stalling to protect the compressor. The unit stalled in the stalling window, drawing approximately 82 Amps at 229 VAC, for as long as 0.5 seconds before it either returned to the normal running state or it went into the NO-LOAD condition. If the power contactor opened and then reclosed, the compressor stalled for as long as 1.4 seconds drawing approximately 84 Amps at 229 VAC then either resumed the normal running state or went into the NO-LOAD condition. The following are the details for each of the temperatures:

- At 80 °F
  - The compressor did not stall in the 3 and 6 cycle tests.
  - At times the compressor stalled, drawing approximately 82 Amps at 229 VAC, for as long as 0.5 seconds before it returned to the normal running mode.
  - At times the compressor stalled, drawing approximately 82 Amps at 229 VAC, for as long as 0.3 seconds before the thermal protection switch opened to protect the compressor. The compressor did not restart normally.
  - If the power contactor opened and then reclosed, the compressor stalled, drawing approximately 84 Amps at 229 VAC, for as long as 1.4 seconds before it returned to the normal running state.

- At 100 °F
  - The compressor stalled, drawing approximately 84 Amps at 229 VAC, for as long as 0.4 seconds and then went into the NO-LOAD condition.
  - If the power contactor opened and then reclosed, the compressor stalled, drawing approximately 85 Amps at 229 VAC, for as long as 0.3 seconds. At times it went into the NO-LOAD condition but at other times it returned to the normal running mode.
- At 115 °F
  - Usually the compressor stalled, drawing approximately 80 Amps at 229 VAC, for as long as 0.4 seconds and then went into the NO-LOAD condition.
  - At times the compressor stalled, drawing approximately 81 Amps at 229 VAC, for as long as 0.5 seconds before it returned to the normal running state
  - If the power contactor opened and then reclosed, the compressor stalled, drawing approximately 83 Amps at 229 VAC, for as long as 0.4 seconds before it returned to the normal running mode.

8.0 A/C #5 - TEST RESULTS

The air conditioner's compressor stalled when the voltage was in the stalling window (between the stall threshold voltage and contactor dropout voltage) when exposed to any of the three types of transients. When exposed to the *long notch* type of transients in the stalling window, this compressor stalled, drawing approximately 81 Amps at 135 VAC, for as long as 26.0 seconds before the thermal protection switch opened to protect the compressor for as long as 30.0 seconds (drawing approximately 73 Amps at 124 VAC) before resuming the normal running mode. The compressor did not restart normally after the thermal protection switch opened and needed to be turned off and then on again in order to resume the normal running mode. The compressor stalled, drawing approximately 99 Amps at 172 VAC, for as long as 15.9 seconds before returning to the normal running mode, when exposed to the *delayed recovery* type of transients in the stalling window. The compressor stalled, drawing approximately 87 Amps at 145 VAC, for the complete 30 second transient time before going into the IDLE condition, when exposed to the *circuit breaker clearing* type of transients in the stalling window. When the contactor opened under the *delayed recovery* type of transients and then reclosed, the compressor stalled, drawing approximately 115 Amps at 193 VAC, for as long as 8.1 seconds before returning to the normal running mode. In general, opening the contactor did not help prevent the compressor from stalling; it just delayed the stall. If the unit did not restart normally or went into the IDLE condition, then the compressor needed to be turned off and then on again in order to return to the normal running mode. The compressor in the IDLE condition consumed the same power as with normal running but without producing any work (cooling). The compressor was more prone to go into the IDLE condition when it stalled during the *circuit breaker clearing* type of transients.

8.1 SYSTEM SPECIFICATIONS

The tested air conditioner system has the following specifications:

MAIN SYSTEM	
Manufacturer	Coleman
Condenser Unit	AC3B048F1A
Evaporator Coil	CK3BA048
Size (Tons)	4
Compressor Type	Scroll
Refrigerant	R-410A
SEER	13
Condition	New
Unit Cost	$1,630.00

COMPRESSOR	
Manufacturer	Benchmark
Model	H83R413ABCA
Type	Scroll
FLA (AMPS)	21.1
LRA (AMPS)	150
Phase	1
Refrigerant	R410A
Charge (LBS)	8.75
Voltage (V)	230/208
PMAX High (PSI)	-
PMAXLow (PSI)	-

FAN MOTOR	
Manufacturer	Motor Division
Model	K55HXKWQ-9803
Voltage (V)	208/230
Current (I)	1.5
Power (HP)	0.25
RPM	850
FLA (AMPS)	1.5

CONTACTOR	
Manufacturer	GE
Model	CR453CE3HBLAY
Rating (V)	240/277
FLA (AMPS)	40
LRA (AMPS)	180
Resistance	50

CAPACITOR	
Manufacturer	CSC
Model	328P7005H37P37A5X
Rating (V)	370
Capacitance (µF)	70

8.2 TEST PARAMETERS

This air conditioner unit has the following testing parameters.

	80°F	100°F	115°F
T_{INLET} (°C)	22.0	23.2	23.2
T_{OUTLET} (°C)	9.4	11.2	12.2
$T_{COMP.\ AMB.}$ (°C)	26.7	38.1	46.2
T_{CASE} (°C)	71.8	88.9	107.1
T_{GAS} (°C)	-	-	-
T_{LIQ} (°C)	-	-	-
R_{FLOW} (Kcfm)	1.7	1.5	1.5
P_{LOW} (PSI)	105.9	116.5	123.9
P_{HIGH} (PSI)	353.5	474.7	693.6
$I_{RUNNING}$ (A)	17.0	22.0	26.0
$W_{RUNNING}$ (W)	4030.0	5047.0	6106.0
$VAR_{RUNNING}$ (VAR)	1100.0	1225.0	1443.0

A more detail internal performance parameter table can be found in APPENDIX #2 -- Attachment # 5.

8.3 INRUSH TEST RESULTS\

It would take approximately 13 cycles to come to the normal steady running state. The data below was recorded for the whole air conditioner system.

Inrush	
V_{INRUSH}	221 VAC
I_{INRUSH}	148 A
W_{INRUSH}	22,000 W
VAR_{INRUSH}	24,200 VAR
t	13 cycles

8.4 POWER CONTACTOR TEST RESULTS

The power contactor opened at 50% voltage sag. The compressor had the following responses right after contactor reclosed:

- *Long notch* type of transient
  - At 80 °F and 100 °F, the compressor restarted normally after the contactor reclosed.
  - At 115 °F, the compressor stalled, drawing approximately 146 Amps at 223 VAC, for as long as 2 seconds after the contacts reclosed before returned to the normal running state.
- *Delayed Recovery* type of transient
  - The compressor stalled, drawing approximately 116 Amps at 193 VAC, right after the contactor reclosed for as long as 8.1 seconds before it returned to the normal running condition.
- *Circuit Breaker Clearing* type of transient
  - At 80 °F
    - At times the compressor went into the IDLE condition.
    - At times the compressor returned to the normal running mode.
  - At 100 °F
    - At times the compressor stalled, drawing approximately 141 Amps at 221 VAC, for 2.0 seconds right after the power contactor reclosed before the thermal protection switch open to protect the compressor.
    - At times the compressor returned to the normal running mode.
  - At 115 °F
    - The compressor stalled for a couple of cycles right after the power contactor reclosed and then went into the IDLE condition.

8.5 *30-SECOND LONG NOTCH* TYPE OF TRANSIENT TEST RESULTS

This compressor had the following threshold voltages 58% at 80 °F, 63% at 100 °F, and 70% at 115 °F when exposed to the *long notch* type of transients. Therefore, the stalling windows are the following: 58% to 50% at 80 °F, 63% to 50% at 100 °F, and 70% to 50% at 115 °F. The thermal protection switch opened to protect the compressor but not always after the unit stalled. The compressor did not always restart normally after the thermal protection switch reclosed and needed to be turned off and then on again in order to restart normally. The compressor stalled in the

stalling window, drawing approximately 81 Amps at 135 VAC, for as long as 26.0 seconds before the thermal protection switch opened to protect the compressor and at times stalled for the complete transient period (30 seconds drawing approximately 73 Amps at 124 VAC) without opening the thermal protection switch. If the power contactor opened and then reclosed, the compressor returned to the normal running mode. The following are the details for each of the temperatures:

- At 80 °F
  - At times the compressor stalled, drawing approximately 143 Amps at 224 VAC, for as long as 6.6 seconds before the thermal protection switch opened to protect the compressor.
  - At times the compressor stalled, drawing approximately 73 Amps at 124 VAC, for the complete transient period without opening the thermal protection switch.
  - If the power contactor opened and then reclosed, the unit returned to normal running mode.
- At 100 °F
  - At times the compressor stalled, drawing approximately 81 Amps at 135 VAC, for as long as 26.0 seconds before the thermal protection switch opened to protect the compressor. The unit did not restart normally.
  - At times the compressor stalled, drawing approximately 74 Amps at 124 VAC, for the complete transient period without opening the thermal protection switch.
  - If the power contactor opened and then reclosed, the compressor returned to the normal running mode.
- At 115 °F
  - At times the compressor stalled, drawing approximately 78 Amps at 135 VAC, for as long as 19.6 seconds before the thermal protection switch opened to protect the compressor. The unit did not restart normally.
  - At times the compressor stalled, drawing approximately 75 Amps at 123 VAC, for the complete transient period without opening the thermal protection switch.
  - If the power contactor opened and then reclosed, the unit returned to the normal running mode.

8.6 *DELAYED RECOVERY* TYPE OF TRANSIENT TEST RESULTS

This compressor had the following threshold voltages 55% at 80 °F, 60% at 100 °F, and 65% at 115 °F when exposed to the *delayed recovery* type of transient. Therefore, the stalling windows are the following: 55% to 50% at 80 °F, 60% to 50% at 100 °F, and 65% to 50% at 115 °F. The thermal protection switch opened to protect the compressor after stalling except when the compressor stalled right after the contactor reclosed. The compressor stalled in the stalling window, drawing approximately 99 Amps at 172 VAC, for as long as 15.9 seconds before the thermal protection switch opened to protect the compressor. If the power contactor opened and then reclosed, the compressor stalled, drawing approximately 115 Amps at 193 VAC, for as long as 8.1 seconds before returned to normal running mode. Opening the contactor did not help in preventing the compressor from stalling, it just delayed it until the contactor reclosed. The following are the details for each of the temperatures:

- At 80 °F
  - The compressor stalled, drawing approximately 101 Amps at 172 VAC, for as long as 14.6 seconds before the thermal protection switch opened to protect the compressor.

- If the power contactor opened and then reclosed, The compressor stalled, drawing approximately 108 Amps at 180 VAC, for as long as 6.8 seconds before it returned to the normal running mode.

- At 100 °F
  - The compressor stalled, drawing approximately 101 Amps at 174 VAC, for as long as 15.1 seconds before the thermal protection switch opened to protect the unit.
  - If the power contactor opened and then reclosed, the compressor stalled, drawing approximately 108 Amps at 180 VAC, for as long as 6.8 seconds before it returned to the normal running mode.
- At 115 °F
  - The compressor stalled, drawing approximately 99 Amps at 172 VAC, for as long as 15.9 seconds before the thermal protection switch opened to protect the unit.
  - If the power contactor opened and then reclosed, the compressor stalled for as long as 8.1 seconds, drawing approximately 115 Amps at 193 VAC, before it returned to the normal running mode.

8.7 *CIRCUIT BREAKER CLEARING* TYPE OF TRANSIENT TEST RESULTS

This compressor had the following threshold voltages at 80 °F, 60% at 100 °F, and 65% at 115 °F when exposed to the *Circuit Breaker Clearing* type of transients. Therefore, the stalling windows are the following: 60% to 50% at 100 °F, and 65% to 50% at 115 °F. The thermal protection switch never opened after stalling to protect the compressor. The compressor stalled in the stalling window, drawing approximately 87 Amps at 145 VAC, for the complete transient time then went into the IDLE condition, except at 80 °F where it did not stall. If the power contactor opened and then reclosed, the compressor usually went into the IDLE condition and at times returned to the normal running state. The following are the details for each of the temperatures:

- At 80 °F
  - The compressor did not stall in the stalling window.
  - If the power contactor opened and then reclosed, the compressor at times went into the IDLE condition and at other times resumed the normal running state.
- At 100 °F
  - The compressor stalled, drawing approximately 80 Amps at 134 VAC, for the complete transient period then the compressor went into the IDLE condition.
  - If the power contactor opened and then reclosed, the compressor usually stalled, drawing approximately 147 Amps at 221 VAC, for as long as 2 seconds before going into the IDLE condition.
- At 115 °F
  - The compressor stalled, drawing approximately 87 Amps at 145 VAC, for the complete transient period then the compressor went into the IDLE condition.
  - If the power contactor opened and then reclosed, the compressor went into the IDLE condition.

9.0 A/C #6 - TEST RESULTS

The air conditioner's compressor stalled when the voltage was in the stalling window (between the stall threshold voltage and contactor dropout voltage) when exposed to any of the three types of transients. When exposed to the *long notch* type of transients in the stalling window, this compressor stalled, drawing approximately 64 Amps at 124 VAC, for as long as 30.0 seconds before either the thermal protection switch opened to protect the compressor or it resumed the normal running mode. At times, the compressor stalled, drawing approximately 64 Amps at 123 VAC, for short period of time (1.0 second) and then went into the NO-LOAD condition. The compressor stalled, drawing approximately 80 Amps at 166 VAC, for as long as 14.8 seconds before the thermal protection switch opened to protect the compressor, when exposed to the *delayed recovery* type of transients in the stalling window. At times, the compressor stalled, drawing approximately 50 Amps at 103 VAC, for a short period of time (1.0 second) then went into the NO-LOAD condition. The compressor stalled, drawing approximately 128 Amps at 223 VAC, for about 0.5 seconds before either returning to the normal running mode or went into the NO-LOAD condition, when exposed to the *circuit breaker clearing* type of transients in the stalling window. In general, opening the contactor did not help to prevent the compressor from stalling; it just delayed it except when exposed to the *long notch* transient where it did not stall and returned to normal running mode. When the contactor opened under the *delayed recovery* type of transients and then reclosed, the compressor stalled for as long as 11.4 seconds before the thermal protection switch opened to protect the compressor. When the contactor opened under the *circuit breaker clearing* type of transients and then reclosed, the compressor stalled and then either returned to normal running mode or went into the NO-LOAD condition. If the unit did not restart normally or went into the NO-LOAD condition, then the compressor needed to be turned off and then on again in order to restart normally. The compressor at the NO-LOAD condition consumed ½ of the normal running power but without producing any work (cooling). At high temperatures, the compressor is more sensitive to transients where most of the tests ended up in NO-LOAD condition or the unit did not restart normally after the thermal protection switch reclosed.

This air conditioner unit was also tested under overcharge conditions. The stalling behavior was similar for all cases except that the stalling threshold voltage increased to 60% at 80 °F, 70% at 100 °F, and 78% at 115 °F. The power contactor dropout voltage did not change and is 45%.

9.1 SYSTEM SPECIFICATIONS

The tested air conditioner system has the following specifications:

MAIN SYSTEM	
Manufacturer	Rheem
Condenser Unit	RAB048-JAZ
Evaporator Coil	CK3BA048
Size (Tons)	4
Compressor Type	Scroll
Refrigerant	R-22
SEER	10
Condition	New
Unit Cost	$1,171.00

COMPRESSOR	
Manufacturer	Copeland
Model	ZR47KC-PFV-235
Type	Scroll
FLA (AMPS)	26.5
LRA (AMPS)	131
Phase	1
Refrigerant	R22
Charge (LBS)	6.4
Voltage (V)	230/208
PMAX High (PSI)	398.8
PMAXLow (PSI)	290

FAN MOTOR	
Manufacturer	GE
Model	5KCP39GG
Voltage (V)	220/240
Current (I)	1.5
Power (HP)	1.5
RPM	1075
FLA (AMPS)	1.5

CONTACTOR	
Manufacturer	Cutler-Hammer
Model	C25CNY42
Rating (V)	240/277
FLA (AMPS)	30
LRA (AMPS)	150
Resistance	40

CAPACITOR	
Manufacturer	CSC
Model	328P4505H37N37P5X
Rating (V)	370
Capacitance (µF)	50

9.2 TEST PARAMETERS

This air conditioner unit has the following testing parameters.

	80°F	100°F	115°F
T_{INLET} (°C)	74.2	96.4	118.6
T_{OUTLET} (°C)	90.8	118.8	147.2
$T_{COMP.\ AMB.}$ (°C)	107.5	141.2	175.7
T_{CASE} (°C)	124.2	163.6	204.3
T_{GAS} (°C)	-	-	-
T_{LIQ} (°C)	-	-	-
R_{FLOW} (Kcfm)	2627.4	3193.4	3847.6
P_{LOW} (PSI)	3111.1	3777.9	4547.2
P_{HIGH} (PSI)	3594.7	4362.3	5246.8
$I_{RUNNING}$ (A)	4078.3	4946.8	5946.4
$W_{RUNNING}$ (W)	4562.0	5531.3	6646.0
$VAR_{RUNNING}$ (VAR)	5045.6	6115.7	7345.6

A more detailed internal performance parameter table can be found in APPENDIX #2 -- Attachment # 6.

Overcharged)			
	80°F	100°F	115°F
T_{INLET} (°C)	74.2	96.4	118.6
T_{OUTLET} (°C)	90.8	118.8	147.2
$T_{COMP. AMB.}$ (°C)	107.5	141.2	175.7
T_{CASE} (°C)	124.2	163.6	204.3
T_{GAS} (°C)	-	-	-
T_{LIQ} (°C)	-	-	-
R_{FLOW} (Kcfm)	2627.4	3193.4	3847.6
P_{LOW} (PSI)	3111.1	3777.9	4547.2
P_{HIGH} (PSI)	3594.7	4362.3	5246.8
$I_{RUNNING}$ (A)	4078.3	4946.8	5946.4
$W_{RUNNING}$ (W)	4562.0	5531.3	6646.0
$VAR_{RUNNING}$ (VAR)	5045.6	6115.7	7345.6

9.3 INRUSH TEST RESULTS

This unit took approximately 13 cycles to come to the normal steady running state. The data below was recorded for the whole air conditioner system.

Inrush	
V_{INRUSH}	222 VAC
I_{INRUSH}	137 A
W_{INRUSH}	21,300 W
VAR_{INRUSH}	21,900 VAR
t	15 cycles

9.4 POWER CONTACTOR TEST RESULTS

The power contactor opened at 45% voltage sag. The compressor had the following responses right after contactor reclosed:

- *Long notch* type of transient
  - The compressor returned to the normal running state after the power contactor reclosed.
- *Delayed Recovery* type of transient
  The compressor restarted normally right after the power contactor reclosed or after the thermal protection switch reclosed.
  - At 80 °F
    - The compressor stalled, drawing approximately 82 Amps at 167 VAC, right after contactor reclosed for as long as 11.4 seconds before the compressor returned to the normal running mode.
  - At 100 °F

- The compressor stalled, drawing approximately 83 Amps at 166 VAC, right after contactor reclosed for as long as 11.4 seconds before the thermal protection switch opened to protect the unit.

- At 115 °F
  - The compressor stalled, drawing approximately 81 Amps at 160 VAC, right after contactor reclosed for as long as 9.5 seconds before the thermal protection switch opened to protect the unit.

- *Circuit Breaker Clearing* type of transient
  - At 80 °F
    - Usually the compressor returned to normal running state after power contactor reclosed.
    - Occasionally the compressor stalled, drawing approximately 127 Amps at 223 VAC, then returned to the normal running mode.
  - At 100 °F
    - At times the compressor returned to the normal running state after the power contactor reclosed.
    - At times the compressor stalled, drawing approximately 124 Amps at 224 VAC, then went into a NO-LOAD condition.
  - At 115 °F
    - At times the compressor returned to the normal running state after power contactor reclosed.
    - At times the compressor stalled, drawing approximately 122 Amps at 224 VAC, then went into a NO-LOAD condition.

9.5 *30-SECOND LONG NOTCH* TYPE OF TRANSIENT TEST RESULTS

The compressor had the following threshold voltages 58% at 80 °F, 63% at 100 °F, and 70% at 115 °F when exposed to the *long notch* type of transients. Therefore, the stalling windows are the following: 58% to 45% at 80 °F, 63% to 45% at 100 °F, and 45% to 50% at 115 °F. The thermal protection switch opened to protect the compressor but did not always open after the compressor stalled. The compressor did not always restarted normally after either the thermal protection switch reclosed or the unit stalled. It needed to be turned off and then on again in order to restart normally. The compressor stalled in the stalling window, drawing approximately 57 Amps at 112 VAC, for as long as 30 seconds before the thermal protection switch opened to protect the compressor. If the power contactor opened and then reclosed, the compressor returned to normal running mode. The following are the details for each of the temperatures:

- At 80 °F
  - At times the compressor stalled, drawing approximately 51 Amps at 102 VAC, for the complete transient time and then returned to the normal running mode.
  - At times the compressor stalled, drawing approximately 69 Amps at 131 VAC, for as long as 25.5 seconds before the thermal protection switch opened to protect the compressor. The unit did not restart normally.
  - At times the compressor stalled, drawing approximately 64 Amps at 123 VAC, for as long as 1.0 second and then the unit went into the NO-LOAD condition.
  - If the power contactor opened and then reclosed the compressor returned to the normal running mode.
- At 100 °F

- At times the compressor stalled, drawing approximately 54 Amps at 109 VAC, for the complete transient time and then returned to the normal running mode.
- At times the compressor stalled, drawing approximately 64 Amps at 124 VAC, for the complete transient time and then at recovery the thermal protection switch opened to protect the compressor. The unit did not restart normally.
- At times the compressor stalled, drawing approximately 69 Amps at 136 VAC, for as long as 0.7 seconds and then the compressor went into the NO-LOAD condition.
- If the power contactor opened and then reclosed again the compressor returned to the normal running mode.

♦ At 115 °F

- At times the compressor stalled, drawing approximately 57 Amps at 112 VAC, for the complete transient time and then returned to the normal running mode.
- At times the compressor stalled, drawing approximately 79 Amps at 160 VAC, for as long as 7.1 seconds and then the compressor went into the NO-LOAD condition.
- If the power contactor opened and then reclosed, the compressor returned to the normal running mode.

9.6 *DELAYED RECOVERY* TYPE OF TRANSIENT TEST RESULTS

This compressor had the following threshold voltages 58% at 80 °F, 63% at 100 °F, and 70% at 115 °F when exposed to the *long notch* type of transients. Therefore, the stalling windows are the following: 58% to 45% at 80 °F, 63% to 45% at 100 °F, and 70% to 45% at 115 °F. The thermal protection switch opened to protect the compressor but did not always open after stalling and instead went into the NO-LOAD condition. At times, the compressor did not return to normal running state after the thermal protection switch reclosed and need it to be turned off and then on again in order to return to the normal running mode. The compressor stalled in the stalling window, drawing approximately 80 Amps at 166 VAC, for as long as 14.8 seconds before the thermal protection switch opened to protect the compressor. At times the compressor stalled as long as 1 second, drawing approximately 50 Amps at 103 VAC, then went into the NO-LOAD condition. If the power contactor opened and then reclosed, the compressor stalled for as long as 11.4 seconds , drawing approximately 82 Amps at 167 VAC, before the thermal protection switch opened to protect the compressor. The following are the details for each of the temperatures:

♦ At 80 °F

- The compressor stalled, drawing approximately 81 Amps at 165 VAC, for as long as 12.9 seconds before the thermal protection switch opened to protect the compressor. The unit did not restart normally.
- If the power contactor opened and then reclosed, the compressor stalled, drawing approximately 82 Amps at 167 VAC, for as long as 11.4 seconds before it returned to the normal running mode.

