English Conversion Factors & Data

To Convert Measurements

From	To	Multiply By
Cubic Feet	Cubic Inches	1728.
Cubic Inches	Cubic Feet	0.00058
Cubic Feet	Gallons	7.480
Gallons	Cubic Feet	0.1337
Cubic Inches	Gallons	0.00433
Gallons	Cubic Inches	231.
Barrels	Gallons	42.
Gallons	Barrels	0.0238
Imperial Gallons	U.S. Gallons	1.2009
U.S. Gallons	Imperial Gallons	0.8326
Feet	Inches	12.
Inches	Feet	0.0833
Square Feet	Square Inches	144.
Square Inches	Square Feet	0.00695
Short Tons	Pounds	2000.
Liters	U.S. Gallons	0.2642

To Convert Pressure (at 32° F)

From	To	Multiply By
Inches of Water	Pounds per Sq. Inch	0.03612
Pounds per Sq. Inch	Inches of Water	27.686
Feet of Water	Pounds o Sq. Inch	0.4334
Pounds per Sq. Inch	Feet of Water	2.307
Inches of Mercury	Pounds per Sq. Inch	0.4912
Pounds per Sq. Inch	Inches of Mercury	2.036
Atmospheres	Pounds per Sq. Inch	14.696
Pounds per Sq. Inch	Atmospheres	0.06804

To Convert Power

From	To	Multiply By
Horsepower	Metric Horsepower	1.014
Horsepower	Ft./Power per Minute	33000.
Horsepower	Kilowatts	0.746
Kilowatts	Horsepower	1.3404
British Thermal Units	Foot/Pounds	778.177
Foot/Pounds	British Thermal Units	0.001285
British Thermal Units	Horsepower Hours	0.0003927
Horsepower Hours	British Thermal Units	2544.1
British Thermal Units	Kilowatt Hours	0.0002928
Kilowatt Hours	British Thermal Units	3415.
Watt Hours	British Thermal Units	3.415

Volume-Weight Conversions

	wt. lbs.
1 Cubic Foot of Water	62.4*
1 Cubic Inch of Water	0.0361*
1 Gallon of Water	8.33*
1 Cubic Foot of Air	.075+
1 Cubic Inch of Steel	0.284
1 Cubic Foot of Brick (Building)	112-120
1 Cubic Foot of Concrete	120-140
1 Cubic Foot of Earth	70-120

* at 32° F
\+ at 70° F. -29.92" Hg.

English to Metric Conversion Factors

To Convert Measurements

From	To	Multiply By
Cubic Feet	Cubic Centimeters	28317.0
Cubic Inches	Cubic Centimeters	16.387
Cubic Feet	Liters	28.32
Gallons	Liters	3.7854
Cubic Inches	Liters	0.0164
Gallons	Cubic Centimeters	3785.4
Barrels	Cubic Meters	1.0551
Imperial Gallons	Cubic Meters	0.0045461
U.S. Gallons	Cubic Meters	0.0037854
Feet	Meters	0.3048
Inches	Meters	0.0254
Square Feet	Square Meters	0.0929
Square Inches	Square Centimeters	6.452
Ton (Short, 2000 lb.)	Kilograms	907.2
Liter	Cubic Meters	0.001
Pounds	Kilograms	0.45359

To Convert Pressure (at 32° F)

From	To	Multiply By
Inches of Water	Newton/Sq. Meter	249.082
Pounds per Sq. Inch	Newton/Sq. Meter	6894.8
Feet of Water	Newton/Sq. Meter	2988.98
Pounds per Sq. Inch	Kilograms/Sq. Cent	0.07031
Inches of Mercury	Newton/Sq. Meter	3386.4
Pounds per Sq. Inch	Dyne/Sq. Cent.	68948.0
Atmospheres	Newton/Sq. Meter	101325.0
Pascal	Newton/Sq. Meter	1.0

To Convert Energy, Heat and Power

From	To	Multiply By
Horsepower	Watt	745.7
British Thermal Units	Joule	1054.35
Foot-Pounds	Joule	1.3558
British Thermal Units	Calorie	252.0
British Thermal Units	Watt-Second	1054.35
Watt-Second	Joule	1.0
Calorie	Joule	4.184
Watt-Hours	Joule	3600.0
Kilocalorie/Minute	Watt	69.73
Ton (Refrigeration)	Watt	3516.8
BTU/Hour	Watt	0.29288
BTU/In/Hr. Ft.(2) ° F	Watt/Meter K	0.14413
BTU/Hr. at 10° F TD	Kcal/Hr. at 6° C. TD	0.252
BTU/Hr. at 15° F TD	Kcal/Hr. at 8° C. TD	0.252