♦ At 100 °F

- At times the compressor stalled, drawing approximately 82 Amps at 165 VAC, for as long as 14.0 seconds before the thermal protection switch opened to protect the compressor. The compressor did not restart normally.
- At times the compressor stalled, drawing approximately 50 Amps at 103 VAC, for as long as 1.0 second. It then went into the NO-LOAD condition.

- If the power contactor opened and then reclosed, the compressor stalled, drawing approximately 83 Amps at 166 VAC, for as long as 11.4 seconds before the thermal protection switch opened to protect the compressor.

♦ At 115 °F
- At times the compressor stalled, drawing approximately 80 Amps at 166 VAC, for as long as 14.8 seconds before the thermal protection switch opened to protect the compressor. The compressor did not restart normally.
- At times the compressor stalled, drawing approximately 78 Amps at 153 VAC, for as long as 0.9 seconds before the compressor went into the NO-LOAD condition.
- If the power contactor opened and then reclosed, the compressor stalled, drawing approximately 81 Amps at 160 VAC, for as long as 9.5 seconds before the thermal protection switch opened to protect the compressor.

9.7 *CIRCUIT BREAKER CLEARING* TYPE OF TRANSIENT TEST RESULTS

This compressor had the following threshold voltages 55% at 80 °F, 60% at 100 °F, and 65% at 115 °F when exposed to the *Circuit Breaker Clearing* type of transients. Therefore, the stalling windows are the following: 55% to 45% at 80 °F, 60% to 45% at 100 °F, and 65% to 45% at 115 °F. The thermal protection switch never opened after stalling to protect the compressor. This compressor stalled in the stalling window, drawing approximately 127 Amps at 223 VAC then either it returned to the normal running mode or went into the NO-LOAD condition. This compressor did not stall with the 3 cycle transient at 80 °F. If the power contactor opened and then reclosed, the compressor usually stalled and went into the IDLE condition and at other times it returned to the normal running mode. The following are the details for each of the temperatures:

♦ At 80 °F
- The compressor did not stall with the 3 cycle transients.
- At times, the compressor stalled, drawing approximately 127 Amps at 223 VAC, for as long as 0.6 seconds and then the compressor went into the NO-LOAD condition.
- At times, the compressor stalled, drawing approximately 128 Amps at 223 VAC for as long as 0.5 seconds before it returned to the normal running mode.
- If the power contactor opened and then reclosed, the unit either returned to the normal running mode or stalled, drawing approximately 127 Amps at 223 VAC, for 0.5 seconds before returning to the normal running mode.

♦ At 100 °F
- Usually the compressor stalled, drawing approximately 124 Amps at 224 VAC, for as long as 0.4 seconds before the compressor went into the NO-LOAD condition.
- Sometime the compressor stalled, drawing approximately 124 Amps at 224 VAC, for as long as 0.4 seconds before it returned to the normal running mode.
- If the power contactor opened and then reclosed, the compressor either returned to the normal running mode or stalled, drawing approximately 124 Amps at 224 VAC, for a couple of cycles and then went into the NO-LOAD condition.

♦ At 115 °F
- Usually the compressor stalled, drawing approximately 122 Amps at 224 VAC, for as long as 0.4 seconds and then the compressor went into the NO-LOAD condition.
- Sometime the compressor stalled, drawing approximately 122 Amps at 224 VAC, for as long as 0.5 seconds before it returned to the normal running mode.

- If the power contactor opened and then reclosed, the compressor either returned to the normal running mode or stalled, drawing approximately 122 Amps at 224 VAC, for 0.3 seconds before it went into the NO-LOAD condition.

10.0 A/C #7 - TEST RESULTS

The air conditioner's compressor stalled when the voltage was in the stalling window (between the stall threshold voltage and contactor dropout voltage) when exposed to any of the three types of transients. When exposed to the *long notch* type of transients in the stalling window, this compressor stalled, drawing approximately 74 Amps at 135 VAC, for as long as 30.0 seconds before returning to the normal running mode. The compressor stalled, drawing approximately 85 Amps at 163 VAC, for as long as 11.0 seconds before returning to the normal running mode, when exposed to the *delayed recovery* type of transients in the stalling window. The compressor stalled, drawing approximately 130 Amps at 223 VAC except at 80 °F, for about 0.5 seconds before returning to the normal running mode, when exposed to the *circuit breaker clearing* type of transients in the stalling window. There were a couple of cases where the unit went into the NO-LOAD condition at the *circuit breaker clearing* type of transient. If the power contactor opened under the *delayed recovery* transient and then reclosed, the compressor stalled, drawing approximately 83 Amps at 163 VAC, for as long as 6 seconds before returning to the normal running mode. In general, opening the contactor did not help to prevent the compressor from stalling; it just delayed it. If the compressor went into the IDLE condition, then the compressor needed to be turned off and then on again in order to return to the normal running mode. The compressor at the NO-LOAD condition consumed ½ of the normal running power but without producing any work (cooling).

10.1 SYSTEM SPECIFICATIONS

The tested air conditioner system has the following specifications:

MAIN SYSTEM	
Manufacturer	Carrier
Condenser Unit	38TRA-048
Evaporator Coil	CK3BA048
Size (Tons)	4
Compressor Type	Scroll
Refrigerant	R-22
SEER	12.5
Condition	New
Unit Cost	$1,930.00

COMPRESSOR	
Manufacturer	Copeland
Model	ZR47K3-PFV-135
Type	Scroll
FLA (AMPS)	22.7
LRA (AMPS)	137
Phase	1
Refrigerant	R22
Charge (LBS)	9.75
Voltage (V)	230/208
PMAX High (PSI)	398.8
PMAXLow (PSI)	290

FAN MOTOR	
Manufacturer	GE
Model	5KCP39GFS166S
Voltage (V)	208/230
Current (I)	0.95
Power (HP)	0.2
RPM	825
FLA (AMPS)	1.1

CONTACTOR	
Manufacturer	Product Unlimited
Model	HN51KCF024
Rating (V)	240/277
FLA (AMPS)	30
LRA (AMPS)	150
Resistance	40

CAPACITOR	
Manufacturer	GE
Model	97F9898
Rating (V)	440
Capacitance (µF)	60

10.2 TEST PARAMETERS

This air conditioner unit has the following testing parameters.

	80°F	100°F	115°F
T_{INLET} (°C)	21.7	22.2	21.7
T_{OUTLET} (°C)	10.1	10.0	10.5
$T_{COMP.\ AMB.}$ (°C)	26.1	37.4	46.0
T_{CASE} (°C)	67.5	84.3	98.4
T_{GAS} (°C)	-	-	-
T_{LIQ} (°C)	-	-	-
R_{FLOW} (Kcfm)	1.9	1.6	1.5
P_{LOW} (PSI)	59.7	60.3	63.3
P_{HIGH} (PSI)	192.4	254.6	312.9
$I_{RUNNING}$ (A)	15.0	19.0	22.0
$W_{RUNNING}$ (W)	3525.0	4279.0	5029.0
$VAR_{RUNNING}$ (VAR)	1050.0	1098.0	1159.0

A more detail internal performance parameter table can be found in APPENDIX #2 -- Attachment # 7.

10.3 INRUSH TEST RESULTS

This unit took approximately 12 cycles before entering its normal steady running state. The data below was recorded for the whole air conditioner system.

Inrush	
V_{INRUSH}	222 VAC
I_{INRUSH}	133 A
W_{INRUSH}	22,000 W
VAR_{INRUSH}	19,700 VAR
t	12 cycles

10.4 POWER CONTACTOR TEST RESULTS

The power contactor opened at 50% voltage sag. The compressor had the following responses right after contactor reclosed:

- *Long notch* type of transient
  - The compressor never stalled after the power contactor reclosed.
- *Delayed Recovery* type of transient
  - The compressor stalled, drawing approximately 83 Amps at 163 VAC, right after the contactor reclosed for as long as 6 seconds before it returned to the normal running mode.

- *Circuit Breaker Clearing* type of transient
  - The compressor returned to the normal running mode after the power contactor reclosed except in one case where it stalled. In this case, it drew approximately 121 Amps at 233 VAC, for a couple of cycles and then went into the NO-LOAD condition.

10.5 *30-SECOND LONG NOTCH* TYPE OF TRANSIENT TEST RESULTS

This compressor had the following threshold voltages 55% at 80 °F, 60% at 100 °F, and 68% at 115 °F when exposed to the *long notch* type of transients. Therefore, the stalling windows are the following: 55% to 50% at 80 °F, 60% to 50% at 100 °F, and 68% to 50% at 115 °F. The thermal protection switch seldom opened to protect the compressor and the compressor did not restart normally after the thermal protection switch reclosed. The compressor stalled in the stalling window, drawing approximately 74 Amps at 135 VAC, for as long as 30 seconds before it returned to the normal running state. On one occasion, the thermal protection switch opened to protect the compressor after stalling for 21 seconds and the compressor did not restart normally. If the power contactor opened and then reclosed, the compressor returned to the normal running mode. The following are the details for each of the temperatures:

- At 80 °F
  - The compressor stalled, drawing approximately 68 Amps at 123 VAC, for as long as 30 seconds before it returned to the normal running mode.
  - If the power contactor opened and then reclosed, the compressor returned to the normal running mode.
- At 100 °F
  - The compressor stalled, drawing approximately 74 Amps at 135 VAC, for as long as 30 seconds before it returned to the normal running mode.
  - If the power contactor opened and then reclosed the compressor returned to the normal running mode.
- At 115 °F
  - The compressor stalled, drawing approximately 72 Amps at 135 VAC, for as long as 30 seconds before it returned to the normal running mode except in one case where the thermal protection switch opened to protect the compressor. The unit did not restart normally.
  - If the power contactor opened and then reclosed, the compressor returned to the normal running mode.

10.6 *DELAYED RECOVERY* TYPE OF TRANSIENT TEST RESULTS

This compressor had the following threshold voltages 55% at 80 °F, 60% at 100 °F, and 65% at 115 °F when exposed to the *delayed recovery* type of transient. Therefore, the stalling windows are the following: 55% to 50% at 80 °F, 60% to 50% at 100 °F, and 65% to 50% at 115 °F. The thermal protection switch never opened to protect the compressor and it returned to the normal running mode after any stall. The compressor stalled in the stalling window, drawing approximately 85 Amps at 163 VAC, for as long as 11 seconds before it returned to the normal running mode. If the power contactor opened and then reclosed, the compressor stalled, drawing approximately 83 Amps at 163 VAC, for as long as 6 seconds before it returned to the normal

running mode. In general, opening the contactor did not prevent the compressor from stalling, it just delayed the stall. The following are the details for each of the temperatures:

- At 80 °F
  - The compressor stalled, drawing approximately 85 Amps at 163 VAC, for as long as 11 seconds before it returned to the normal running mode.
  - If the power contactor opened and then reclosed, the compressor stalled, drawing approximately 85 Amps at 159 VAC, for as long as 6 seconds before returning to the normal running mode.
- At 100 °F
  - The compressor stalled, drawing approximately 81 Amps at 158 VAC, for as long as 10 seconds before returning to the normal running mode.
  - If the power contactor opened and then reclosed, the compressor stalled, drawing approximately 85 Amps at 164 VAC, for as long as 6 seconds before returning to the normal running mode.
- At 115 °F
  - The compressor stalled, drawing approximately 79 Amps at 160 VAC, for as long as 10 seconds before returning to normal running mode.
  - If the power contactor opened and then reclosed, the compressor stalled, drawing approximately 83 Amps at 163 VAC, for as long as 6 seconds before returning to the normal running mode.

10.7 *CIRCUIT BREAKER CLEARING* TYPE OF TRANSIENT TEST RESULTS

This compressor had the following threshold voltages 55% at 80 °F, 60% at 100 °F, and 65% at 115 °F when exposed to the *circuit breaker clearing* type of transients. Therefore, the stalling windows are the following: 55% to 50% at 80 °F, 60% to 50% at 100 °F, and 65% to 50% at 115 °F. The thermal protection switch never opened to protect the compressor. This compressor did not stall at 80 °F. In general, the compressor did not stall except in a couple of cases where it stalled in the stalling window, drawing approximately 130 Amps at 223 VAC, for as long as 0.5 seconds and then went into a NO-LOAD condition. If the power contactor opened and then reclosed, the compressor returned to the normal running mode except in couple cases. In these cases, it stalled, drawing approximately 121 Amps at 233 VAC, and then went into the NO-LOAD condition. The following are the details for each of the temperatures:

- At 80 °F
  - The compressor did not stall in the stalling window.
- At 100 °F
  - The compressor stalled, drawing approximately 130 Amps at 223 VAC, for as long as 0.5 seconds before it returned to the normal running mode.
  - If the power contactor opened and then reclosed, the compressor mostly returned to the normal running mode except in one case where it stalled. In this case it drew approximately 121 Amps at 233 VAC, for couple of cycles and then went into the NO-LOAD condition.
- At 115 °F
  - The compressor stalled, drawing approximately 127 Amps at 123 VAC, for as long as 0.4 seconds before it went into the NO-LOAD condition.
  - If the power contactor opened and then reclosed, the compressor returned to a normal running mode.

11.0 A/C #8 - TEST RESULTS

The air conditioner's compressor stalled when the voltage was in the stalling window (between the stall threshold voltage and contactor dropout voltage) when exposed to any of the three types of transients. When exposed to the *long notch* type of transients in the stalling window, this compressor stalled, drawing approximately 64 Amps at 137 VAC, for as long as 8.1 seconds before the thermal protection switch opened to protect the compressor but the unit did not restart normally. When exposed to the *delayed recovery* type of transients in the stalling window, this compressor stalled, drawing approximately 69 Amps at 154 VAC, for as long as 6.3 seconds before the thermal protection switch opened to protect the compressor but the unit did not restart normally. When exposed to the *circuit breaker clearing* type of transients in the stalling window, this compressor stalled, drawing approximately 111 Amps at 225 VAC, before the thermal protection switch opened to protect the compressor but the unit did not restart normally. When the contactor opened under the *delayed recovery* type of transients and then reclosed, the compressor stalled, drawing approximately 77 Amps at 169 VAC, for as long as 5.6 seconds before the thermal protection switch opened to protect the compressor but did not restart normally. In general, opening the contactor did not help to prevent the compressor from stalling; it just delayed the stall.

11.1 SYSTEM SPECIFICATIONS

The tested air conditioner system has the following specifications:

MAIN SYSTEM	
Manufacturer	Goodman
Condenser Unit	CLK048
Evaporator Coil	CK3BA048
Size (Tons)	4
Compressor Type	Reciprocating
Refrigerant	R-22
SEER	10
Condition	New
Unit Cost	$953.00

COMPRESSOR	
Manufacturer	Copeland
Model	CR42K6-PFV-223
Type	Reciprocating
FLA (AMPS)	18.3
LRA (AMPS)	102
Phase	1
Refrigerant	R22
Charge (LBS)	7
Voltage (V)	230/208
PMAX High (PSI)	-
PMAXLow (PSI)	-

FAN MOTOR	
Manufacturer	A.O. Smith
Model	F48F97A76
Voltage (V)	208/230
Current (I)	1.5
Power (HP)	0.25
RPM	1075
FLA (AMPS)	1.8

CONTACTOR	
Manufacturer	GE
Model	CR453CCHBAFG
Rating (V)	240/277
FLA (AMPS)	30
LRA (AMPS)	180
Resistance	40

CAPACITOR	
Manufacturer	GE
Model	97F9638
Rating (V)	440
Capacitance (µF)	40

11.2 TEST PARAMETERS

This air conditioner unit has the following testing parameters.

	80°F	100°F	115°F
T_{INLET} (°C)	22.0	21.9	21.9
T_{OUTLET} (°C)	10.9	11.8	13.0
$T_{COMP.\ AMB.}$ (°C)	26.6	37.6	45.9
T_{CASE} (°C)	43.2	41.9	47.2
T_{GAS} (°C)	7.9	9.3	11.7
T_{LIQ} (°C)	33.0	44.5	52.5
R_{FLOW} (Kcfm)	1.7	1.5	1.7
P_{LOW} (PSI)	65.3	69.0	74.3
P_{HIGH} (PSI)	205.3	270.9	324.5
$I_{RUNNING}$ (A)	17.0	19.0	20.0
$W_{RUNNING}$ (W)	3762.0	4221.0	4535.0
$VAR_{RUNNING}$ (VAR)	1700.0	1750.0	1750.0

A more detail internal performance parameter table can be found in APPENDIX #2 -- Attachment # 8.

11.3 INRUSH TEST RESULTS

This unit took approximately 12 cycles before entering its normal steady running state. The data below was recorded for the whole air conditioner system.

Inrush	
V_{INRUSH}	223 VAC
I_{INRUSH}	119 A
W_{INRUSH}	19,200 W
VAR_{INRUSH}	18,500 VAR
t	12 cycles

11.4 POWER CONTACTOR TEST RESULTS

The power contactor opened with a 53% voltage sag. In general, opening the contactor made the compressor stall harder after the contactor reclosed with the unit not returning to the normal running state. The compressor needed to be turned off and then on again in order to return to the normal running state. The compressor had the following responses right after contactor reclosed:

- *Long notch* type of transient
  - The compressor stalled, drawing approximately 115 Amps at 226 VAC, right after contactor reclosed for as long as 2.2 seconds before the thermal protection switch opened to protect the compressor. The unit did not restart normally.

- *Delayed Recovery* type of transient
  - The compressor stalled, drawing approximately 77 Amps at 169 VAC, right after the contactor reclosed for as long as 5.6 seconds before the thermal protection switch opened to protect the compressor. The unit did not restart normally.
- *Circuit Breaker Clearing* type of transient
  - The compressor stalled, drawing approximately 112 Amps at 225 VAC, right after the contactor reclosed for as long as 1.7 seconds before the thermal protection switch opened to protect the compressor. The unit did not restart normally.

11.5 *30-SECOND LONG NOTCH* TYPE OF TRANSIENT TEST RESULTS

This compressor had the following threshold voltages 65% at 80 °F, 65% at 100 °F, and 68% at 115 °F when exposed to the *long notch* type of transients. Therefore, the stalling windows are the following: 65% to 53% at 80 °F, 65% to 53% at 100 °F, and 68% to 53% at 115 °F. The thermal protection switch opened after each stall to protect the compressor but the compressor never restarted normally. The compressor stalled in the stalling window, drawing approximately 64 Amps at 137 VAC, for as long as 8.1 seconds before the thermal protection switch opened to protect the compressor. If the power contactor opened and then reclosed, the compressor stalled, drawing approximately 115 Amps at 226 VAC, for as long as 2.2 seconds. The unit did not restart normally. The following are the details for each of the temperatures:

- At 80 °F
  - The compressor stalled, drawing approximately 64 Amps at 137 VAC, for as long as 7.5 seconds before the thermal protection switch opened to protect the compressor. The unit did not restart normally.
  - If the power contactor opened and then reclosed, the compressor stalled, drawing approximately 115 Amps at 226 VAC, for as long as 2.2 seconds before the thermal protection opened to protect the compressor. The unit did not restart normally.
- At 100 °F
  - The compressor stalled, drawing approximately 64 Amps at 137 VAC, for as long as 8.1 seconds before the thermal protection switch opened to protect the compressor. The unit did not restart normally.
  - If the power contactor opened and then reclosed, the compressor stalled, drawing approximately 114 Amps at 227 VAC, for as long as 1.9 seconds before the thermal protection opened to protect the compressor. The unit did not restart normally.
- At 115 °F
  - The compressor stalled, drawing approximately 63 Amps at 137 VAC, for as long as 7.3 seconds before the thermal protection switch opened to protect the compressor. The unit did not restart normally.
  - If the power contactor opened and then reclosed, the compressor stalled, drawing approximately 112 Amps at 226 VAC, for as long as 2.0 seconds before the thermal protection switch opened to protect the compressor. The unit did not restart normally.

11.6 *DELAYED RECOVERY* TYPE OF TRANSIENT TEST RESULTS

This compressor had the following threshold voltages 65% at 80 °F, 65% at 100 °F, and 68% at 115 °F when exposed to the *delayed recovery* type of transient. Therefore, the stalling windows

are the following: 65% to 53% at 80 °F, 65% to 53% at 100 °F, and 68% to 53% at 115 °F. The thermal protection switch opened after each stall to protect the compressor but the unit never restarted normally after the thermal protection switch reclosed. The compressor stalled in the stalling window, drawing approximately 69 Amps at 154 VAC, for as long as 6.3 seconds before the thermal protection switch opened to protect the compressor. If the power contactor opened and then reclosed, the compressor stalled, drawing approximately 77 Amps at 169 VAC, for as long as 5.6 seconds. The unit did not restart normally. In general, opening the contactor did not prevent the compressor from stalling it just delayed it. The following are the details for each of the temperatures:

- At 80 °F
  - The compressor stalled, drawing approximately 70 Amps at 151 VAC, for as long as 6.0 seconds before the thermal protection switch opened to protect the compressor. The unit did not restart normally.
  - If the power contactor opened and then reclosed, the compressor stalled, drawing approximately 77 Amps at 166 VAC, for as long as 1.3 seconds before the thermal protection switch opened to protect the compressor. The unit did not restart normally.
- At 100 °F
  - The compressor stalled, drawing approximately 70 Amps at 153 VAC, for as long as 5.9 seconds before the thermal protection switch opened to protect the compressor. The unit did not restart normally.
  - If the power contactor opened and then reclosed, the compressor stalled, drawing approximately 77 Amps at 169 VAC, for as long as 5.6 seconds before the thermal protection switch opened to protect the compressor. The unit did not restart normally.
- At 115 °F
  - The compressor stalled, drawing approximately 69 Amps at 154 VAC, for as long as 6.3 seconds before the thermal protection switch opened to protect the compressor. The unit did not restart normally.
  - If the power contactor opened and then reclosed, the compressor stalled, drawing approximately 75 Amps at 168 VAC, for as long as 5.0 seconds before the thermal protection switch opened to protect the compressor. The unit did not restart normally.

11.7 *CIRCUIT BREAKER CLEARING* TYPE OF TRANSIENT TEST RESULTS

This compressor had the following threshold voltages 65% at 80 °F, 65% at 100 °F, and 68% at 115 °F when exposed to the *Circuit Breaker Clearing* type of transients. Therefore, the stalling windows are the following: 65% to 50% at 80 °F, 65% to 50% at 100 °F, and 68% to 50% at 115 °F. The thermal protection switch opened after each stall to protect the compressor but never restarted normally after the thermal protection switch reclosed. The compressor stalled in the stalling window, drawing approximately 111 Amps at 225 VAC, for as long as 1.9 seconds before the thermal protection switch opened to protect the compressor. If the power contactor opened and then reclosed, the compressor stalled, drawing approximately 112 Amps at 225 VAC, for as long as 1.7 seconds. The unit did not restart normally. In general, opening the contactor did not prevent the compressor from stalling it just delayed it. The following are the details for each of the temperatures:

- At 80 °F

- The compressor stalled, drawing approximately 113 Amps at 225 VAC, for as long as 1.5 seconds before the thermal protection switch opened to protect the compressor. The unit did not restart normally.
- If the power contactor opened and then reclosed, the compressor stalled, drawing approximately 114 Amps at 225 VAC, for as long as 1.7 seconds before the thermal protection switch opened to protect the compressor. The unit did not restart normally.

♦ At 100 °F
- The compressor stalled, drawing approximately 112 Amps at 225 VAC, for as long as 1.7 seconds before the thermal protection switch opened to protect the compressor. The unit did not restart normally.
- If the power contactor opened and then reclosed, the compressor stalled, drawing approximately 113 Amps at 225 VAC, for as long as 1.7 seconds before the thermal protection switch opened to protect the compressor. The unit did not restart normally.

♦ At 115 °F
- The compressor stalled, drawing approximately 111 Amps at 225 VAC, for as long as 1.9 seconds before the thermal protection switch opened to protect the compressor. The unit did not restart normally.
- If the power contactor opened and then reclosed, the compressor stalled, drawing approximately 112 Amps at 225 VAC, for as long as 1.7 seconds before the thermal protection switch opened to protect the compressor. The unit did not restart normally.

12.0 A/C #9 - TEST RESULTS

The air conditioner's compressor stalled when the voltage was in the stalling window (between the stall threshold voltage and contactor dropout voltage) when exposed to any of the three types of transients. When exposed to the *long notch* type of transients at the stalling window, this compressor stalled, drawing approximately 64 Amps at 49 VAC, for as long as 25.3 seconds before the thermal protection switch opened to protect the compressor. In a particular test, the compressor stalled twice, the first for 5.3 seconds and the second for 1.0 second, and in both cases the thermal protection switch opened to protect the compressor. When exposed to the *delayed recovery* type of transients in the stalling window, this compressor stalled, drawing approximately 67 Amps at 166 VAC, for as long as 11.9 seconds before the thermal protection switch opened to protect the compressor or it stalled drawing approximately 66 Amps at 147 VAC, for as long as 10.9 seconds before returning to the normal running mode. When exposed to the *circuit breaker clearing* type of transients in the stalling window except at 80 °F, this compressor stalled, drawing approximately 114 Amps at 224 VAC, for as long as 1.7 seconds before the thermal protection switch opened to protect the compressor. It also stalled, drawing approximately 113 Amps at 225 VAC, for as long as 0.9 seconds before returning to the normal running mode. When the contactor opened under the *delayed recovery* type of transients and then reclosed, the compressor stalled, drawing approximately 72 Amps at 157 VAC, for as long as 11.2 seconds before the thermal protection switch opened to protect the compressor or stalled, drawing approximately 82 Amps at 175 VAC, for as long as 3.0 before returning to the normal running mode. In general, opening the contactor did not help to prevent the compressor from stalling; it just delayed it.

12.1 SYSTEM SPECIFICATIONS

The tested air conditioner system has the following specifications:

MAIN SYSTEM	
Manufacturer	Day & Night
Condenser Unit	5680J048
Evaporator Coil	CK3BA048
Size (Tons)	4
Compressor Type	Reciprocating
Refrigerant	R-22
SEER	10
Condition	Used
Unit Cost	$0.00

COMPRESSOR	
Manufacturer	Copeland Weld
Model	CRL1-0350-PFV
Type	Reciprocating
FLA (AMPS)	24
LRA (AMPS)	114
Phase	1
Refrigerant	R22
Charge (LBS)	11.25
Voltage (V)	230/208
PMAX High (PSI)	-
PMAXLow (PSI)	-

FAN MOTOR	
Manufacturer	GE
Model	5KCP39GJ352S
Voltage (V)	208/230
Current (I)	1
Power (HP)	0.1
RPM	825
FLA (AMPS)	1

CONTACTOR	
Manufacturer	Cutler-Hammer
Model	C35BNB 240T
Rating (V)	240
FLA (AMPS)	40
LRA (AMPS)	240
Resistance	50

CAPACITOR	
Manufacturer	SPRAGUE/GE/GE
Model	HC95DE208 / 97F5362 / 97F5341
Rating (V)	320 / 440 / 440
Capacitance (µF)	- / 25 / 15

12.2 TEST PARAMETERS

This air conditioner unit has the following testing parameters.

	80°F	100°F	115°F
T_{INLET} (°C)	22.4	22.8	24.1
T_{OUTLET} (°C)	12.4	13.1	15.0
$T_{COMP.\ AMB.}$ (°C)	25.7	37.9	46.5
T_{CASE} (°C)	31.1	42.0	51.5
T_{GAS} (°C)	8.4	9.5	12.9
T_{LIQ} (°C)	22.7	29.3	37.0
R_{FLOW} (Kcfm)	1.5	1.5	1.5
P_{LOW} (PSI)	67.4	70.7	77.6
P_{HIGH} (PSI)	198.0	261.9	313.0
$I_{RUNNING}$ (A)	20.0	23.0	25.0
$W_{RUNNING}$ (W)	4347.0	4892.0	5380.0
$VAR_{RUNNING}$ (VAR)	2124.0	2221.0	2330.0

A more detail internal performance parameter table can be found in APPENDIX #2 -- Attachment # 9.

12.3 INRUSH TEST RESULTS

This unit took approximately 5 cycles before entering its normal steady running state. The data below was recorded for the whole air conditioner system.

Inrush	
V_{INRUSH}	224 VAC
I_{INRUSH}	119 A
W_{INRUSH}	23,050 W
VAR_{INRUSH}	13,200 VAR
t	5 cycles

12.4 POWER CONTACTOR TEST RESULTS

The power contactor opened with a 55% voltage sag. Opening the contactor did not help to prevent stalling, it just delayed it. The compressor had the following responses right after the contactor reclosed:

- *Long notch* type of transient
  - The compressor never stalled after the contactor reclosed.
- *Delayed Recovery* type of transient

- At 80 °F
  - The compressor stalled, drawing approximately 71 Amps at 152 VAC, right after the contactor reclosed for as long as 2.0 seconds before it returned to the normal running mode.
- At 100 °F
  - The compressor stalled, drawing approximately 72 Amps at 157 VAC, right after the contactor reclosed for as long as 11.2 seconds before the thermal protection switch opened to protect the compressor.
- At 115 °F
  - The compressor stalled, drawing approximately 82 Amps at 175 VAC, right after the contactor reclosed for as long as 3.0 seconds before it returned to the normal running mode.

♦ *Circuit Breaker Clearing* type of transient
- At 80 °F
  - The compressor never stalled after the contactor reclosed.
- At 100 °F
  - The compressor stalled, drawing approximately 115 Amps at 224 VAC, right after the contactor reclosed for as long as 0.9 seconds then the unit returned to the normal running mode.
- At 115 °F
  - The compressor stalled, drawing approximately 113 Amps at 225 VAC, right after the contactor reclosed for as long as 0.9 seconds before it returned to the normal running mode.

12.5 30-SECOND LONG NOTCH TYPE OF TRANSIENT TEST RESULTS

This compressor had the following threshold voltages 65% at 80 °F, 70% at 100 °F, and 75% at 115 °F when exposed to the *long notch* type of transients. Therefore, the stalling windows are the following: 65% to 55% at 80 °F, 70% to 55% at 100 °F, and 75% to 55% at 115 °F. The thermal protection switch opened after each stall to protect the compressor. The compressor stalled in the stalling window, drawing approximately 64 Amps at 49 VAC, for as long as 25.3 seconds before the thermal protection switch opened to protect the compressor. If the power contactor opened and then reclosed, the compressor returned to the normal running mode. The following are the details for each of the temperatures:

♦ At 80 °F
- The compressor stalled, drawing approximately 54 Amps at 138 VAC, for as long as 22.0 seconds before the thermal protection switch opened to protect the compressor.
- In a particular test, the compressor stalled, drawing approximately 70 Amps at 148 VAC, for as long as 5.3 seconds before the thermal protection switch opened to protect the compressor. Then the thermal protection switch reclosed and the unit stalled again, drawing approximately 69 Amps at 148 VAC, for 1.0 second before it returned to the normal running mode.
- If the power contactor opened and then reclosed, the compressor returned to the normal running mode.

♦ At 100 °F
- The compressor stalled, drawing approximately 64 Amps at 49 VAC, for as long as 25.3 seconds before the thermal protection switch opened to protect the compressor.

- In a particular test the unit stalled, drawing approximately 68 Amps at 163 VAC, for the complete transient period without opening the thermal protection switch to protect the compressor.
- If the power contactor opened and then reclosed, the compressor returned to normal running mode.

♦ At 115 °F
- The compressor stalled, drawing approximately 63 Amps at 148 VAC, for as long as 17.7 seconds before the thermal protection switch opened to protect the compressor.
- If the power contactor opened and then reclosed, the compressor returned to the normal running mode.

12.6 DELAYED RECOVERY TYPE OF TRANSIENT TEST RESULTS

This compressor had the following threshold voltages 60% at 80 °F, 70% at 100 °F, and 70% at 115 °F when exposed to the *delayed recovery* type of transient. Therefore, the stalling windows are the following: 60% to 55% at 80 °F, 70% to 55% at 100 °F, and 70% to 55% at 115 °F. The thermal protection switch rarely opened to protect the compressor. The compressor stalled in the stalling window, drawing approximately 75 Amps at 164 VAC, for as long as 11.9 seconds before the thermal protection switch opened to protect the compressor. At times, the compressor stalled, drawing approximately 66 Amps at 147 VAC, for as long as 10.9 seconds without opening the thermal protection switch and then returned to the normal running mode. If the power contactor opened and then reclosed, the compressor either stalled, drawing approximately 72 Amps at 157 VAC, for as long as 3.0 seconds before returned to the normal running mode or stalled, drawing approximately 82 Amps at 175 VAC, for as long as 11.2 seconds before the thermal protection switch opened to protect the compressor. In general, opening the contactor did not prevent the compressor from stalling it just delayed it. The following are the details for each of the temperatures:

♦ At 80 °F
- The compressor stalled, drawing approximately 66 Amps at 147 VAC, for as long as 10.9 seconds before it returned to the normal running mode.
- If the power contactor opened and then reclosed, the compressor stalled, drawing approximately 71 Amps at 152 VAC, for as long as 2.0 seconds before returning to the normal running mode.

♦ At 100 °F
- The compressor stalled, drawing approximately 67 Amps at 166 VAC, for as long as 9.0 seconds before returning to the normal running mode.
- The compressor stalled, drawing approximately 75 Amps at 164 VAC, for as long as 11.9 seconds before thermal protection switch opened to protect the compressor.
- If the power contactor opened and then reclosed, the compressor stalled, drawing approximately 72 Amps at 157 VAC, for as long as 11.2 seconds before the thermal protection switch opened to protect the compressor.

♦ At 115 °F
- The compressor stalled, drawing approximately 72 Amps at 169 VAC, for as long as 4.7 seconds before it returned to the normal running mode.
- The compressor stalled, drawing approximately 72 Amps at 156 VAC, for as long as 7.3 seconds before the thermal protection switch opened to protect the compressor.

- If the power contactor opened and then reclosed, the compressor stalled, drawing approximately 82 Amps at 175 VAC, for as long as 3.0 seconds before returning to the normal running state.

12.7 CIRCUIT BREAKER CLEARING TYPE OF TRANSIENT TEST RESULTS

This compressor had the following threshold voltages no-stall at 80 °F, 60% at 100 °F, and 65% at 115 °F when exposed to the *circuit breaker clearing* type of transients. Therefore, the stalling windows are the following: NONE at 80 °F, 60% to 45% at 100 °F, and 65% to 50% at 115 °F. The thermal protection switch rarely opened to protect the compressor furthermore the compressor restarted normally after each stall. This compressor never stalled at 80 °F. The compressor stalled in the stalling window, drawing approximately 114 Amps at 224 VAC, for as long as 1.7 seconds before the thermal protection switch opened to protect the compressor. At times, the compressor stalled, drawing approximately 113 Amps at 225 VAC, for as long as 0.9 seconds before returning to the normal running mode. If the power contactor opened and then reclosed, the compressor either stalled, drawing approximately 115 Amps at 224 VAC, for as long as 0.9 seconds or returned to the normal running mode. In general, opening the contactor did not prevent the compressor from stalling it just delayed it. The following are the details for each of the temperatures:

- At 80 °F
  - The compressor never stalled in the stalling window.
- At 100 °F
  - The compressor only stalled with the 12 cycles transient, drawing approximately 114 Amps at 224 VAC, for as long as 1.7 seconds before the thermal protection switch opened to protect the compressor.
  - If the power contactor opened and then reclosed, the compressors either stalled, drawing approximately 115 Amps at 224 VAC, for as long as 0.9 seconds before it returned to the normal running mode.
- At 115 °F
  - The compressor only stalled at the 6 and 12 cycle transients, drawing approximately 113 Amps at 225 VAC, for as long as 0.9 seconds before it returned to the normal running mode.
  - If the power contactor opened and then reclosed, the compressor stalled, drawing approximately 113 Amps at 225 VAC, for as long as 0.8 seconds before it returned to the normal running mode.

13.0 A/C #10 - TEST RESULTS

The air conditioner's compressor stalled when the voltage was in the stalling window (between the stall threshold voltage and contactor dropout voltage) when exposed to any of the three types of transients except at 80 °F with the *delayed recovery* type of transients. When exposed to the *long notch* type of transients in the stalling window, this compressor stalled, drawing approximately 88 Amps at 133 VAC, for as long as 27.3 seconds before the thermal protection switch opened to protect the compressor or stalled, drawing approximately 88 Amps at 128 VAC, for 30 seconds before returning to the normal running mode. When exposed to the *delayed recovery* type of transients in the stalling window, this compressor stalled, drawing approximately 103 Amps at 165 VAC, for as long as 11.5 seconds before either the thermal protection switch opened to protect the compressor or it returned to the normal running mode. When exposed to the *circuit breaker clearing* type of transients in the stalling window except at 80 °F, this compressor stalled, drawing approximately 153 Amps at 219 VAC, for as long as 0.9 seconds before returning to the *normal running* mode. When the contactor opened under the *delayed recovery* type of transients and then reclosed, the compressor stalled, drawing approximately 120 Amps at 180 VAC, for as long as 6.6 seconds before the thermal protection switch opened to protect the compressor or stalled for as long as 0.7 before returning to the normal running mode. In general, opening the contactor did not help to prevent the compressor from stalling; it just delayed it.

13.1 SYSTEM SPECIFICATIONS

The tested air conditioner system has the following specifications:

MAIN SYSTEM	
Manufacturer	Carrier
Condenser Unit	38TXA060-31
Evaporator Coil	TBD
Size (Tons)	5
Compressor Type	Scroll
Refrigerant	R-410A
SEER	13
Condition	New
Unit Cost	$2,253.00

COMPRESSOR	
Manufacturer	Copeland
Model	ZP54K3E-PFV-130
Type	Scroll
FLA (AMPS)	27.6
LRA (AMPS)	158
Phase	1
Refrigerant	R410A
Charge (LBS)	11.5
Voltage (V)	230/208
PMAX High (PSI)	623.7
PMAXLow (PSI)	406.1

FAN MOTOR	
Manufacturer	GE
Model	5KCP39FG S071 S
Voltage (V)	208/230
Current (I)	1.4
Power (HP)	0.25
RPM	1100
FLA (AMPS)	1.4

CONTACTOR	
Manufacturer	Product Unlimited
Model	3100-30Q1028TT
Rating (V)	240
FLA (AMPS)	40
LRA (AMPS)	240
Resistance	-

CAPACITOR	
Manufacturer	GE
Model	27L681
Rating (V)	370
Capacitance (µF)	80

13.2 TEST PARAMETERS

This air conditioner unit has the following testing parameters.

	80°F	100°F	115°F
T_{INLET} (°C)	22.6	22.4	22.2
T_{OUTLET} (°C)	12.9	13.5	15.3
$T_{COMP.\ AMB.}$ (°C)	26.3	38.0	46.5
T_{CASE} (°C)	86.6	109.0	130.7
T_{GAS} (°C)	15.8	18.2	21.8
T_{LIQ} (°C)	25.2	37.0	44.8
R_{FLOW} (Kcfm)	2.3	2.0	2.2
P_{LOW} (PSI)	90.4	95.8	105.8
P_{HIGH} (PSI)	310.6	415.4	490.8
$I_{RUNNING}$ (A)	21.0	26.0	32.0
$W_{RUNNING}$ (W)	4561.0	5948.0	7234.0
$VAR_{RUNNING}$ (VAR)	1602.0	1750.0	1941.0

A more detail internal performance parameter table can be found in APPENDIX #2 -- Attachment # 10.

13.3 INRUSH TEST RESULTS

It would take approximately 22 cycles to come into its normal steady running state. The data below was recorded for the whole air conditioner system.

Inrush	
V_{INRUSH}	218 VAC
I_{INRUSH}	163 A
W_{INRUSH}	25,950 W
VAR_{INRUSH}	24,300 VAR
t	22 cycles

13.4 POWER CONTACTOR TEST RESULTS

The power contactor opened at a 55% voltage sag. In general, the thermal protection switch never opened to protect the unit from stalling after the contactor reclosed. The compressor had the following responses right after contactor reclosed:

- *Long notch* type of transient
  - The compressor never stalled after contactor reclosed.
- *Delayed Recovery type of transient*

- At 80 °F
  - The compressor stalled, drawing approximately 120 Amps at 180 VAC, right after the contactor reclosed for as long as 6.6 seconds before the thermal protection opened to protect the compressor.
- At 100 °F
  - The compressor stalled, drawing approximately 111 Amps at 161 VAC, right after the contactor reclosed for as long as 0.7 seconds before it returned to the normal running mode.
- At 115 °F
  - The compressor stalled, drawing approximately 110 Amps at 165 VAC, right after the contactor reclosed for as long as 0.7 seconds before it returned to the normal running mode.

- *Circuit Breaker Clearing* type of transient
  - At 80 °F
    - The compressor stalled, drawing approximately 162 Amps at 219 VAC, right after the contactor reclosed for as long as 4.0 seconds before it returned to the normal running mode.
  - At 100 °F
    - The compressor stalled, drawing approximately 159 Amps at 219 VAC, right after the contactor reclosed for as long as 0.9 seconds before it returned to the normal running mode.
  - At 115 °F
    - The compressor stalled, drawing approximately 155 Amps at 219 VAC, right after the contactor reclosed for as long as 0.6 seconds before it returned to the normal running mode.

13.5 30-SECOND LONG NOTCH TYPE OF TRANSIENT TEST RESULTS

This compressor had the following threshold voltages 58% at 80 °F, 63% at 100 °F, and 70% at 115 °F when exposed to the *long notch* type of transients. Therefore, the stalling windows are the following: 58% to 55% at 80 °F, 63% to 55% at 100 °F, and 70% to 55% at 115 °F. The thermal protection switch opened to protect the compressor, except in some cases where the compressor stalled for the complete transient period and the thermal protection switch never opened. The unit stalled in the stalling window, drawing approximately 88 Amps at 133 VAC, for as long as 27.3 seconds before the thermal protection switch opened to protect the compressor. In some cases the compressor stalled, drawing approximately 88 Amps at 128 VAC, for the complete transient period before it returned to the normal running mode. If the power contactor opened and then reclosed, the compressor returned to the normal running mode. In general, opening the contactor helped the unit by keeping it out of stalling under this type of transient. The following are the details for each of the temperatures:

- At 80 °F
  - The compressor stalled, drawing approximately 88 Amps at 128 VAC, for the complete transient period (30.0 seconds) before returned to normal running mode.
  - If the power contactor opened and then reclosed, the compressor returned to the normal running mode.
- At 100 °F

- The compressor stalled, drawing approximately 88 Amps at 133 VAC, for as long as 27.3 seconds before the thermal protection switch opened to protect the compressor.
- If the power contactor opened and then reclosed, the compressor returned to the normal running mode.

♦ At 115 °F
- The compressor stalled, drawing approximately 86 Amps at 134 VAC, for as long as 22.3 seconds before the thermal protection switch opened to protect the compressor. In one instance the compressor stalled, drawing approximately 104 Amps at 155 VAC, four (4) times without opening the thermal protection switch.
- If the power contactor opened and then reclosed, the compressor returned to the normal running mode.

13.6 DELAYED RECOVERY TYPE OF TRANSIENT TEST RESULTS

This compressor had the following threshold voltages 63% at 100 °F and 68% at 115 °F when exposed to the *delayed recovery* type of transient. Therefore, the stalling windows are the following: 63% to 55% at 100 °F, and 68% to 55% at 115 °F. The unit did not stall at 80 °F. The thermal protection switch opened to protect the compressor. The compressor stalled in the stalling window, drawing approximately 103 Amps at 165 VAC, for as long as 11.5 seconds before the thermal protection switch opened to protect the compressor. If the power contactor opened and then reclosed, the compressor stalled, drawing approximately 120 Amps at 180 VAC, for as long as 6.6 seconds before the thermal protection switch opened to protect the compressor. There were a couple cases where the compressor stalled and then returned to the normal running mode. In general, opening the contactor did not help keep the unit out of stalling under these transients. The following are the details for each of the temperatures:

♦ At 80 °F
- The compressor never stalled in the stalling window.
- If the power contactor opened and then reclosed, the compressor stalled, drawing approximately 120 Amps at 180 VAC, for as long as 6.6 seconds before the thermal protection switch opened to protect the compressor.

♦ At 100 °F
- The compressor stalled, drawing approximately 106 Amps at 167 VAC, for as long as 11.4 seconds before returning to the normal running mode.
- If the power contactor opened and then reclosed, the compressor stalled for as long as 0.7 seconds, drawing approximately 111 Amps at 161 VAC, before returning to the normal running mode.

♦ At 115 °F
- The compressor stalled, drawing approximately 103 Amps at 165 VAC, for as long as 11.5 seconds before the thermal protection switch opened to protect the compressor.
- If the power contactor opened and then reclosed, the compressor stalled, drawing approximately 110 Amps at 165 VAC, for as long as 0.7 seconds before returning to the normal running mode.

13.7 CIRCUIT BREAKER CLEARING TYPE OF TRANSIENT TEST RESULTS

This compressor had the following threshold voltages: none at 80 °F, 60% at 100 °F, and 68% at 115 °F when exposed to the *Circuit Breaker Clearing* type of transients. Therefore, the stalling windows are the following: none at 80 °F, 60% to 50% at 100 °F, and 68% to 50% at 115 °F. The thermal protection switch never opened to protect the compressor, furthermore the compressor restarted normally after any stall conditions. This compressor never stalled at 80 °F. The compressor stalled in the stalling window, drawing approximately 153 Amps at 219 VAC, for as long as 0.9 seconds before it returned to a normal running mode. If the power contactor opened and then reclosed, the compressor at times stalled, drawing approximately 162 Amps at 219 VAC, for as long as 4.0 seconds before returned to normal running mode. In general, opening the contactor did not prevent the compressor from stalling it just delayed it. The following are the details for each of the temperatures:

- At 80 °F
  - The compressor never stalled in the stalling window.
  - If the power contactor opened and then reclosed, the compressor stalled, drawing approximately 162 Amps at 219 VAC, for as long as 4.0 seconds before it returned to the normal running mode.
- At 100 °F
  - Only stalled at the 12 cycle transients, drawing approximately 159 Amps at 219 VAC, for as long as 0.8 seconds before it returned to the normal running mode.
  - If the power contactor opened and then reclosed, the compressor stalled for as long as 0.9 seconds, drawing approximately 159 Amps at 219 VAC, before it returned to the normal running mode.
- At 115 °F
  - Only stalled at 6, 9, and 12 cycle transients, drawing approximately 153 Amps at 219 VAC, for as long as 0.9 seconds before it returned to the normal running mode.
  - If the power contactor opened and then reclosed, the compressor stalled, drawing approximately 155 Amps at 219 VAC, for as long as 0.6 seconds before it returned to the normal running mode.