Volume-Weight Conversions

	Wt. Kilograms
1 Cubic Foot of Water	28.3*
1 Cubic Inch of Water	0.0164*
1 Gallon of Water	3.788
1 Cubic Foot of Air	0.034+
1 Cubic Inch of Steel	0.1288
1 Cubic Foot of Brick (Building)	51-54
1 Cubic Foot of Concrete	54-64
1 Cubic Foot of Earth	32-54

* at 32° F
\+ at 70° F. -29.92" Hg.

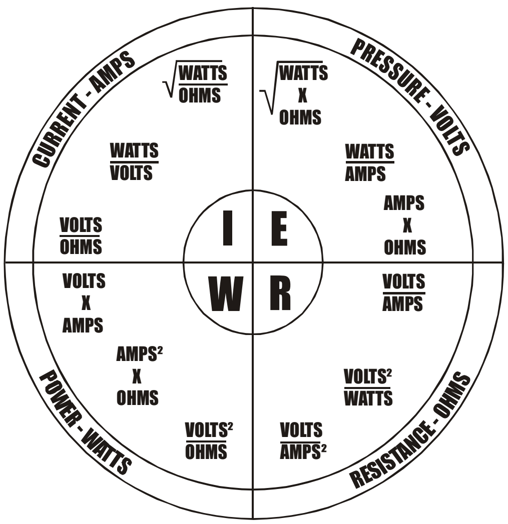
Single Phase Heating Element Conversion Chart

240 Volts	208 Volts	120 Volts
6000 Watts	4500 Watts	1500 Watts
5000 Watts	3750 Watts	1250 Watts
4000 Watts	3000 Watts	1000 Watts
3000 Watts	2250 Watts	750 Watts
2500 Watts	1875 Watts	625 Watts
2000 Watts	1500 Watts	500 Watts

Always use a higher voltage element to replace a lower voltage element
To calculate the wattage at a lower voltage see formula's below.

Convert 480V to 240V, Multiply wattage at 480V times 25%.
Convert 240V to 208V, Multiply wattage at 240V times 75%.
Convert 240V to 120V, Multiply wattage at 240V times 25%.
Convert 208V to 120V, Multiply wattage at 208V times 33%.
For use in single phase 60hz. applications only.

Ohms Law Wheel



This chart shows four ways to figure each value:

Amps (1), Volts (E), Ohms (R), or Watts (W)

Example:

A 4800 watt electric heat element is connected to a 240 volt circuit. How many Amps (1) does it draw?

Solution:

Locate Amps section of chart-

Watts (W) / Volts (E) = Amps (1)

Thus 4800 / 240 = 20 Amps. Carried further, what is the resistance?

Volts(2) (E2) / Watts (W) = Ohms (R) 240 x 240 / 4800 = 12 Ohms

Horse Power - Ampre Table

Approximate Horsepower		120 Volts Full Load	120 Volts Locked Rotor	240 Volts Full Load	240 Volts Locked Rotor
1/4	AC	4.4	26.4	2.2	13.2
	DC	—	—	—	—
1/4	AC	5.8	34.8	2.9	17.4
	DC	2.9	29.0	1.5	15.0
1/3	AC	7.2	43.2	3.6	21.6
	DC	3.6	36.0	1.8	18.0
1/2	AC	9.8	58.8	4.9	29.4
	DC	5.2	52.0	2.6	26.0
3/4	AC	13.8	82.8	6.9	41.4
	DC	7.4	74.0	3.7	37.0
1	AC	16.0	96.0	8.0	48.0
	DC	9.4	94.0	4.7	47.0
1 1/2	AC	20.0	120.0	10.0	60.0
	DC	13.2	132.0	6.6	66.0
2	AC	24.0	144.0	12.0	72.0
	DC	17.0	170.0	8.5	85.0
3	AC	34.0	204.0	17.0	102.0
	DC	25.0	250.0	12.2	122.0
5	AC	56.0	366.0	28.0	168.0
	DC	—	—	20.0	200.0
7 1/2	AC	80.0	480.0	40.0	240.0
	DC	—	—	29.0	290.0

* Locked rotor ratings shown are 6 times full load on AC and 10 time full load on DC. The above chart is offered as a guide only, as all motors do not necessarily come within the maximum ratings shown in the chart.