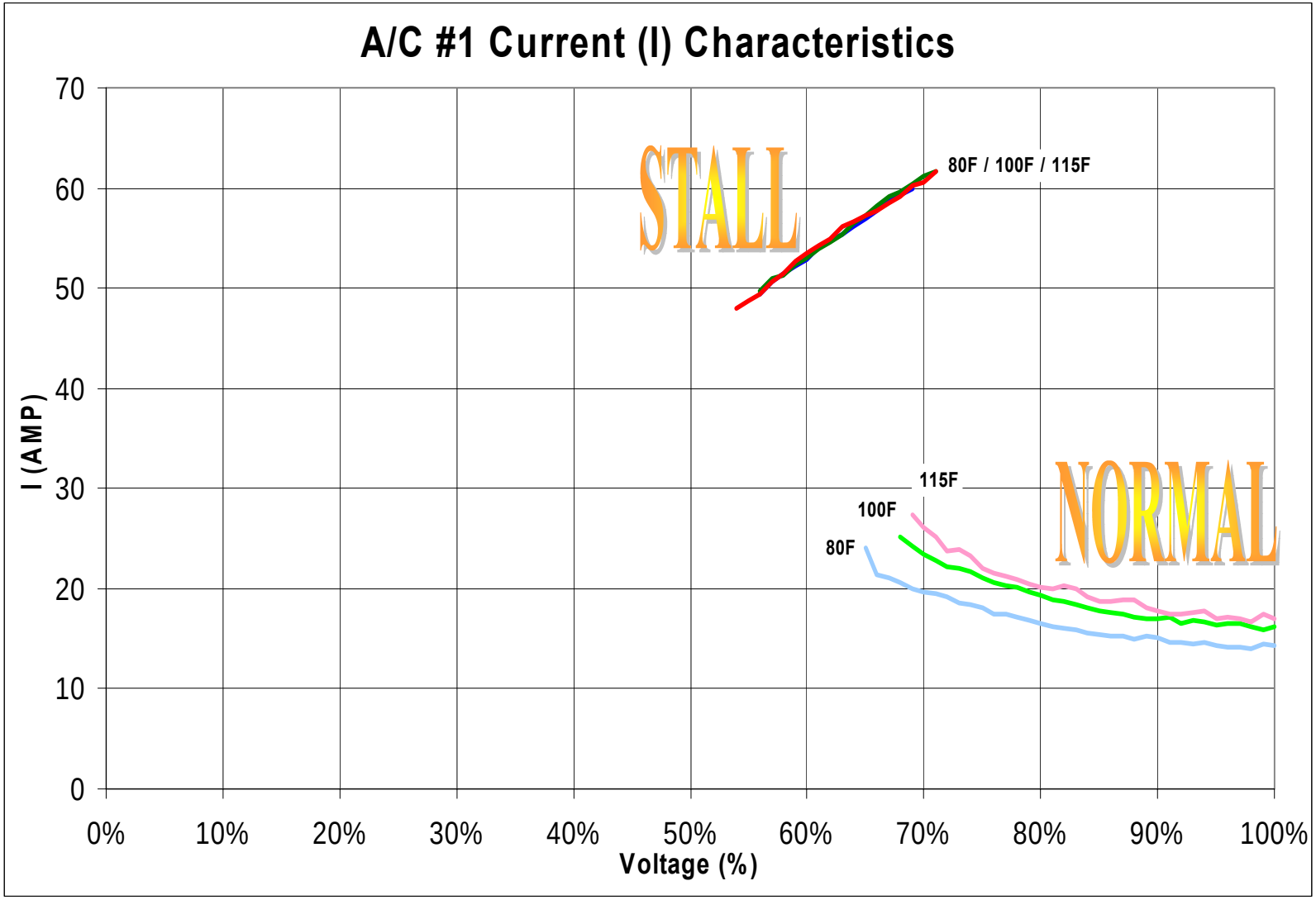
14.0 APPENDIXES

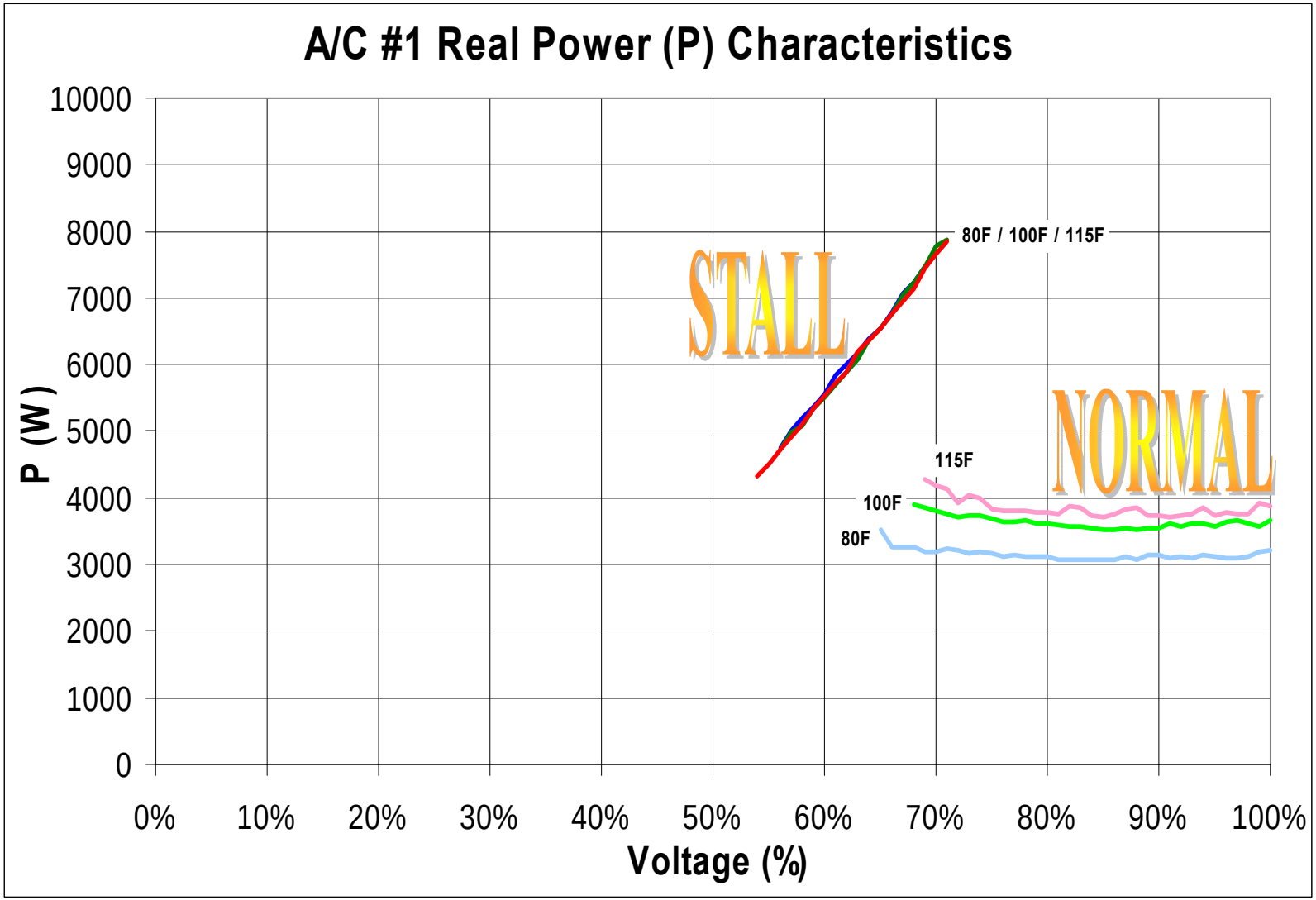
14.1 APPENDIX # 1

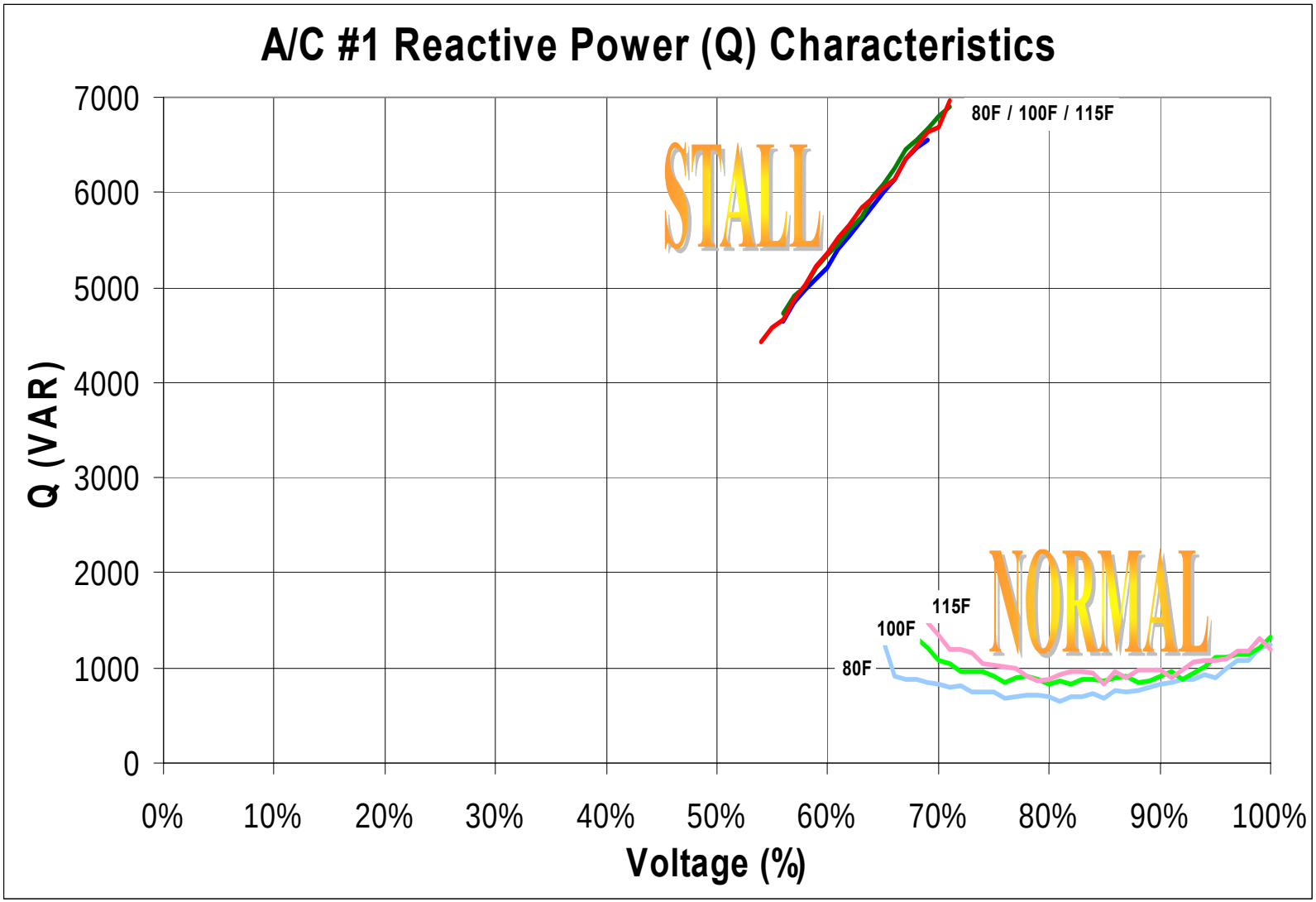
14.1.1 ATTACHMENT #1 -- AIR CONDITIONER TESTING PROCEDURES

14.2 APPENDIX #2

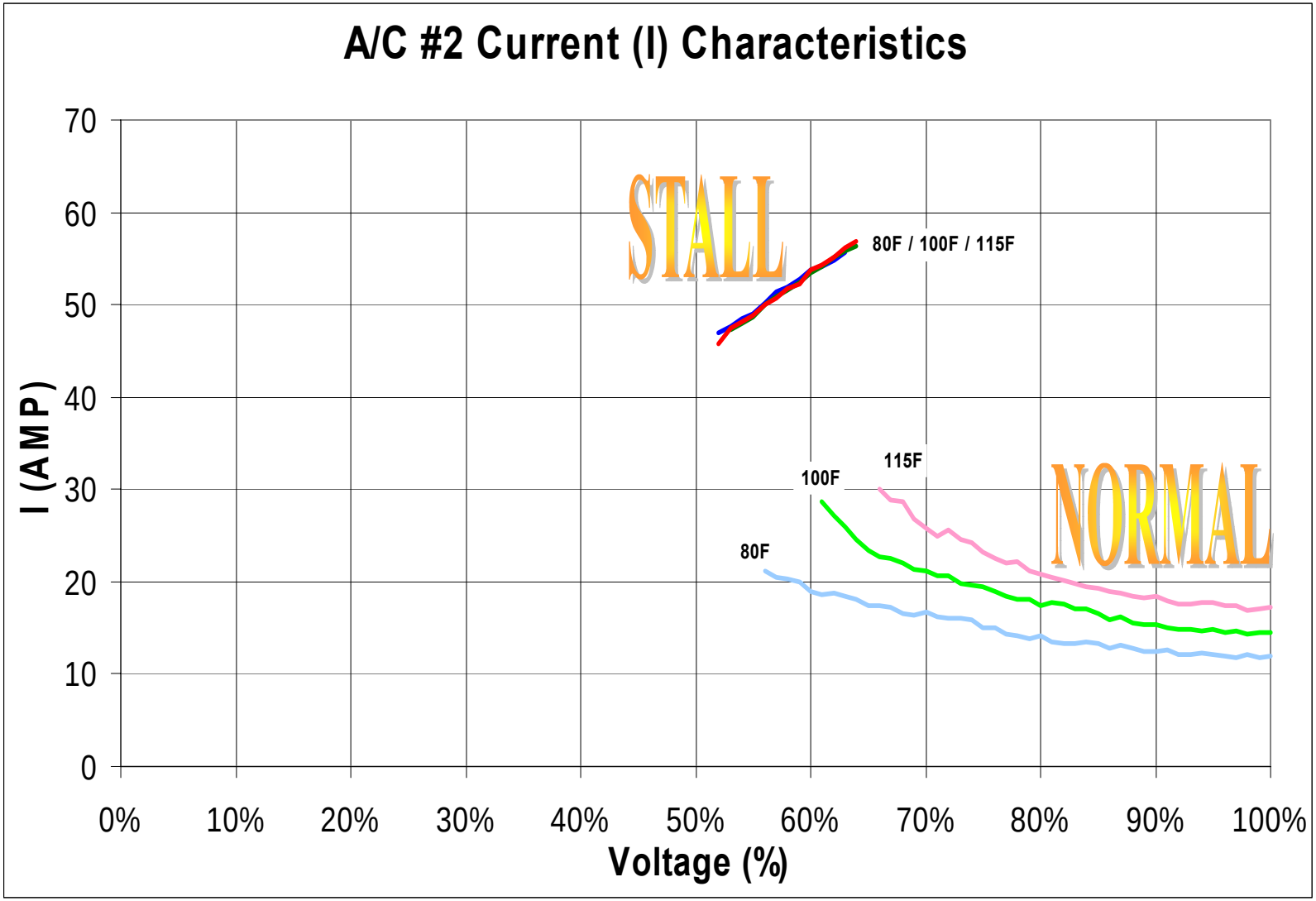
14.2.1 AIR CONDITIONER # 1 INTERNAL PERFORMANCE PARAMETERS

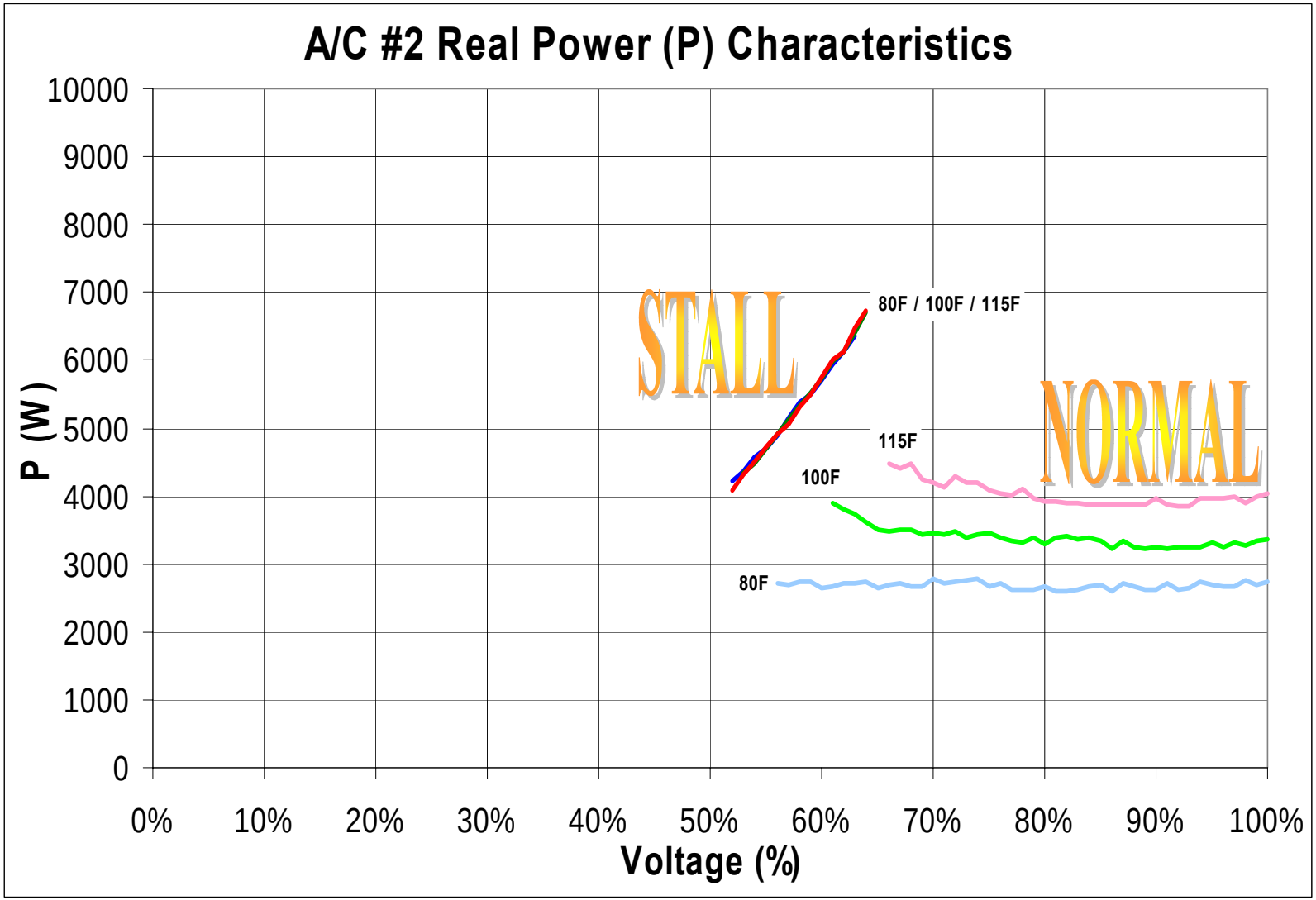


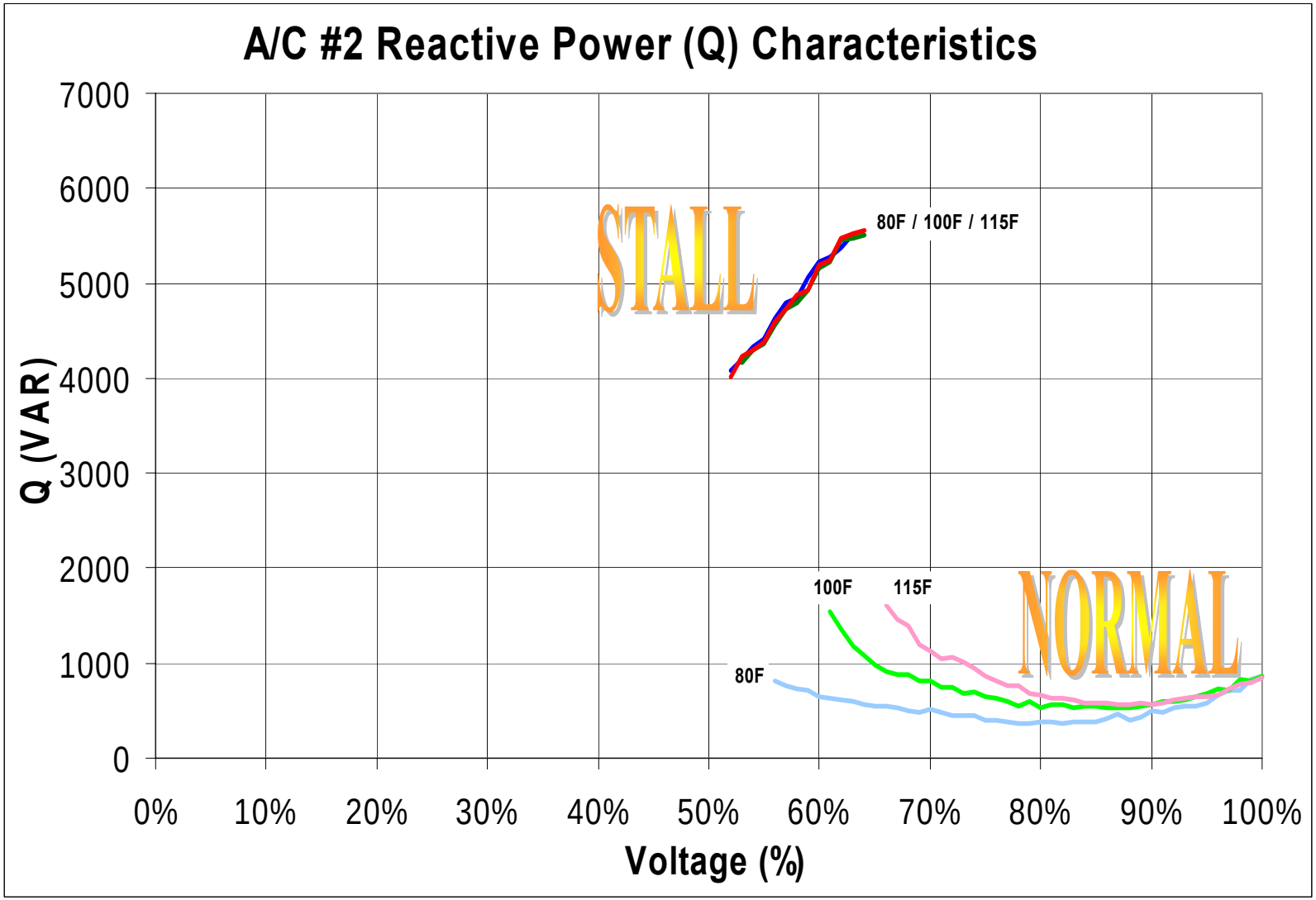

A/C #1 Real Power (P) Characteristics
P (W)
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Voltage (%)
STALL
80F / 100F / 115F
NORMAL
115F
100F
80F


A/C #1 Reactive Power (Q) Characteristics
7000
6000
5000
4000
3000
2000
1000
0
Q (VAR)
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Voltage (%)
80F / 100F / 115F
STALL
NORMAL
115F
100F
80F

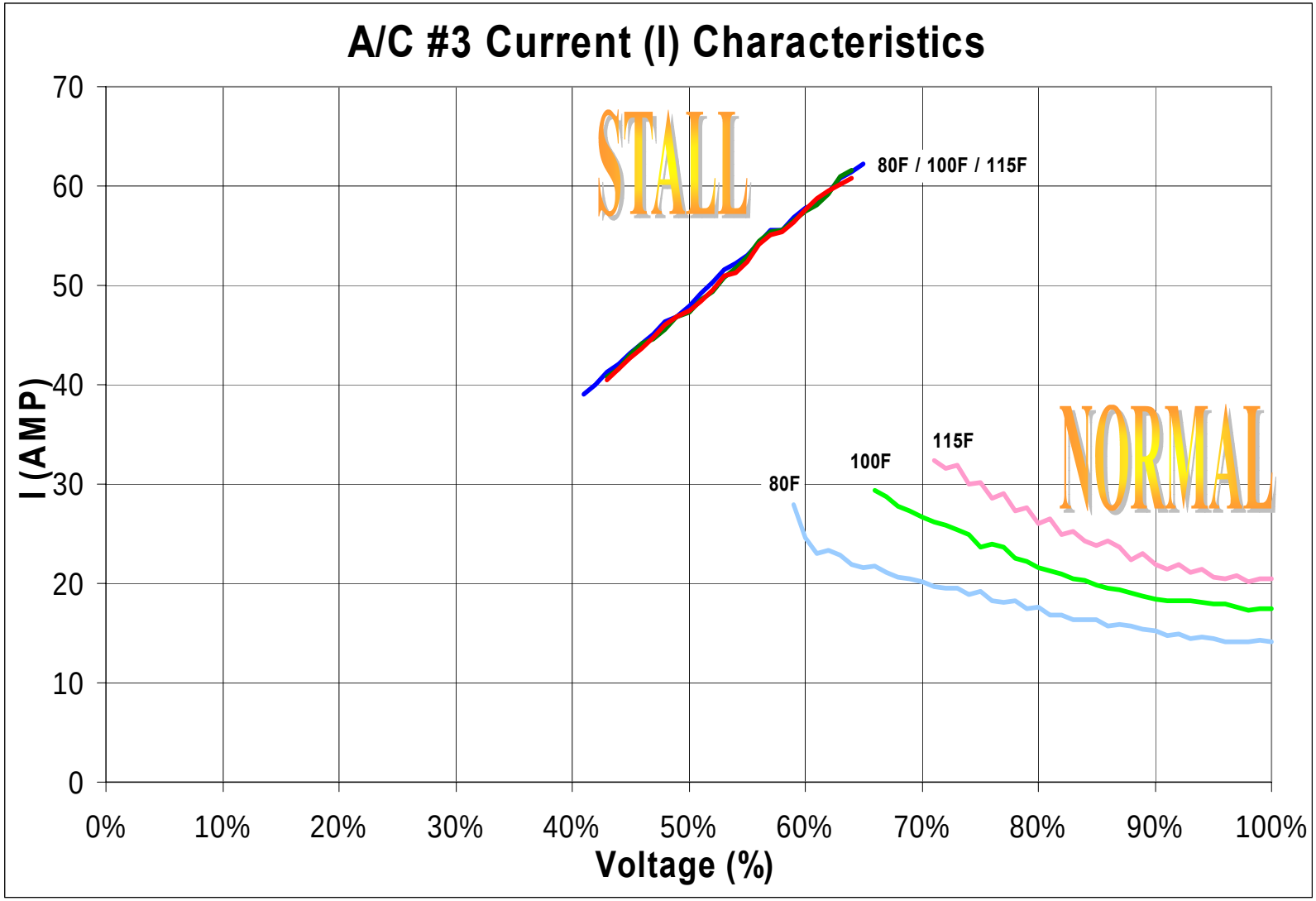
14.2.2 AIR CONDITIONER # 2 INTERNAL PERFORMANCE PARAMETERS

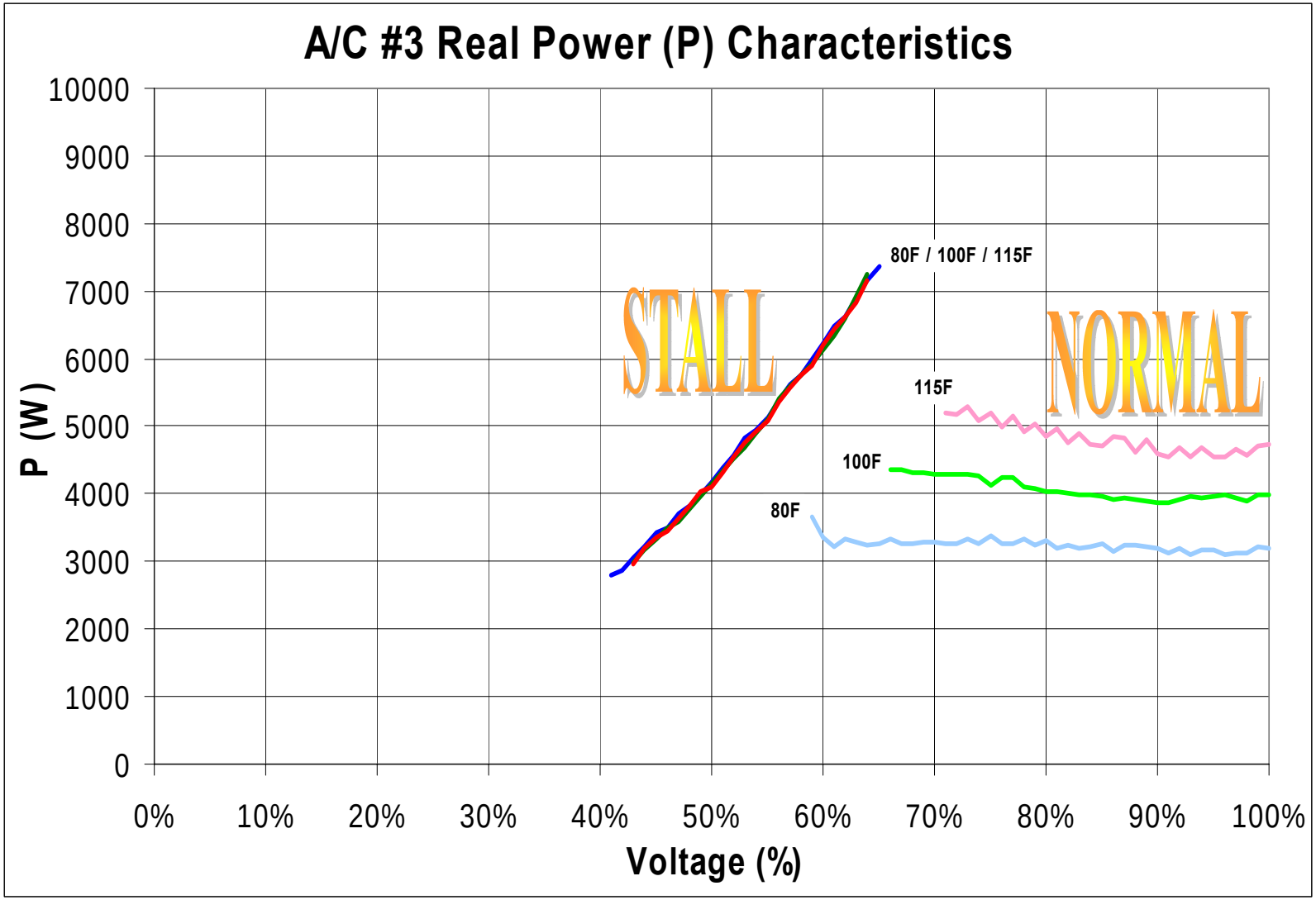


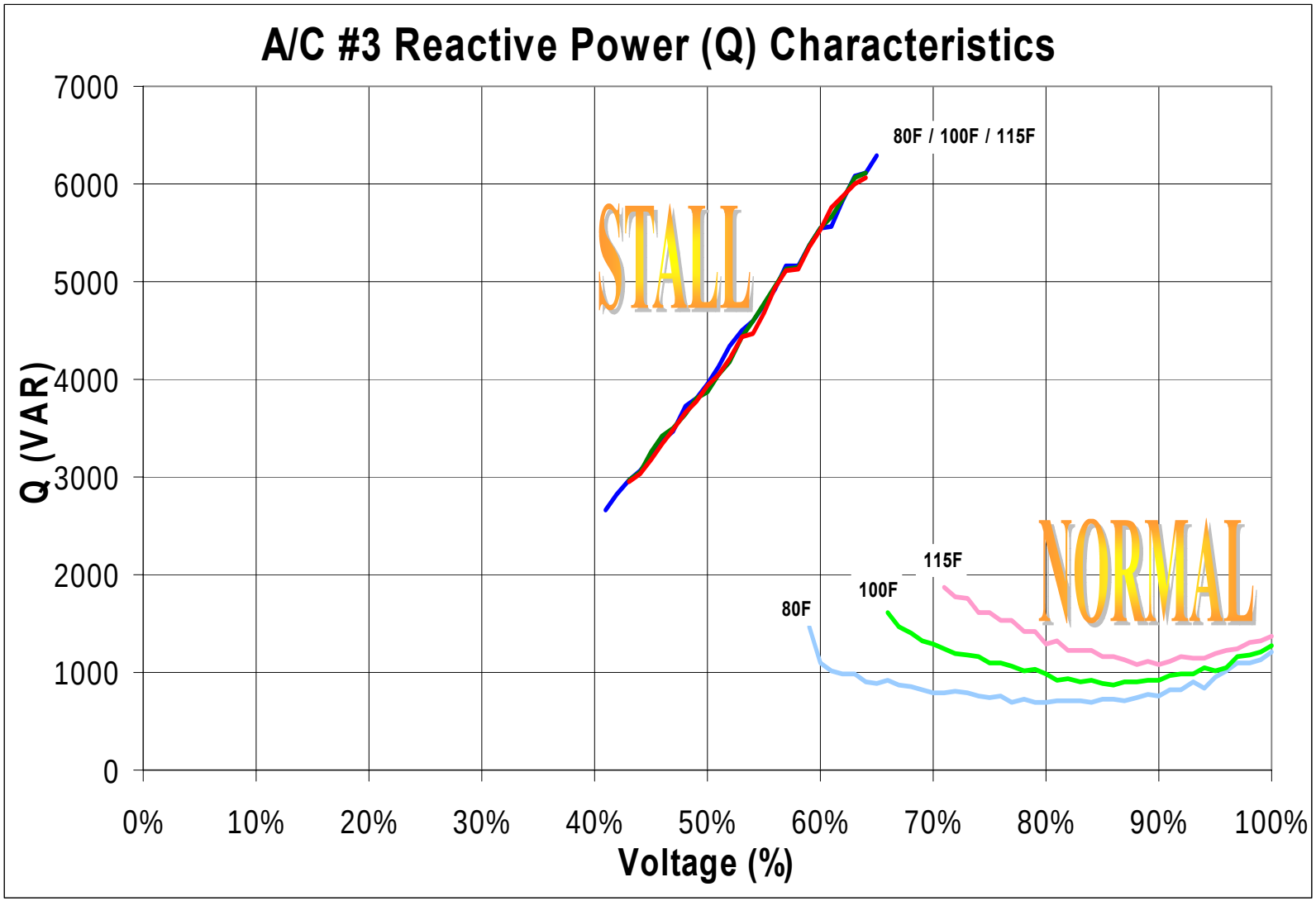

A/C #2 Real Power (P) Characteristics
P (W)
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Voltage (%)
STALL
80F / 100F / 115F
NORMAL
115F
100F
80F


A/C #2 Reactive Power (Q) Characteristics
Q (VAR)
7000
6000
5000
4000
3000
2000
1000
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Voltage (%)
STALL
80F / 100F / 115F
100F
115F
80F
NORMAL

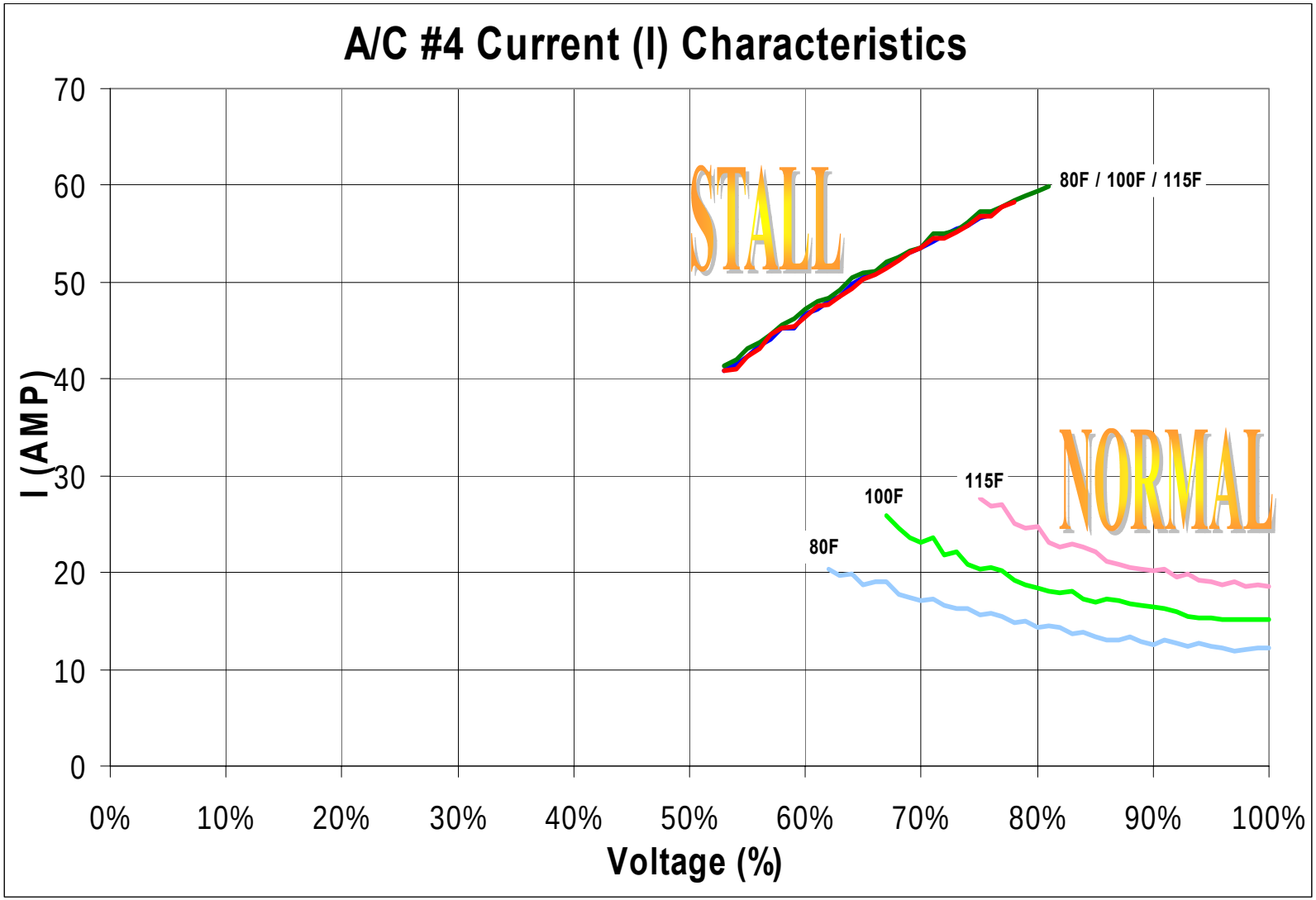
14.2.3 AIR CONDITIONER # 3 INTERNAL PERFORMANCE PARAMETERS

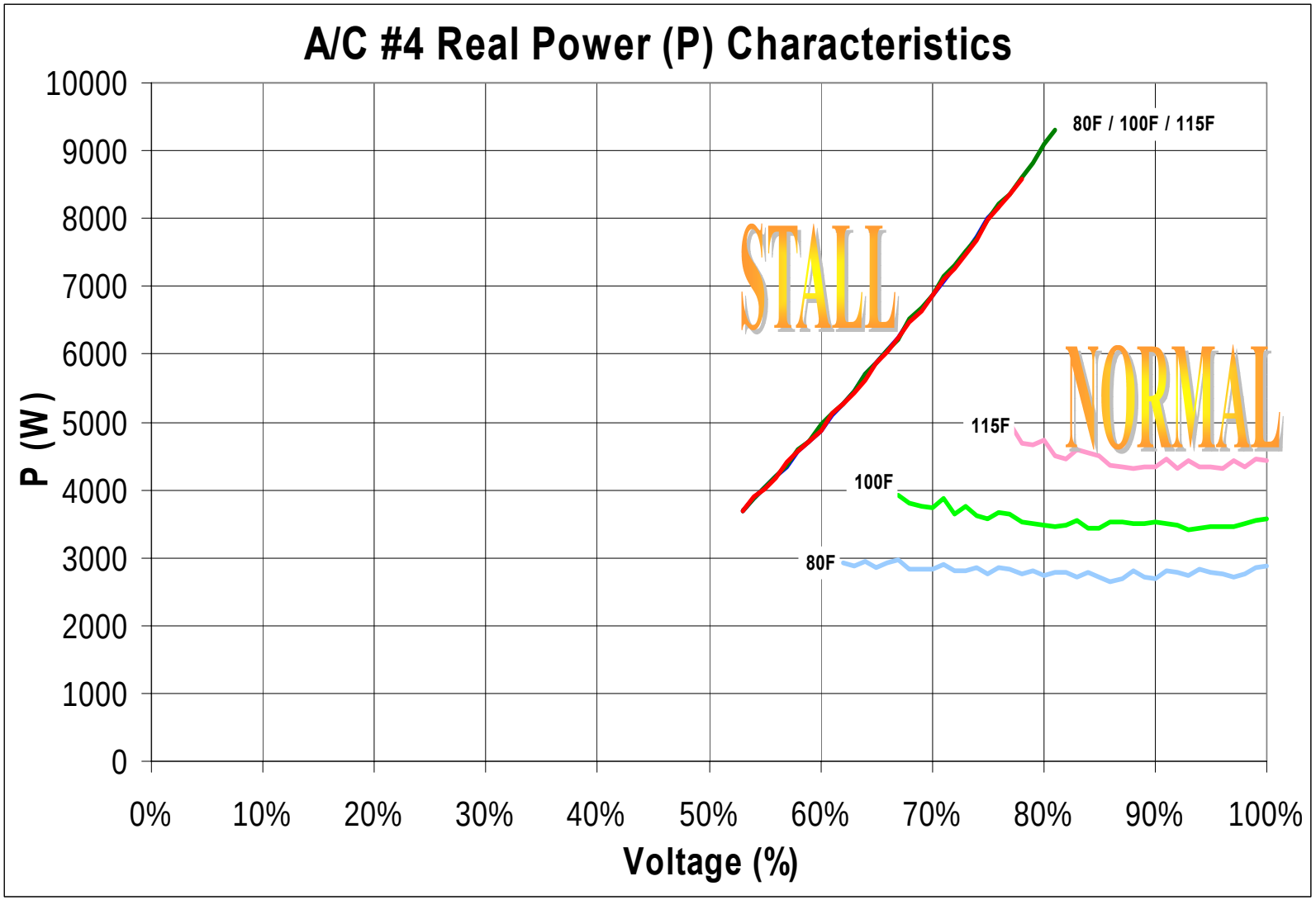


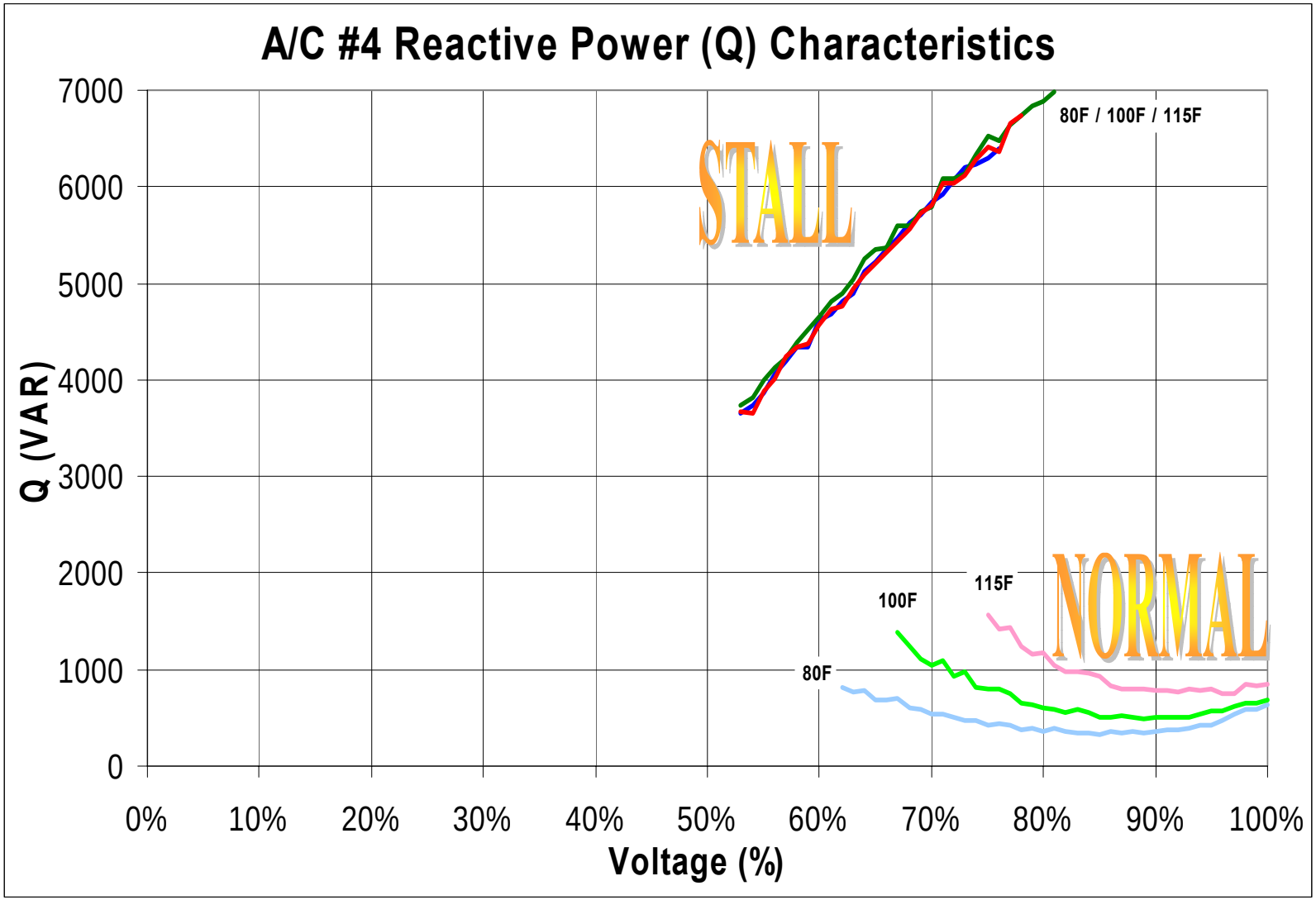

A/C #3 Real Power (P) Characteristics
P (W)
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Voltage (%)
80F / 100F / 115F
STALL
NORMAL
115F
100F
80F


A/C #3 Reactive Power (Q) Characteristics
Q (VAR)
7000
6000
5000
4000
3000
2000
1000
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Voltage (%)
80F / 100F / 115F
STALL
NORMAL
115F
100F
80F