Thermal Units		
Latent heat of ice	= 144 BTU/lb	= 288,000 BTU/ton
1 ton refrigeration	= 12,000 BTU/hr	= 288,000/24 hours
1 British Thermal Unit (BTU)		= .252 kcal
1 kilo - calorie (kcal)		= 3.97 BTU
1 BTU/lb		= 0.555 kcal/kg
1 watt		= 1.8 BTU/lb
		= 1 kcal/kg/°C.
		= 3.413 BTU/hr
HEAT, ENERGY, WORK		
1 ft lb	= .001285 BTU	= 0.13826 kg-meter
1 joule	= 1 watt - second	= .000948 BTU
1 BTU	= 778.1 ft lb	= .252 kcal
1 KCAL	= 3.968 BTU	= 1000 cal
1 hp-hr	= .746 kw-hr	= 2544.7 BTU
1 kw-hr	= 1.341 hp-hr	= 3413 BTU
1 boiler horsepower	= 33479 BTU/hr	= Evaporation of 34.5 water/hr at 212° F.

Approximate Temperature Guide

Application	Average Temperature	Difference Between Coil and Room
Wet produce walk-in	40°	10°
Dry produce walk-in	40°	13°
Produce cases	40°	18°
Mortuary vaults - Blower coil	32° to 35°	18°
Enclosed service meat case	35°	15°
Open shelf service meat case	29°	25°
Dairy case	35° to 38°	25°
Freezer cases - General	-5° to -10°	10°
Ice cream - Holding	-15°	10°
Ice cream - Dipping		
Vanilla	8°	10°
Chocolate	6°	10°
Fruit	4°	10°
Soda fountains - Fruits and syrup	35° to 38°	10°
Air conditioning	75°	40°
Fruit boxes	50° to 55°	20°
Water chillers - Air conditioning	45°	10°
Water coolers - Drinking	38° to 50°	10°
Refrigerators	35°	20°
Biscuit cases	35°	20°
Milk coolers	40°	10°
Work rooms	35° to 50°	10° to 20°

Temperature Conversion Chart

Fahrenheit	Celsius	Fahrenheit	Celsius
500	260.0	150	65.6
475	246.1	145	62.8
450	232.2	140	60.0
425	218.3	135	57.2
400	204.4	130	54.4
390	198.8	125	51.7
380	193.3	120	48.9
370	187.8	115	46.1
360	182.2	110	43.3
350	176.7	105	40.6
340	171.1	100	37.8
330	165.6	95	35.0
320	160.0	90	32.2
310	154.4	85	29.4
300	148.9	80	26.7
290	143.3	75	23.9
280	137.8	70	21.1
270	132.2	65	18.3
260	126.7	60	15.6
250	121.1	55	12.8
245	118.3	50	10.0
240	115.6	45	7.2
235	112.8	40	4.4
230	110.0	35	1.7
225	107.2	32	0.0
220	104.4	30	-1.1
215	101.7	25	-3.9
212	100.0	20	-6.7
210	98.9	15	-9.4
205	96.1	10	-12.2
200	93.3	5	-15.0
195	90.6	0	-17.8
190	87.8	-5	-20.6
185	85.0	-10	-23.3
180	82.2	-15	-26.1
175	79.4	-20	-28.9
170	76.7	-25	-31.7
165	73.9	-30	-34.4
160	71.1	-35	-37.2
155	68.3	-40	-40.0

Conversion Factors:
Fahrenheit to Celsius: Degrees Fahrenheit minus 32 time 5/9 (0.556)
Celsius to Fahrenheit: Degrees Celsius times 9/5 (1.8) plus 32