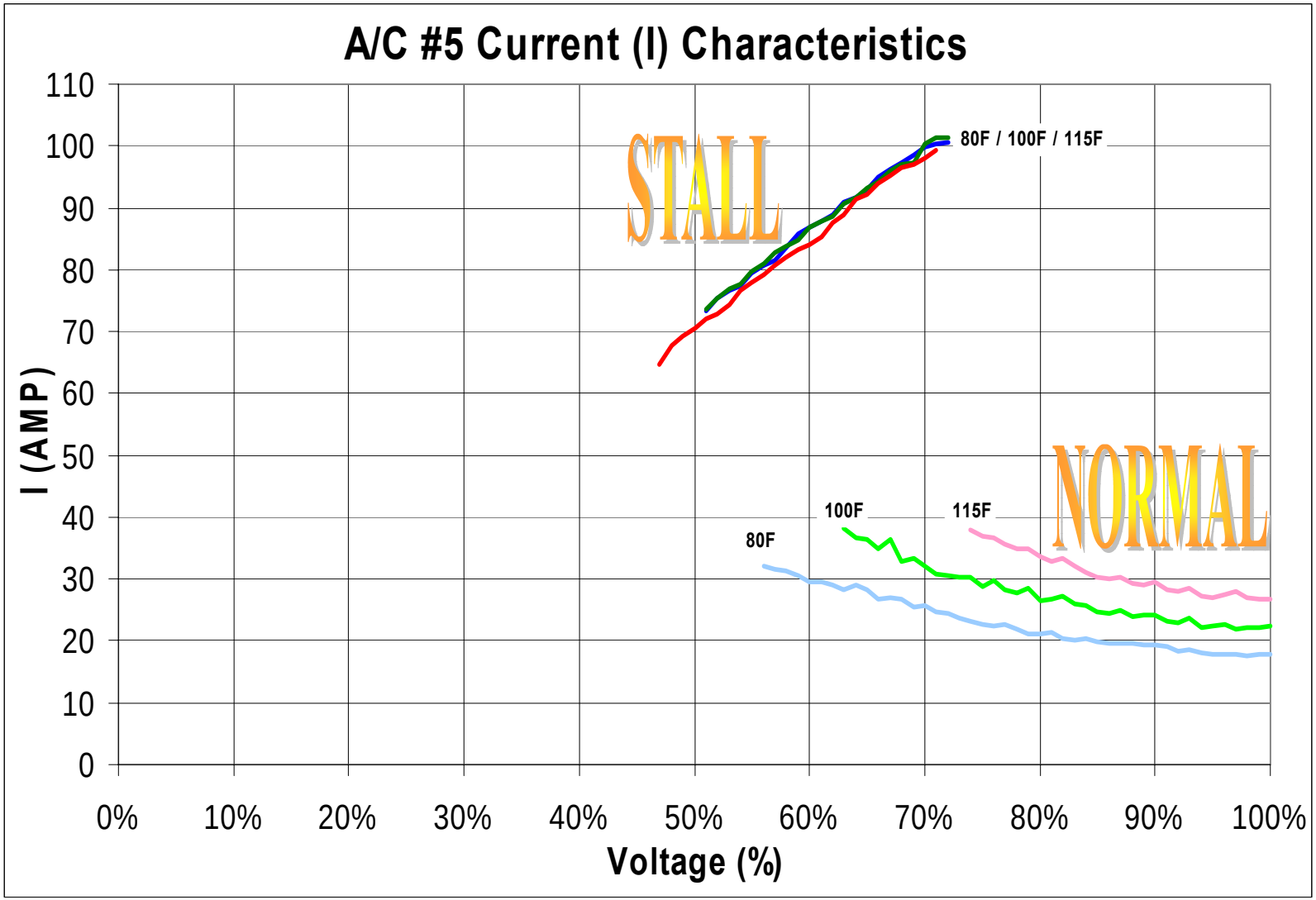
14.2.4 AIR CONDITIONER # 4 INTERNAL PERFORMANCE PARAMETERS

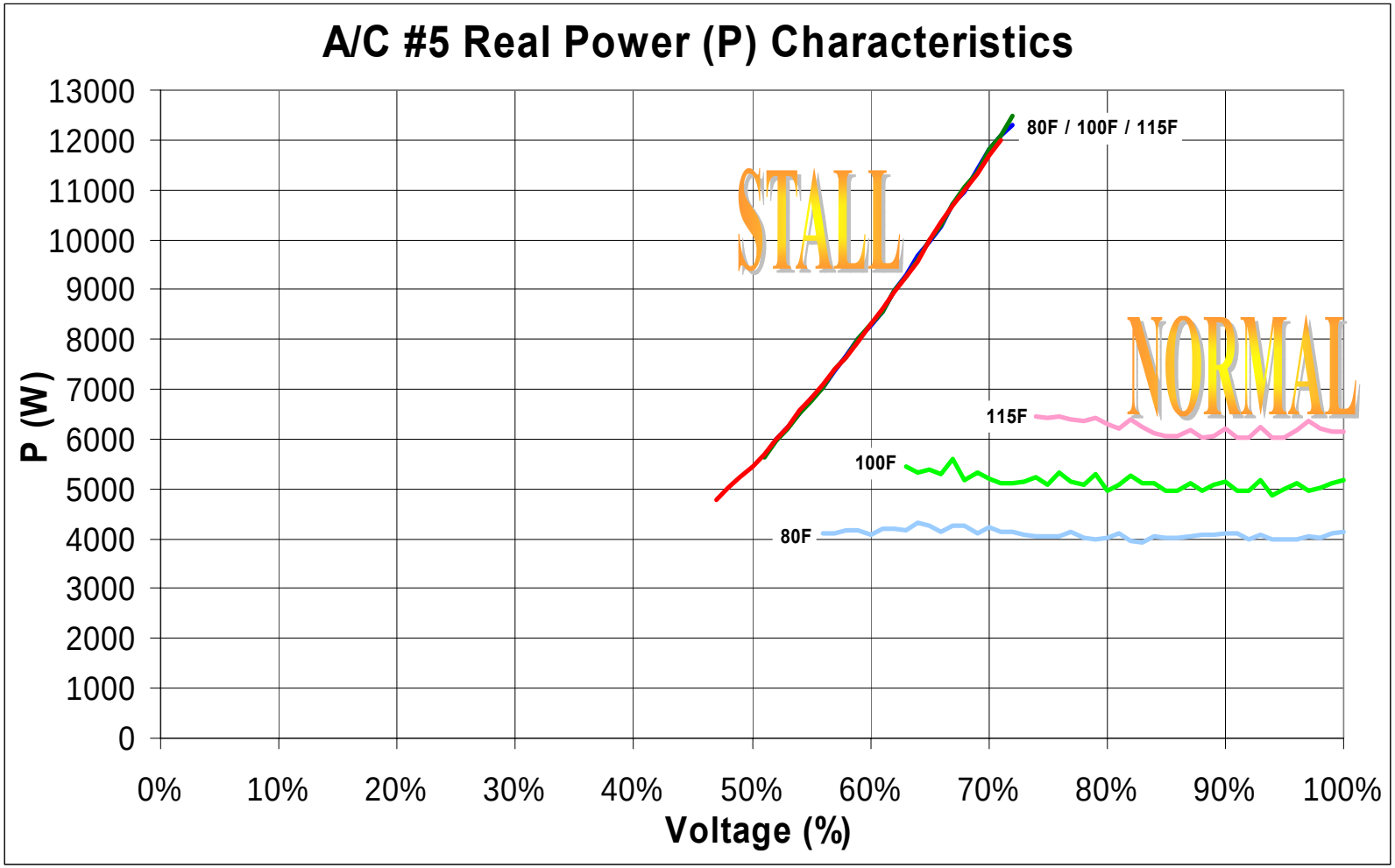


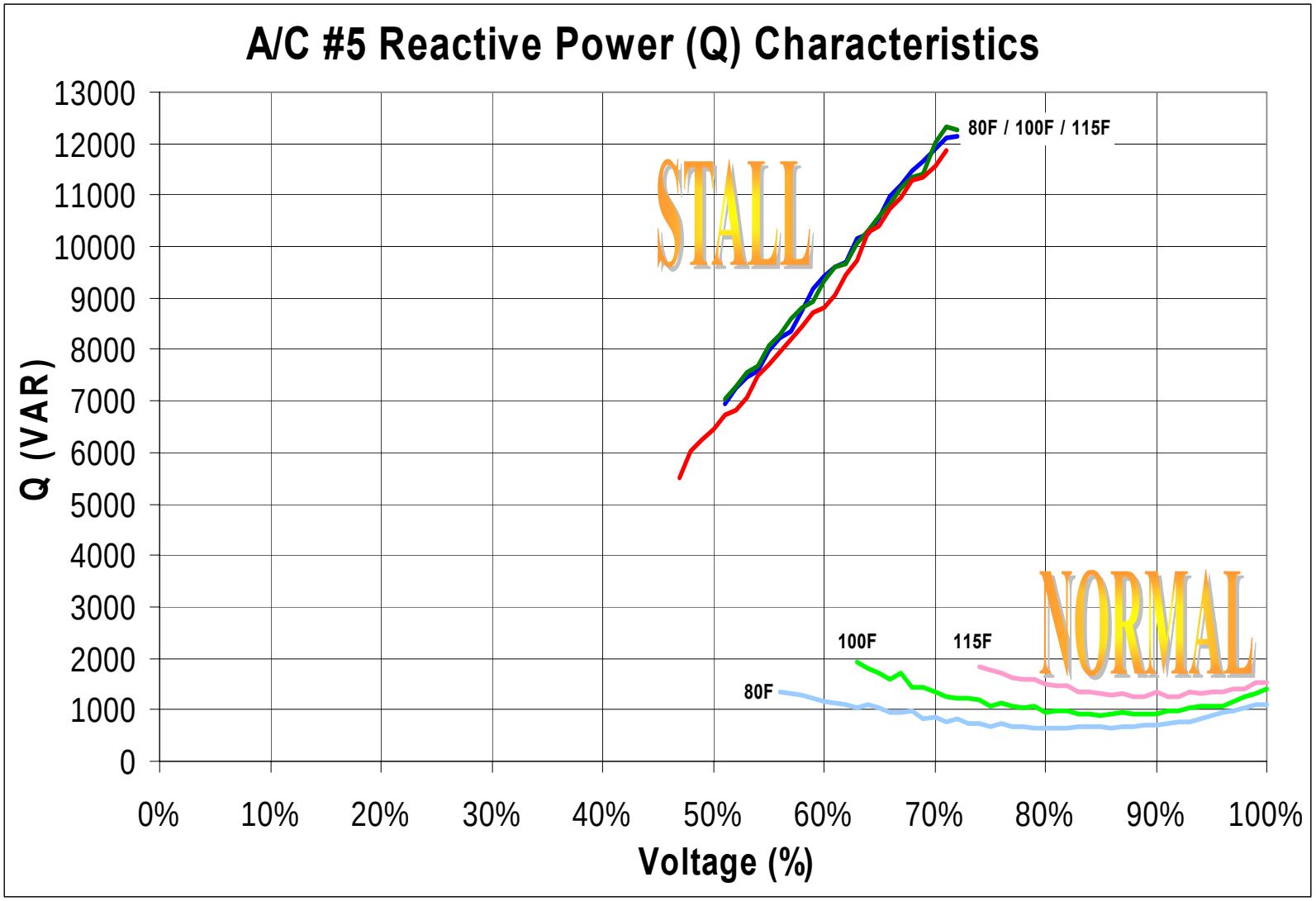

A/C #4 Real Power (P) Characteristics
P (W)
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Voltage (%)
80F / 100F / 115F
STALL
NORMAL
115F
100F
80F


A/C #4 Reactive Power (Q) Characteristics
Q (VAR)
7000
6000
5000
4000
3000
2000
1000
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Voltage (%)
STALL
80F / 100F / 115F
NORMAL
115F
100F
80F

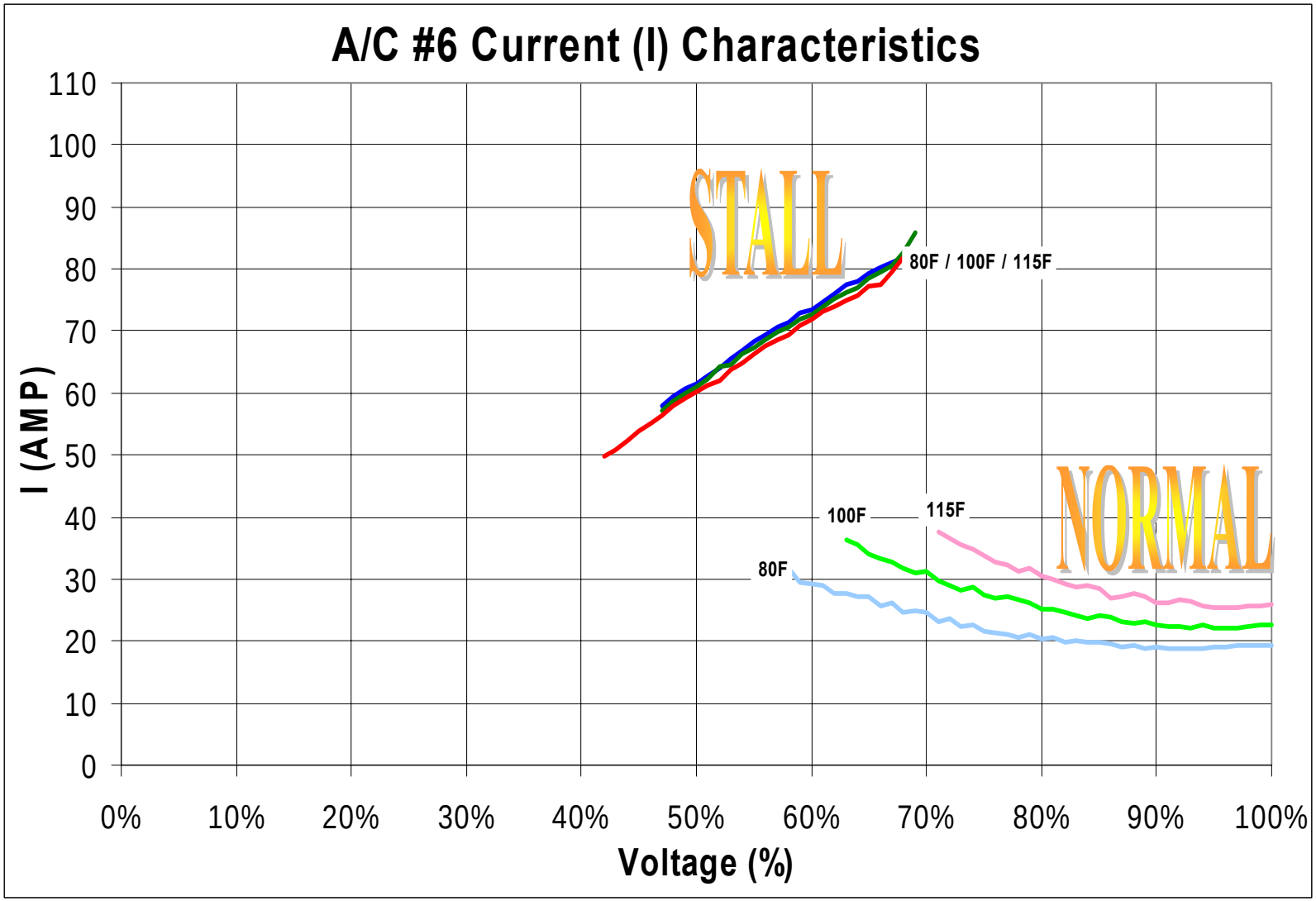
14.2.5 AIR CONDITIONER # 5 INTERNAL PERFORMANCE PARAMETERS

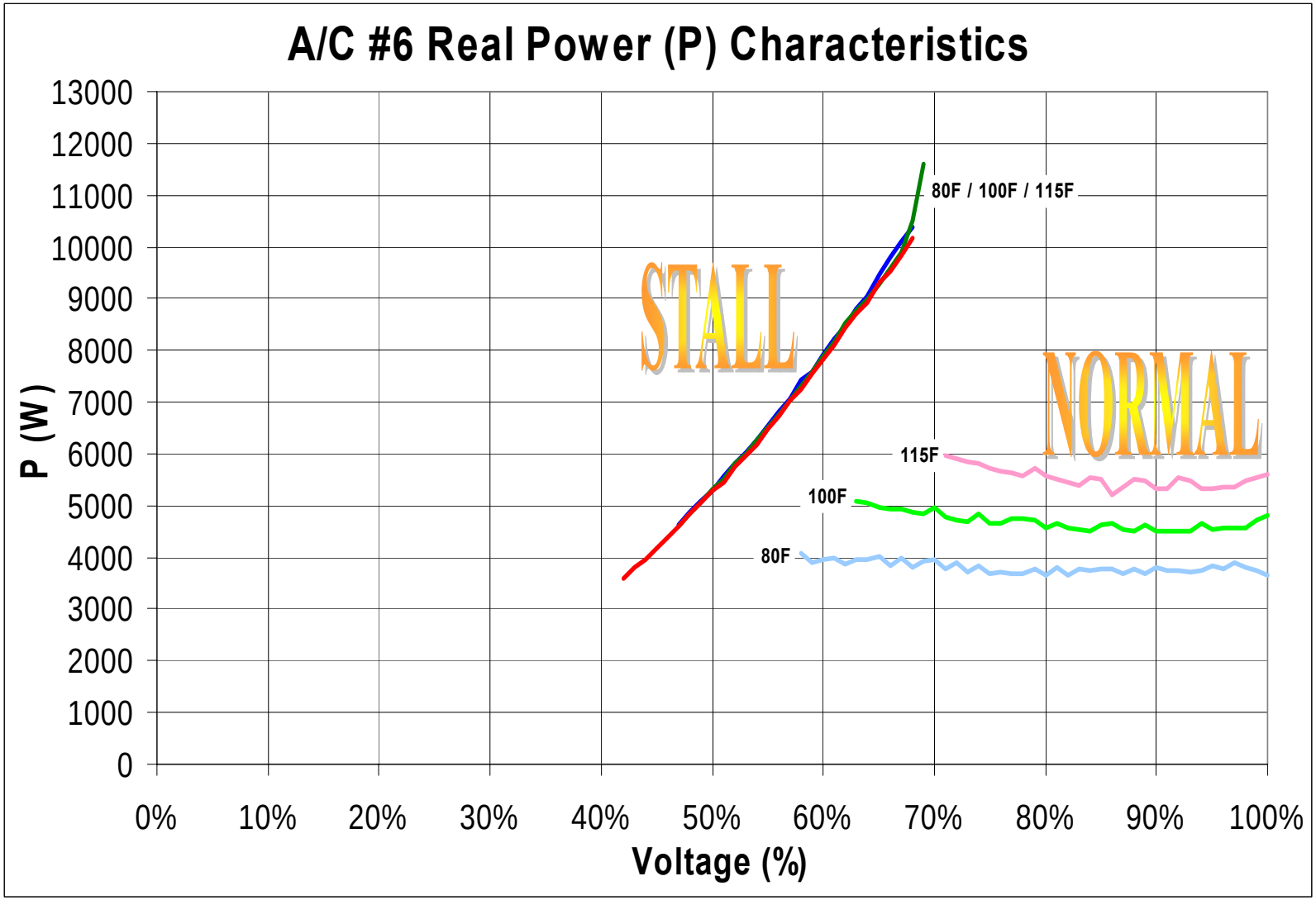


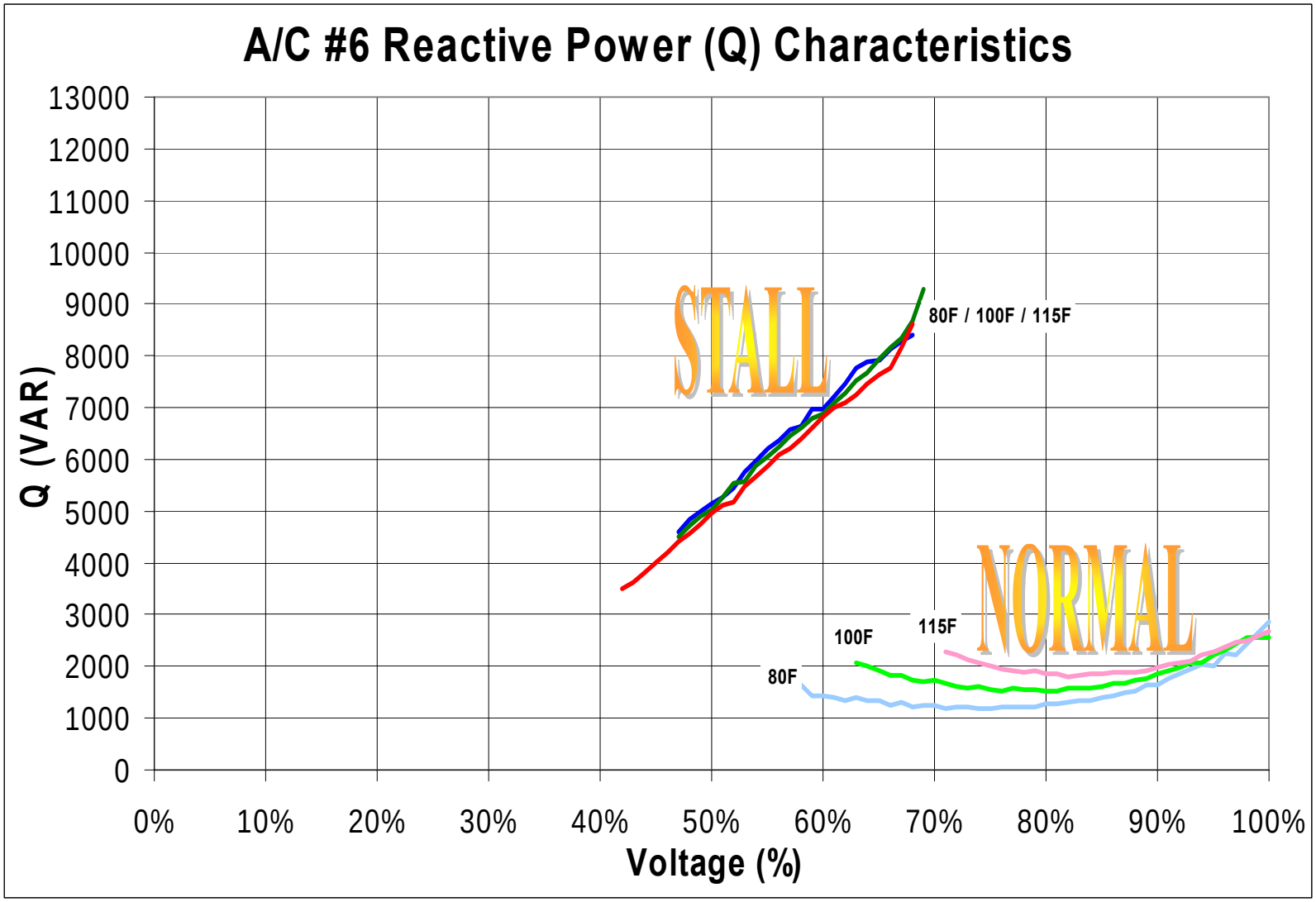

A/C #5 Real Power (P) Characteristics
P (W)
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Voltage (%)
80F / 100F / 115F
STALL
NORMAL
115F
100F
80F


A/C #5 Reactive Power (Q) Characteristics
Q (VAR)
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Voltage (%)
80F / 100F / 115F
STALL
NORMAL
100F
115F
80F