Decimal Equivalents

Inch Fraction	Inch Decimal	Millimeters
1/16	0.0625	1.588
5/64	0.07812	1.984
3/32	0.09375	2.381
7/64	0.10937	2.778
1/8	0.1250	3.175
9/64	0.14062	3.572
5/32	0.15625	3.969
11/64	0.17817	4.366
3/16	0.1875	4.763
13/64	0.20312	5.159
7/32	0.21875	5.556
15/64	0.23437	5.953
1/4	0.2500	6.350
17/64	0.26562	6.747
9/32	0.28125	7.144
19/64	0.29867	7.541
5/16	0.3125	7.938
21/64	0.32812	8.334
11/32	0.34375	8.731
23/64	0.35937	9.128
3/8	0.3750	9.525
25/64	0.39062	9.922
13/32	0.40625	10.319
27/64	0.42187	10.716
7/16	0.4375	11.113
29/64	0.45312	11.509
15/32	0.46875	11.906
31/64	0.48437	12.303
1/2	0.5	12.700
33/64	0.51652	13.097
17/32	0.53125	13.494
35/64	0.54687	13.891
9/16	0.5625	14.288
37/64	0.57812	14.684
19/32	0.59375	15.081
39/64	0.60937	15.478
5/8	0.625	15.875
41/64	0.64062	16.272
21/32	0.65625	16.669
43/64	0.67817	17.066
11/16	0.6875	17.463
45/64	0.70312	17.859
23/32	0.71875	18.256
47/64	0.73437	18.653
3/4	0.750	19.050
49/64	0.76562	19.447
25/32	0.78125	19.884
51/64	0.79687	20.241
13/16	0.8125	20.638
53/64	0.82812	21.034
27/32	0.84375	21.431
55/64	0.85937	21.828
7/8	0.875	22.225
57/64	0.89062	22.622
29/32	0.90625	23.019
59/64	0.92187	23.416
15/16	0.9375	23.813
61/64	0.95312	24.209
31/32	0.96875	24.606
63/64	0.98437	25.003
	1.000	25.400

Refrigerant Temperature Pressure Chart

Figures = Vacuum Black Figures = Vapor (PSIG) **Bold Figures** = Liquid (PSIG)