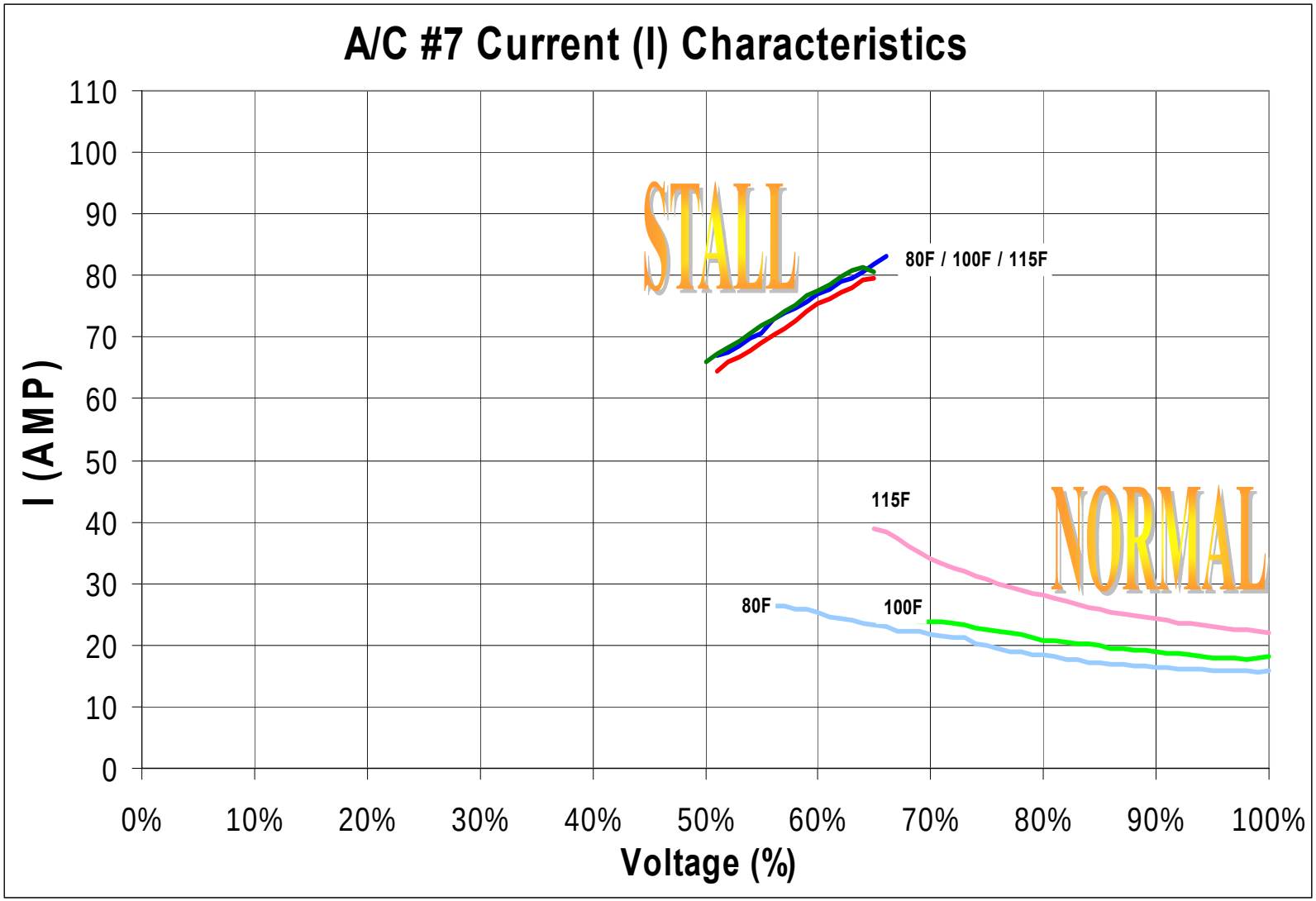
14.2.6 AIR CONDITIONER # 6 INTERNAL PERFORMANCE PARAMETERS

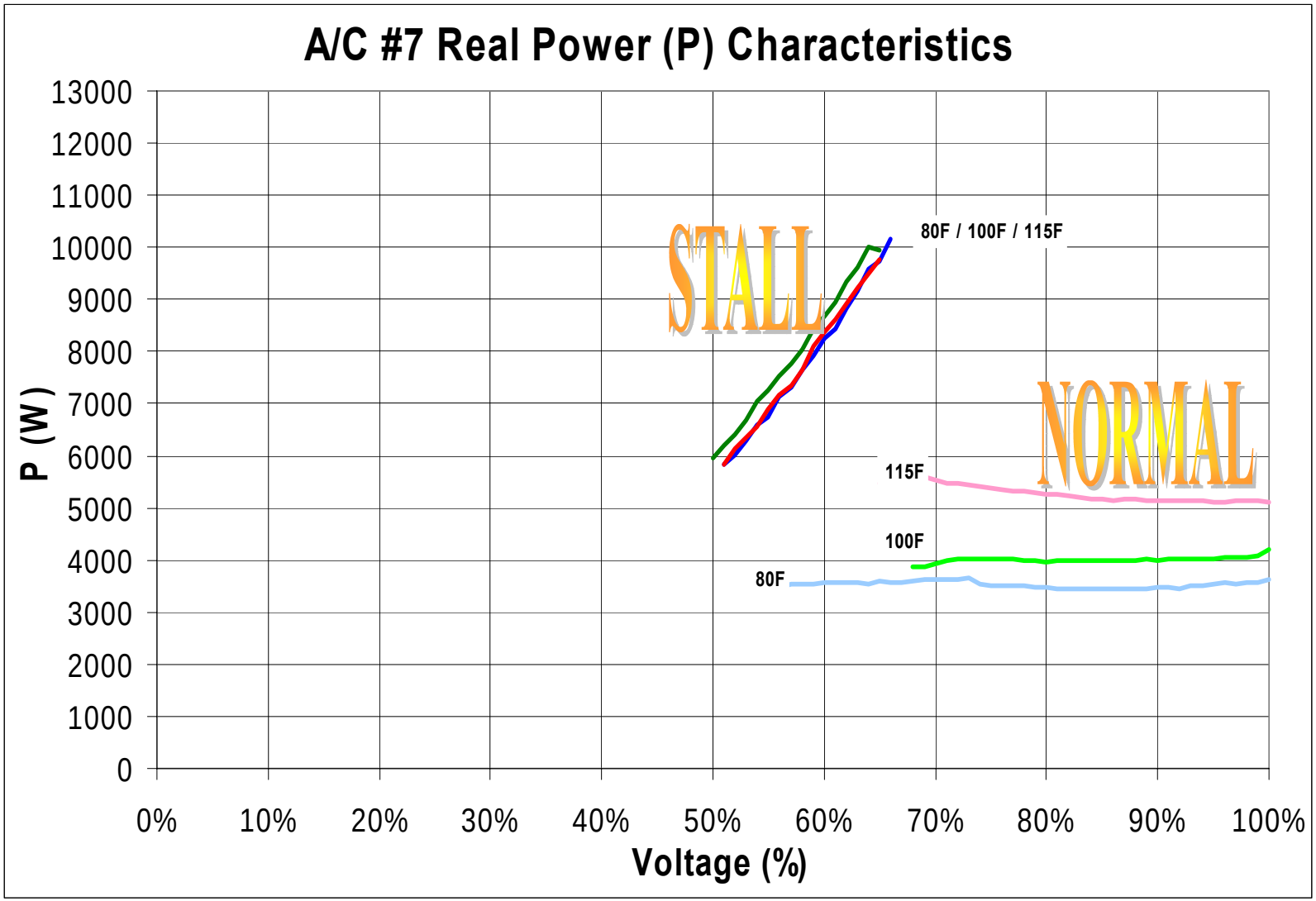


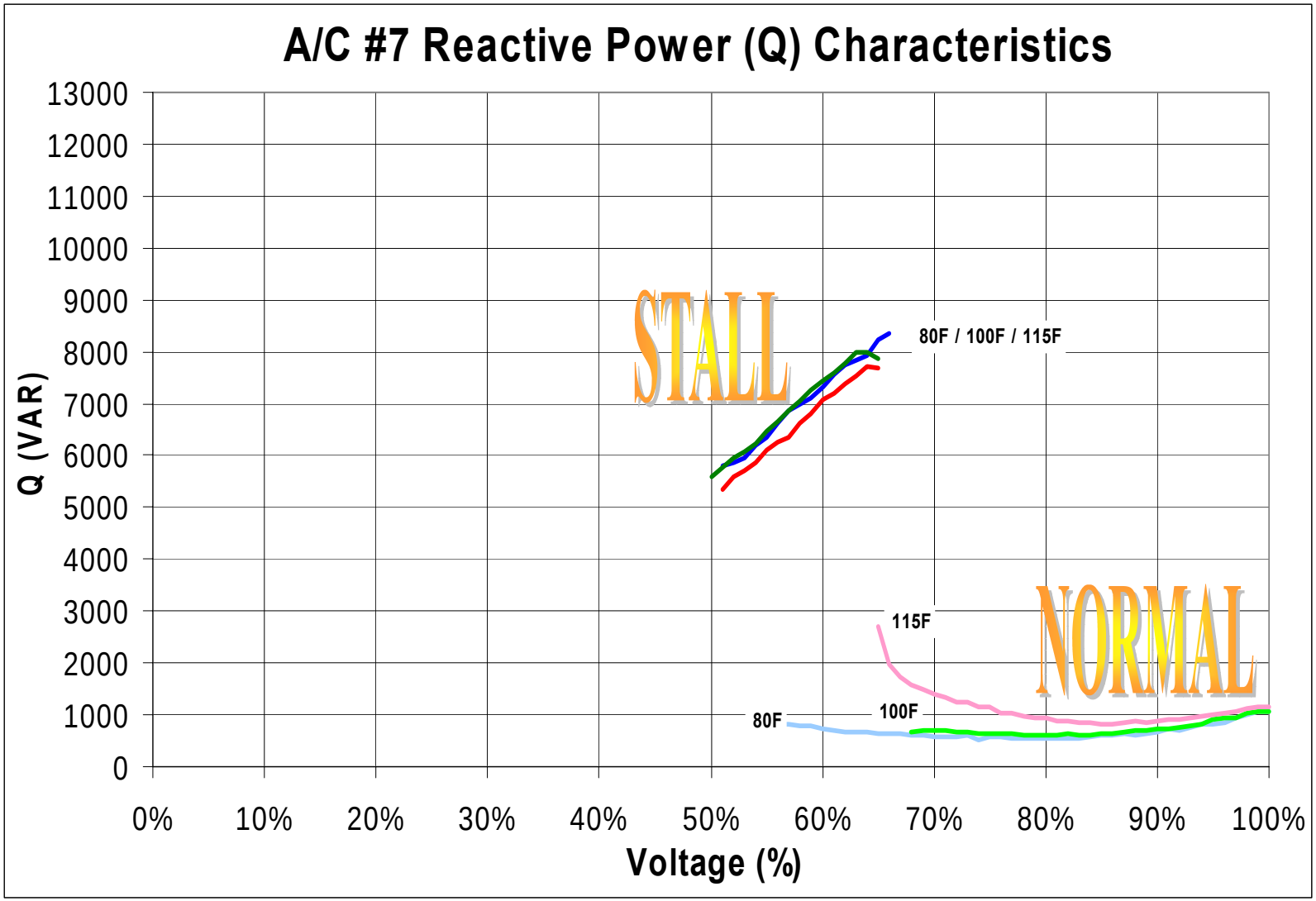

A/C #6 Real Power (P) Characteristics
P (W)
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Voltage (%)
80F / 100F / 115F
STALL
NORMAL
115F
100F
80F


A/C #6 Reactive Power (Q) Characteristics
Q (VAR)
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Voltage (%)
STALL
80F / 100F / 115F
NORMAL
115F
100F
80F

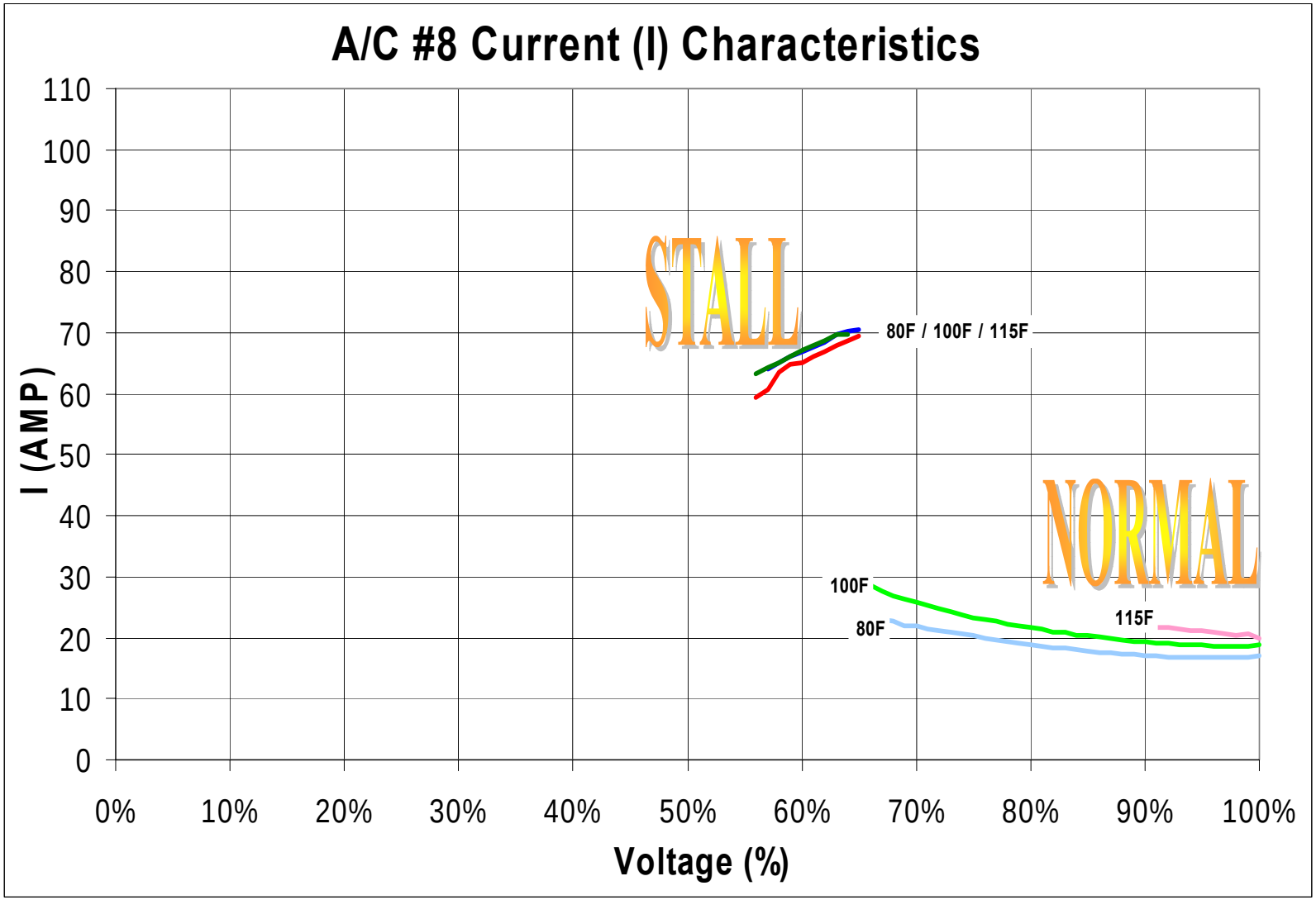
14.2.7 AIR CONDITIONER # 7 INTERNAL PERFORMANCE PARAMETERS

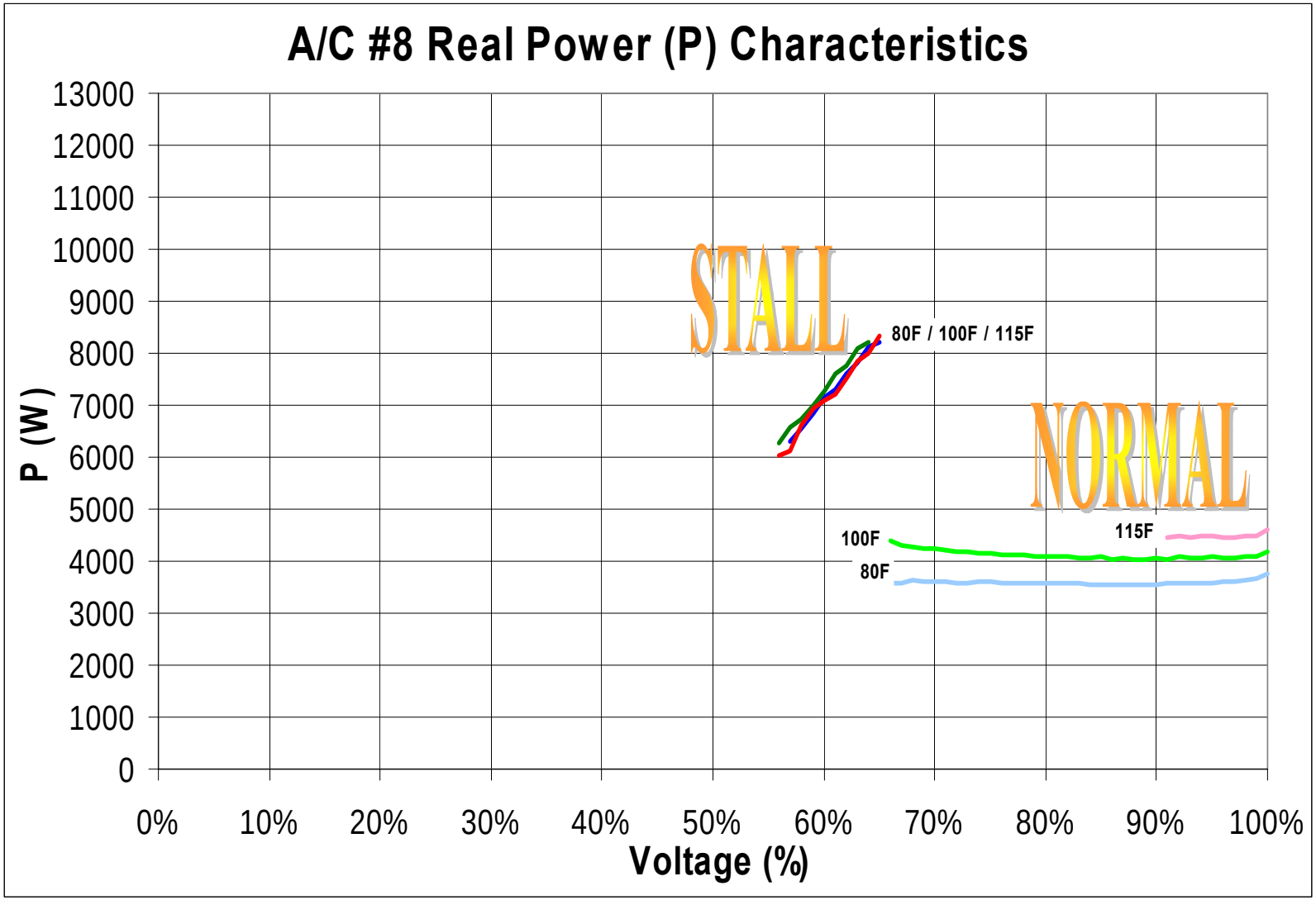


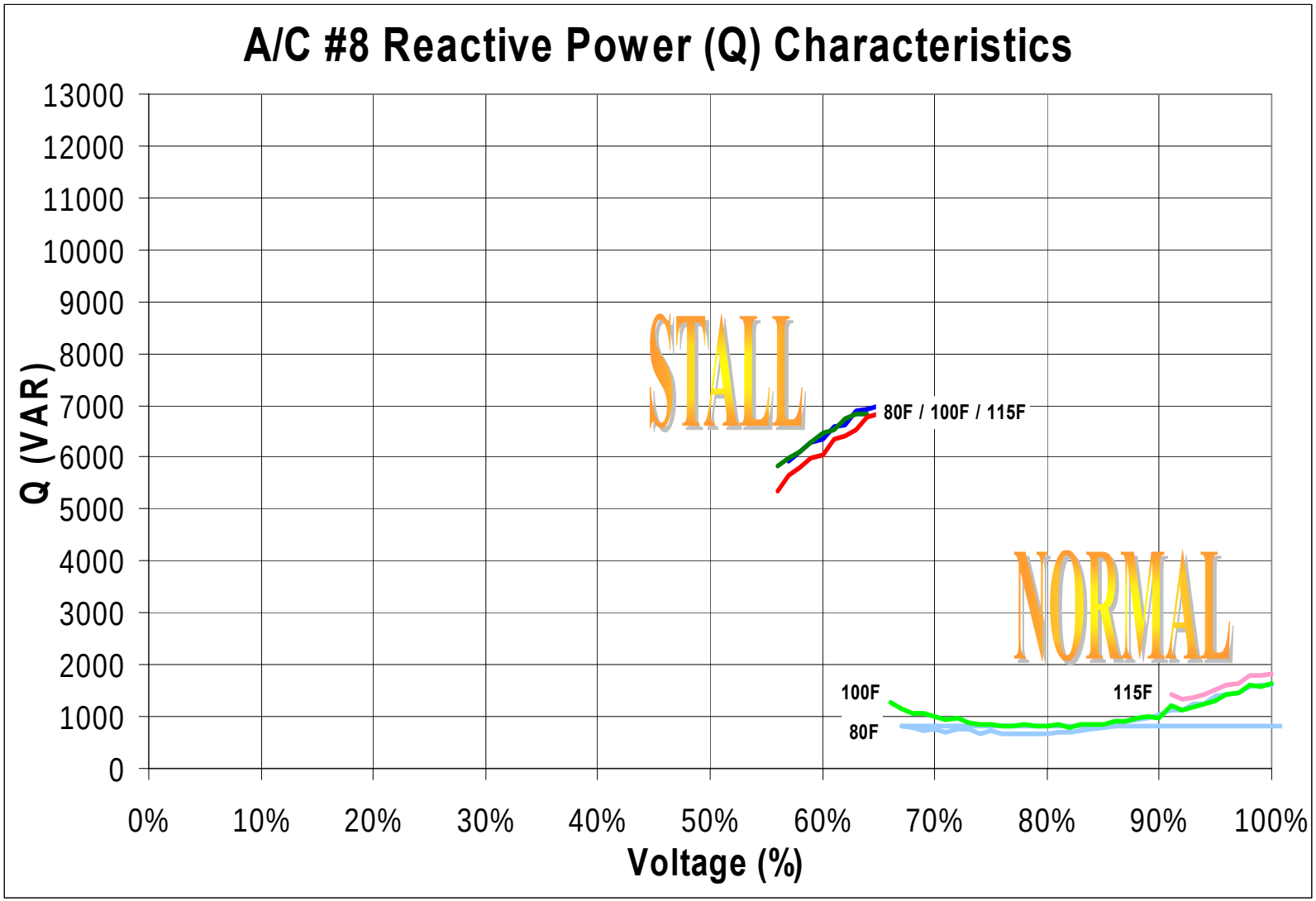

A/C #7 Real Power (P) Characteristics
P (W)
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Voltage (%)
STALL
80F / 100F / 115F
NORMAL
115F
100F
80F


A/C #7 Reactive Power (Q) Characteristics
Q (VAR)
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Voltage (%)
STALL
80F / 100F / 115F
NORMAL
115F
100F
80F