°F	R-12	R-134a	R-401A	R-409A	R-22	R-410A	R-502	R-404A	R-507	R-402A	R-408A	R-717
-50	15.4	18.4	18.5	—	6.2	5.8	0.2	0.0	0.9	1.2	2.4	14.3
-48	14.6	17.7	17.7	—	4.8	6.9	0.7	0.8	1.7	2.1	1.0	13.1
-46	13.8	17.0	17.0	—	3.4	8.0	1.5	1.6	2.6	2.9	.3	12.1
-44	12.9	16.2	16.0	—	2.0	9.2	2.3	2.5	3.5	3.9	1.1	11.0
-42	11.9	15.4	15.0	13.7	0.5	10.4	3.2	3.4	4.5	4.9	1.9	9.9
-40	11.0	14.5	14.5	12.9	0.5	11.7	4.1	5.5	5.5	5.9	2.8	8.7
-38	10.0	13.7	13.5	12.0	1.3	13.0	5.0	6.5	6.5	6.9	3.7	7.4
-36	8.9	12.8	12.5	11.0	2.2	14.4	6.0	7.5	7.6	8.0	4.6	6.1
-34	7.8	11.8	11.5	10.0	3.0	15.9	7.0	8.6	8.7	9.2	5.6	4.7
-32	6.7	10.8	10.6	9.0	4.0	17.3	8.1	9.7	9.9	10.3	6.6	3.2
-30	5.5	9.7	9.0	7.9	4.9	18.9	9.2	10.8	11.1	11.6	7.6	1.6
-28	4.3	8.6	8.3	6.8	5.9	20.5	10.3	12.0	12.4	12.8	8.7	0.0
-26	3.0	7.7	7.0	5.6	6.9	22.2	11.5	13.2	13.7	14.1	9.8	0.6
-24	1.6	6.2	6.0	4.4	7.9	23.9	12.7	14.5	15.0	15.5	11.0	1.7
-22	0.3	4.9	4.5	3.2	9.0	25.7	14.0	15.8	16.4	16.9	12.2	2.6
-20	0.6	3.6	3.5	1.9	10.1	27.5	15.3	17.1	17.8	18.4	13.5	3.6
-18	1.3	2.3	2.0	.5	11.3	29.4	16.7	18.5	19.3	19.9	14.7	4.6
-16	2.1	0.8	0.5	.5	12.5	31.4	18.1	20.0	20.9	21.5	16.1	5.6
-14	2.8	0.3	0.4	1.2	13.8	33.5	19.5	21.5	22.5	23.1	17.5	6.7
-12	3.7	1.1	1.4	2.0	15.1	35.6	21.0	23.0	24.1	24.8	18.9	7.9
-10	4.5	1.9	2.2	2.8	16.5	37.8	22.6	24.6	25.8	26.5	20.4	9.0
-8	5.4	2.8	3.1	3.6	17.9	40.0	24.2	26.3	27.6	28.3	22.0	10.3
-6	6.3	3.6	3.9	4.4	19.3	42.4	25.8	28.0	29.4	30.2	23.6	11.6
-4	7.2	4.5	4.8	5.3	20.8	44.8	27.5	29.8	31.3	32.1	25.2	12.9
-2	8.2	5.5	5.7	6.2	22.4	47.3	29.3	31.6	33.2	34.1	26.9	14.3
0	9.2	6.5	6.7	7.2	24.0	49.8	31.1	33.5	35.2	36.1	28.7	15.7
2	10.2	7.5	8.0	8.2	25.6	52.5	32.9	34.8	37.3	38.1	30.5	17.2
4	11.2	8.5	8.8	9.2	27.3	55.2	34.9	37.4	39.4	40.4	32.3	18.8
6	12.3	9.6	9.9	10.2	29.1	58.0	36.9	39.4	41.6	42.6	34.3	20.4
8	13.5	10.8	11.0	11.3	30.9	60.9	38.9	41.6	43.8	44.9	36.3	22.1
10	14.6	12.0	12.2	12.5	32.8	63.9	41.0	43.7	46.2	47.3	38.3	23.8
12	15.8	13.1	13.4	13.6	34.7	67.0	43.2	46.0	48.5	49.7	40.4	25.6
14	17.1	14.4	14.6	14.8	36.7	70.2	45.4	48.3	51.0	52.5	42.6	27.5
16	18.4	15.7	15.9	16.1	38.7	73.4	47.7	50.7	53.5	54.8	44.9	29.4
18	19.7	17.0	17.2	17.4	40.9	76.8	50.0	53.1	56.1	57.5	47.2	31.4
20	21.0	18.4	18.6	18.7	43.0	80.2	52.5	55.6	58.8	60.2	49.5	33.5
22	22.4	19.9	20.0	20.0	45.3	83.8	54.9	58.2	61.5	63.0	52.0	35.7
24	23.9	21.4	21.5	21.5	47.6	87.4	57.5	60.9	64.3	65.9	54.5	37.9
26	25.4	22.9	23.0	22.9	49.9	91.2	60.1	63.6	67.2	68.9	57.1	40.2
28	26.9	24.5	24.6	24.4	52.4	95.1	62.8	66.5	70.2	72.0	59.8	42.6
30	28.5	26.1	26.2	26.0	54.9	99.0	65.6	69.4	73.3	75.1	62.5	45.0
32	30.1	27.8	27.9	27.6	57.5	103.1	68.4	72.3	76.4	78.3	65.3	47.6
34	31.7	29.5	29.6	29.2	60.1	107.3	71.3	75.4	79.6	81.6	68.2	50.2
36	33.4	31.3	31.3	30.9	62.8	111.6	74.3	78.5	82.9	85.0	71.2	52.9
38	35.2	33.2	33.2	32.7	65.6	116.0	77.4	81.8	86.3	88.5	74.2	55.7
40	36.9	35.1	35.0	34.5	68.5	120.5	80.5	85.1	89.8	92.1	77.4	58.6
42	38.8	37.0	37.0	36.3	71.5	125.1	83.8	88.5	93.4	95.7	80.6	61.6
44	40.7	39.1	39.0	38.2	74.5	129.9	87.0	91.9	97.0	99.5	83.9	64.5
46	42.7	41.1	41.0	40.2	77.6	134.8	90.4	95.5	100.8	103.4	87.3	67.9
48	44.7	43.3	43.1	42.2	80.7	139.8	93.9	99.2	104.6	107.3	90.7	70.9
50	46.7	45.5	45.3	44.3	84.0	144.9	97.4	102.9	108.6	111.4	94.3	74.5
52	48.8	47.7	**60.0**	**63.6**	87.3	150.2	101.0	**109.0**	112.6	**120.0**	**99.4**	77.7
54	51.0	50.1	**62.0**	**66.2**	90.8	155.6	104.8	**113.0**	116.7	**124.0**	**103.0**	81.5
56	53.2	52.3	**65.0**	**68.9**	94.3	161.1	108.6	**117.0**	121.0	**129.0**	**107.1**	85.0
58	55.4	55.0	**68.0**	**71.6**	97.9	166.7	112.4	**121.0**	125.3	**133.0**	**111.0**	89.0
60	57.7	57.5	**70.0**	**74.5**	101.6	172.5	116.4	**125.0**	129.7	**138.0**	**113.5**	92.9
62	60.1	60.1	**73.0**	**77.3**	105.4	178.5	120.4	**130.0**	134.3	**142.0**	**119.2**	96.9
64	62.5	62.7	**76.0**	**80.3**	109.3	184.5	124.6	**134.0**	139.0	**147.0**	**123.5**	100.7
66	65.0	65.5	**79.0**	**83.3**	113.2	190.7	128.8	**139.0**	143.7	**152.0**	**127.0**	105.3
68	67.6	68.3	**82.0**	**86.4**	117.3	197.1	133.2	**144.0**	148.6	**157.0**	**132.0**	109.3
70	70.2	71.2	**85.0**	**89.5**	121.4	203.6	137.6	**148.0**	153.6	**160.4**	**135.1**	114.1
72	72.9	74.2	**89.0**	**92.8**	125.7	210.3	142.2	**153.0**	158.7	**168.0**	**141.5**	118.7
74	75.6	77.2	**92.0**	**96.0**	130.0	217.1	146.8	**158.0**	163.9	**173.0**	**146.2**	123.4
76	78.4	80.3	**95.0**	**99.4**	134.5	224.0	151.5	**164.0**	169.3	**179.0**	**151.0**	128.3
78	81.3	83.5	**99.0**	**102.9**	139.0	231.1	156.3	**169.0**	174.7	**184.0**	**156.0**	133.2
80	84.2	86.8	**102.0**	**106.4**	143.6	238.4	161.2	**174.0**	180.3	**190.0**	**159.4**	138.3
82	87.2	90.2	**106.0**	**110.0**	148.4	245.9	166.2	**180.0**	186.0	**193.6**	**166.4**	143.6
84	90.2	93.6	**109.0**	**113.7**	153.2	253.5	171.4	**185.0**	191.9	**202.0**	**171.0**	149.0
86	93.3	97.1	**113.0**	**117.4**	158.2	261.2	176.6	**191.0**	197.8	**208.0**	**177.0**	154.5
88	96.5	100.7	**117.0**	**121.2**	163.2	269.2	181.9	**197.0**	203.9	**214.0**	**182.0**	160.1
90	99.8	104.4	**121.0**	**125.1**	168.4	277.3	187.4	**203.0**	210.2	**220.0**	**186.4**	165.9
92	103.1	108.2	**125.0**	**129.1**	173.7	285.5	192.9	**209.9**	216.6	**227.0**	**194.2**	171.9
94	106.5	112.1	**129.0**	**133.2**	179.1	294.0	198.6	**215.0**	223.1	**234.0**	**200.1**	178.0
96	110.0	116.1	**133.0**	**137.4**	184.6	302.6	204.3	**222.0**	229.8	**240.0**	**206.2**	184.2