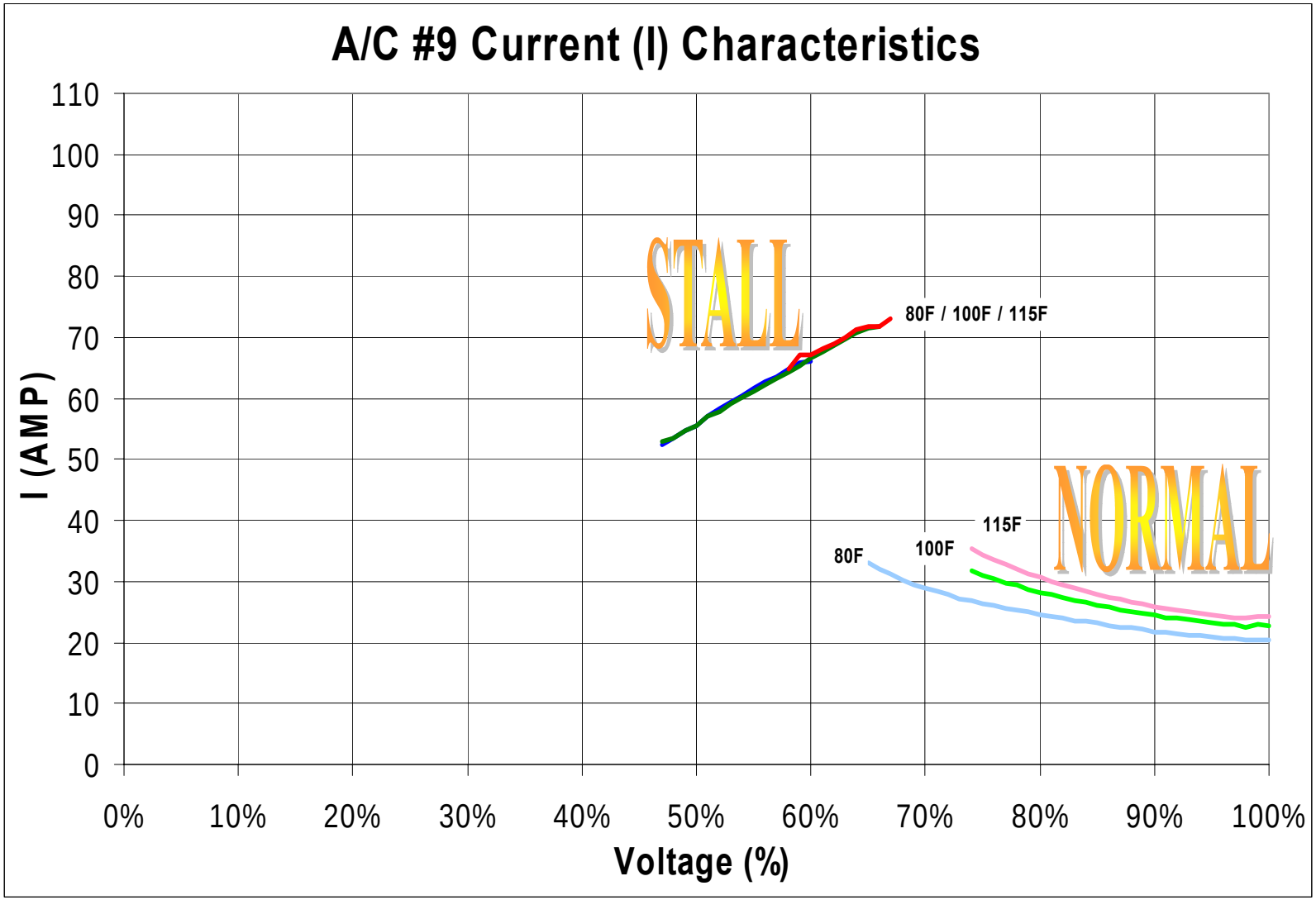
14.2.8 AIR CONDITIONER # 8 INTERNAL PERFORMANCE PARAMETERS

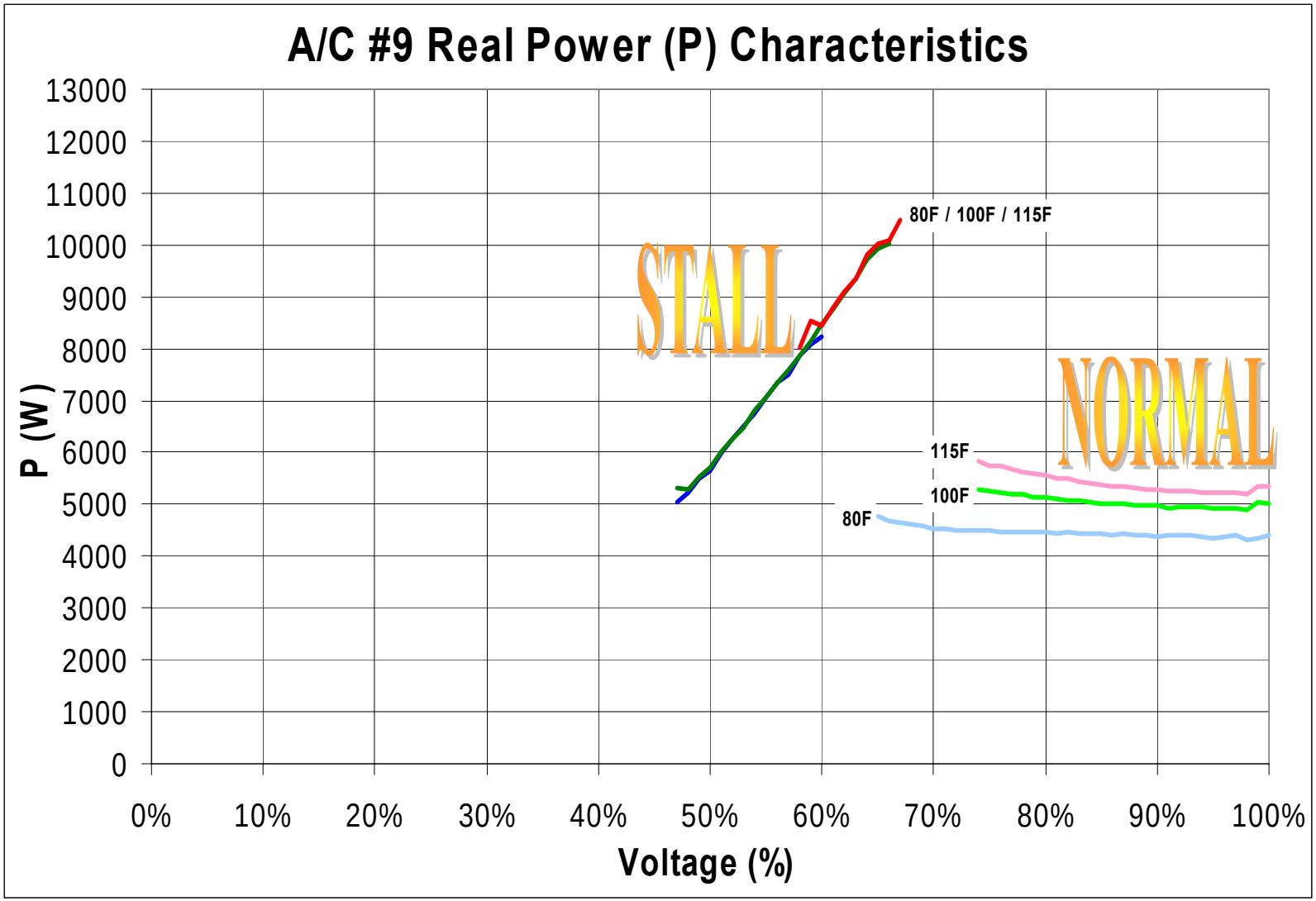


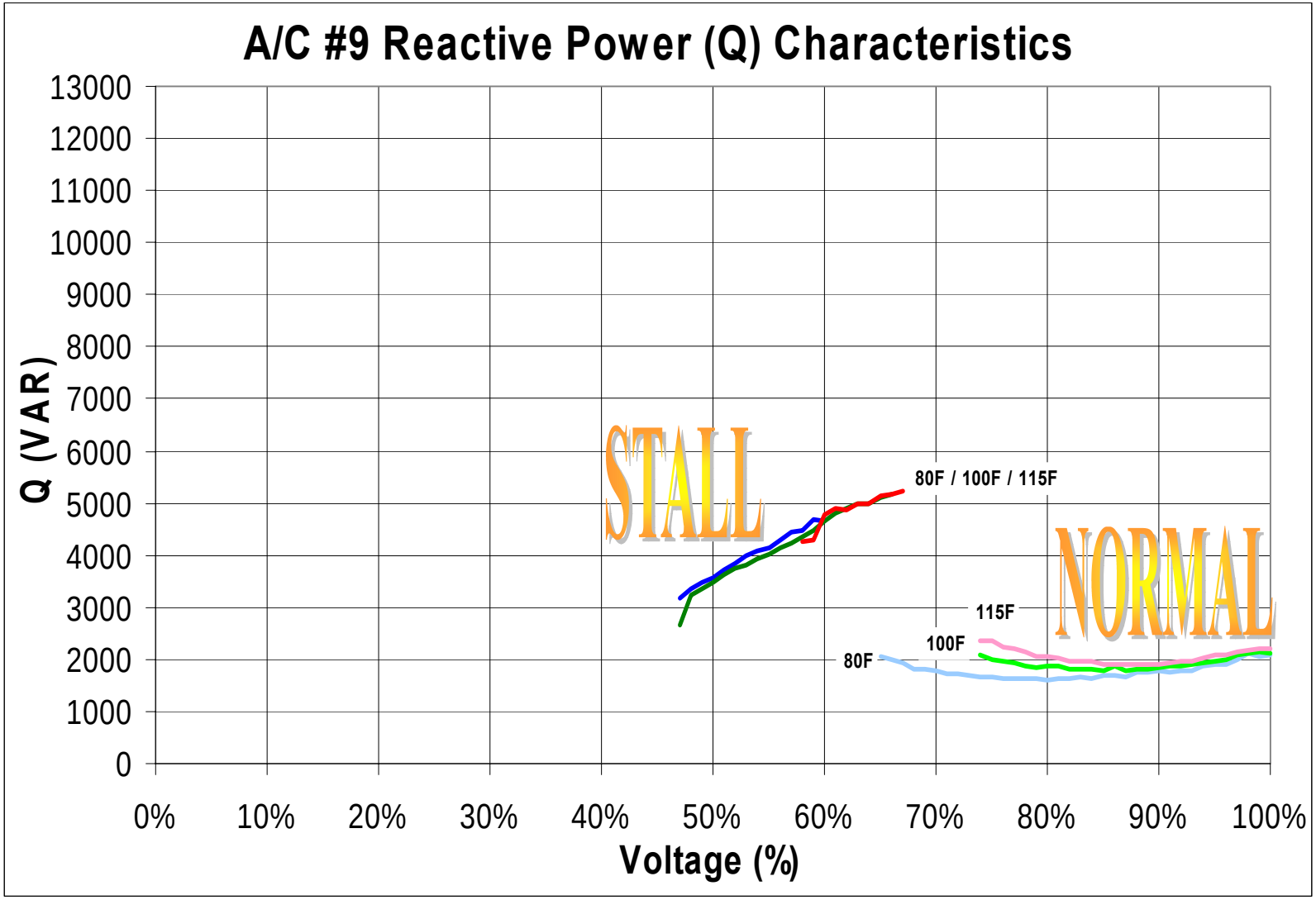

A/C #8 Real Power (P) Characteristics
P (W)
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Voltage (%)
STALL
80F / 100F / 115F
NORMAL
115F
100F
80F


A/C #8 Reactive Power (Q) Characteristics
Q (VAR)
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Voltage (%)
STALL
80F / 100F / 115F
NORMAL
100F
115F
80F

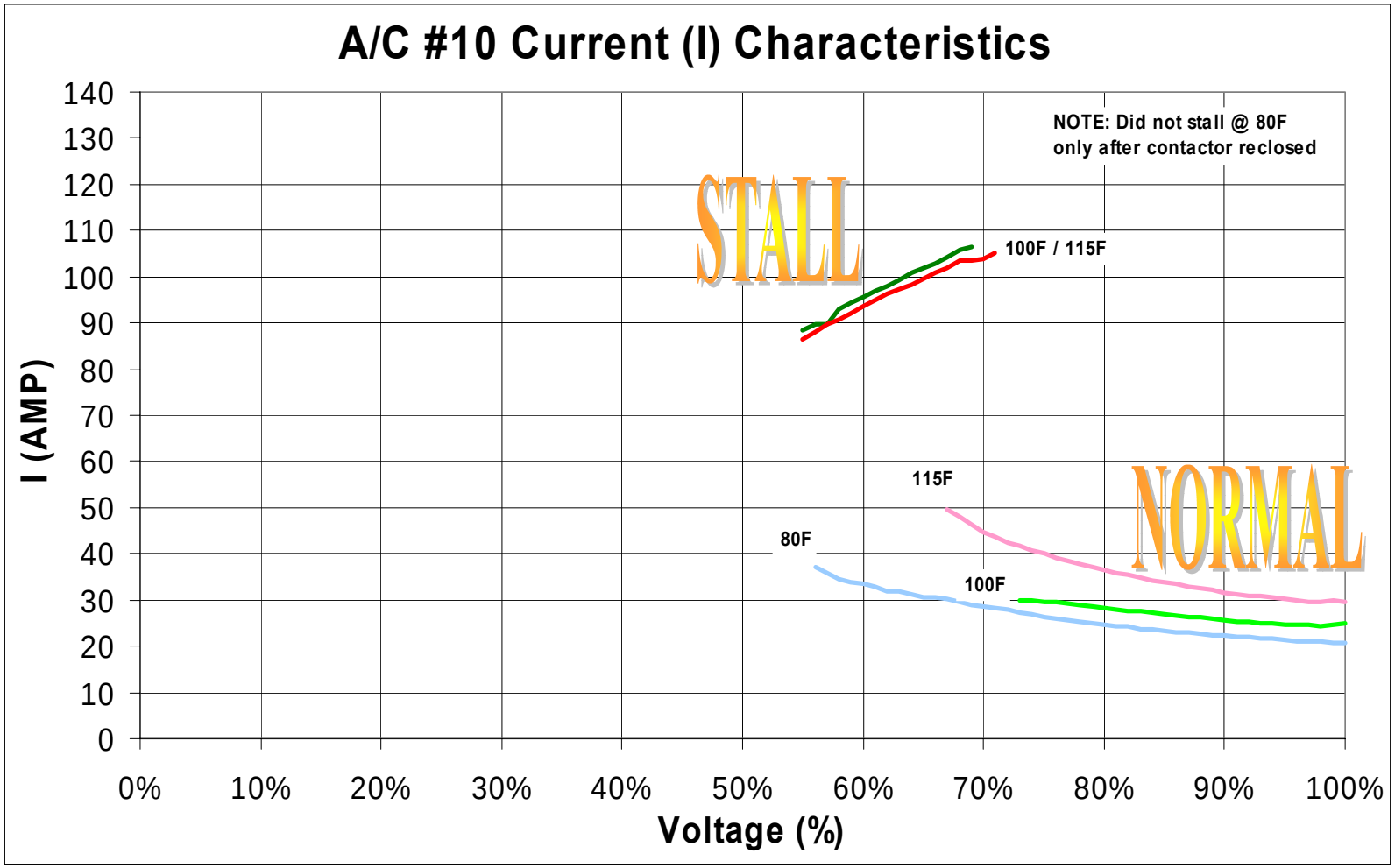
14.2.9 AIR CONDITIONER # 9 INTERNAL PERFORMANCE PARAMETERS

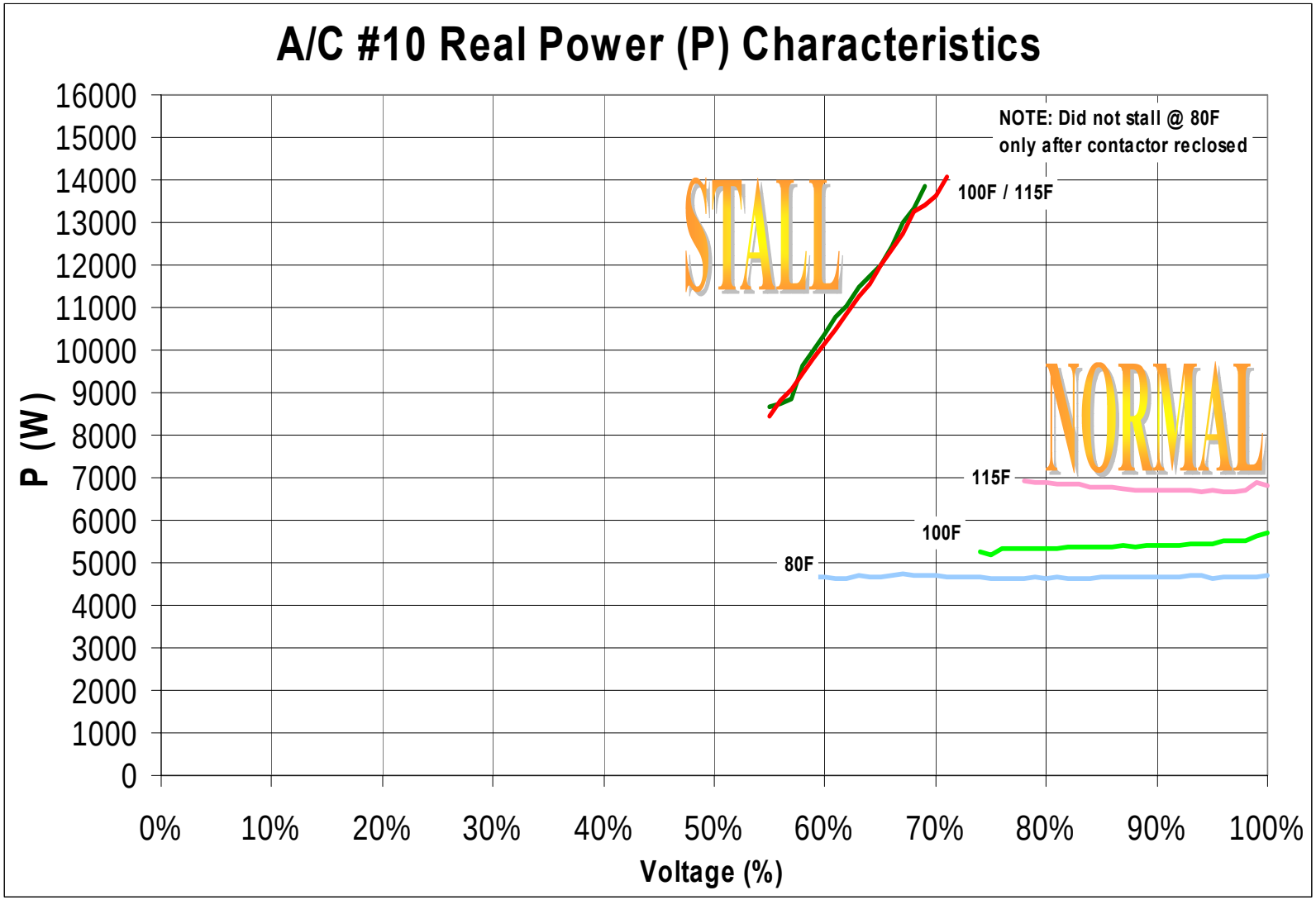


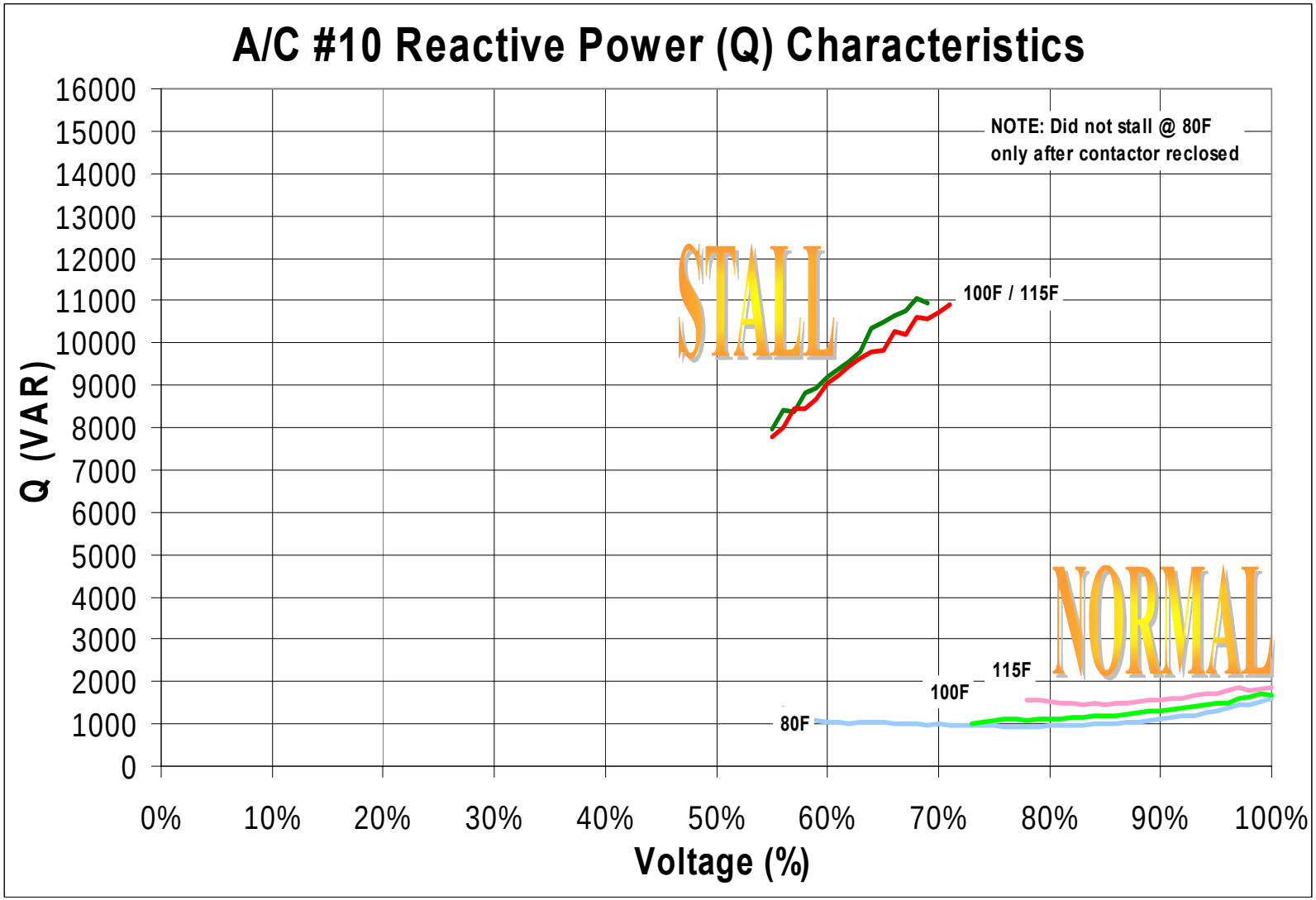

A/C #9 Real Power (P) Characteristics
P (W)
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Voltage (%)
80F / 100F / 115F
STALL
NORMAL
115F
100F
80F


A/C #9 Reactive Power (Q) Characteristics
Q (VAR)
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Voltage (%)
STALL
80F / 100F / 115F
NORMAL
115F
100F
80F

14.2.10 AIR CONDITIONER # 10 INTERNAL PERFORMANCE PARAMETERS




A/C #10 Real Power (P) Characteristics
P (W)
16000
15000
14000
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Voltage (%)
NOTE: Did not stall @ 80F
only after contactor reclosed
STALL
100F / 115F
NORMAL
115F
100F
80F


A/C #10 Reactive Power (Q) Characteristics
Q (VAR)
16000
15000
14000
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Voltage (%)
NOTE: Did not stall @ 80F
only after contactor reclosed
STALL
100F / 115F
NORMAL
115F
100F
80F

14.3 APPENDIX #3

14.3.1 INRUSH REFERENCE GRAPH