98	113.5	120.1	**138.0**	**141.6**	190.2	311.4	210.2	**229.0**	236.6	**247.0**	**212.3**	190.6
100	117.2	124.3	**142.0**	**146.0**	195.9	320.4	216.2	**235.0**	243.5	**254.0**	**216.6**	197.2
102	120.9	128.5	**146.0**	**150.4**	201.8	329.6	222.3	**242.0**	250.6	**261.0**	**225.1**	203.4
104	124.7	132.9	**151.0**	**154.9**	207.7	339.0	228.5	**249.0**	257.9	**269.0**	**231.6**	210.2
106	128.5	137.3	**156.0**	**159.5**	213.8	348.5	234.9	**256.0**	265.3	**276.0**	**238.3**	217.3
108	132.4	142.8	**160.0**	**164.2**	220.0	358.3	241.3	**264.0**	272.9	**284.0**	**245.2**	224.4
110	136.4	146.5	**165.0**	**169.0**	226.4	368.2	247.9	**271.0**	280.6	**292.0**	**250.0**	232.3
112	140.5	151.3	**170.0**	**173.9**	232.8	.78.3	254.6	**279.0**	288.6	**299.0**	**259.2**	239.3
114	144.7	156.1	**175.0**	**178.8**	239.4	388.7	261.5	**286.0**	296.6	**307.0**	**266.0**	247.0
116	148.9	161.1	**180.0**	**183.9**	246.1	399.2	268.4	**294.0**	304.9	**316.0**	**273.0**	254.8
118	153.2	166.1	**185.0**	**189.1**	252.9	410.0	275.5	**302.0**	313.3	**324.0**	**281.0**	262.9
120	157.7	171.3	**191.0**	**194.3**	259.9	420.9	282.7	**311.0**	321.9	**332.0**	**286.8**	271.7
122	162.2	176.6	**196.0**	**199.7**	267.0	432.1	290.1	**319.0**	330.7	**341.0**	**296.9**	279.5
124	166.7	182.0	**202.0**	**205.2**	274.3	443.5	297.6	**328.0**	339.7	**350.0**	**304.9**	288.0
126	171.4	187.5	**207.0**	**210.8**	281.6	455.1	305.2	**336.0**	348.9	**359.0**	**313.0**	296.8
128	176.2	193.1	**213.0**	**216.5**	289.1	466.9	231.9	**345.0**	358.2	**368.0**	**321.3**	305.7
130	181.0	198.9	**219.0**	**222.3**	296.8	478.9	320.8	**354.0**	367.8	**377.0**	**327.4**	315.0
132	185.9	204.7	**225.0**	**228.2**	304.6	491.2	328.9	**364.0**	377.6	**387.0**	**338.3**	324.2
134	191.0	210.7	**231.0**	**234.2**	312.5	503.7	337.1	**373.0**	387.5	**394.6**	**347.1**	333.7
136	196.1	216.8	**237.0**	**240.8**	320.6	516.4	345.4	**383.0**	397.7	**406.0**	**356.0**	343.5
138	201.3	223.0	**243.0**	**246.5**	328.9	529.4	353.9	**392.0**	408.1	**416.0**	**365.0**	353.4
140	206.6	229.4	**250.0**	**252.9**	337.3	542.5	362.6	**402.0**	418.7	**426.0**	**371.9**	365.0
142	212.0	235.8	**256.0**	**259.3**	345.8	556.0	371.4	**413.0**	429.6	**436.0**	**383.7**	373.9
144	217.5	242.4	**263.0**	**265.9**	354.5	569.6	380.4	**423.0**	440.6	**447.0**	**393.3**	384.4
146	223.1	249.2	**269.0**	**272.6**	363.3	583.6	389.5	**434.0**	451.9	**458.0**	**403.0**	395.2
148	228.8	256.0	**277.0**	**279.6**	372.3	597.7	398.9	**444.0**	462.0	**468.0**	**412.9**	406.2
150	234.6	263.0	**283.0**	**286.4**	381.5	612.1	408.4	**449.0**	475.3	**479.0**	**423.0**	420.0

Refrigerant Temperature Pressure Chart

▭ = Vacuum Black Figures = Saturated Vapor (PSIG) **Bold Figures** = Saturated Liquid (PSIG)

°C	°F	R-12	R-134A	R-401A	R-22	R-410A	R-502	R-404A	R-507
-46	-50	15.4	18.4	18.5	6.2	5.8	0.2	0.0	0.9
-44	-48	14.6	17.7	17.7	4.8	6.9	0.7	0.8	1.7
-43	-46	13.8	17.0	17.0	3.4	8.0	1.5	1.6	2.6
-42	-44	12.9	16.2	16.0	2.0	9.2	2.3	2.5	3.5
-41	-42	11.9	15.4	15.0	0.5	10.4	3.2	3.4	4.5
-40	-40	11.0	14.5	14.5	0.5	11.7	4.1	5.5	5.5
-39	-38	10.0	13.7	13.5	1.3	13.0	5.0	6.5	6.5
-38	-36	8.9	12.8	12.5	2.2	14.4	6.0	7.5	7.6
-37	-34	7.8	11.8	11.5	3.0	15.9	7.0	8.6	8.7
-36	-32	6.7	10.8	10.6	4.0	17.3	8.1	9.7	9.9
-34	-30	5.5	9.7	9.0	4.9	18.9	9.2	10.8	11.1
-33	-28	4.3	8.6	8.3	5.9	20.5	10.3	12.0	12.4
-32	-26	3.0	7.7	7.0	6.9	22.2	11.5	13.2	13.7
-31	-24	1.6	6.2	6.0	7.9	23.9	12.7	14.5	15.0
-30	-22	0.3	4.9	4.5	9.0	25.7	14.0	15.8	16.4
-29	-20	0.6	3.6	3.5	10.1	27.5	15.3	17.1	17.8
-28	-18	1.3	2.3	2.0	11.3	29.4	16.7	18.5	19.3
-27	-16	2.1	0.8	0.5	12.5	31.4	18.1	20.0	20.9
-26	-14	2.8	0.3	0.4	13.8	33.5	19.5	21.5	22.5
-24	-12	3.7	1.1	1.4	15.1	35.6	21.0	23.0	24.1
-23	-10	4.5	1.9	2.2	16.5	37.8	22.6	24.6	25.8
-22	-8	5.4	2.8	3.1	17.9	40.0	24.2	26.3	27.6
-21	-6	6.3	3.6	3.9	19.3	42.4	25.8	28.0	29.4
-20	-4	7.2	4.5	4.8	20.8	44.8	27.5	29.8	31.3
-19	-2	8.2	5.5	5.7	22.4	47.3	29.3	31.6	33.2
-18	0	9.2	6.5	6.7	24.0	49.8	31.1	33.5	35.2
-17	2	10.2	7.5	8.0	25.6	52.5	32.9	34.8	37.3
-16	4	11.2	8.5	8.8	27.3	55.2	34.9	37.4	39.4
-14	6	12.3	9.6	9.9	29.1	58.0	36.9	39.4	41.6
-13	8	13.5	10.8	11.0	30.9	60.9	38.9	41.6	43.8
-12	10	14.6	12.0	12.2	32.8	63.9	41.0	43.7	46.2
-11	12	15.8	13.1	13.4	34.7	67.0	43.2	46.0	48.5
-10	14	17.1	14.4	14.6	36.7	70.2	45.4	48.3	51.0
-9	16	18.4	15.7	15.9	38.7	73.4	47.7	50.7	53.5
-8	18	19.7	17.0	17.2	40.9	76.8	50.0	53.1	56.1
-7	20	21.0	18.4	18.6	43.0	80.2	52.5	55.6	58.8
-6	22	22.4	19.9	20.0	45.3	83.8	54.9	58.2	61.5
-4	24	23.9	21.4	21.5	47.6	87.4	57.5	60.9	64.3
-3	26	25.4	22.9	23.0	49.9	91.2	60.1	63.6	67.2
-2	28	26.9	24.5	24.6	52.4	95.1	62.8	66.5	70.2
-1	30	28.5	26.1	26.2	54.9	99.0	65.6	69.4	73.3
0	32	30.1	27.8	27.9	57.5	103.1	68.4	72.3	76.4
1	34	31.7	29.5	29.6	60.1	107.3	713	75.4	79.6
2	36	33.4	31.3	31.3	62.8	11.6	74.3	78.5	82.9
3	38	35.2	33.2	33.2	65.6	116.0	77.4	81.8	86.3
4	40	36.9	35.1	35.0	68.5	120.5	80.5	85.1	89.8
6	42	38.8	37.0	37.0	71.5	125.1	83.8	88.5	93.4
7	44	40.7	39.1	39.0	74.5	129.9	87.0	91.9	97.0
8	46	42.7	41.1	41.0	77.6	134.8	90.4	95.5	100.8
9	48	44.7	43.3	43.1	80.7	139.8	93.9	99.2	104.6
10	50	46.7	45.5	45.3	84.0	144.9	97.4	102.8	108.6
11	52	48.8	47.7	**60.0**	87.3	150.2	101.0	**109.0**	112.6
12	54	51.0	50.1	**62.0**	90.8	155.6	104.8	**113.0**	116.7
13	56	53.2	52.3	**65.0**	94.3	161.1	108.6	**117.0**	121.0
14	58	55.4	55.0	**68.0**	97.9	166.7	112.4	**121.0**	125.3
16	60	57.7	57.5	**70.0**	101.6	172.5	116.4	**125.0**	129.7
17	62	60.1	60.1	**73.0**	105.4	178.5	120.4	**130.0**	134.3
18	64	62.5	62.7	**76.0**	109.3	184.5	124.6	**134.0**	139.0
19	66	65.0	65.5	**79.0**	113.2	190.7	128.8	**139.0**	143.7
20	68	67.6	68.3	**82.0**	117.3	197.1	133.2	**144.0**	148.6
21	70	70.2	71.2	**85.0**	121.4	203.6	137.6	**148.0**	153.6
22	72	72.9	74.2	**89.0**	125.7	210.3	142.2	**153.0**	158.7
23	74	75.6	77.2	**92.0**	130.0	217.1	146.8	**158.0**	163.9
24	76	78.4	80.3	**95.0**	134.5	224.0	151.5	**164.0**	169.3
26	78	81.3	83.5	**99.0**	139.0	231.1	156.3	**169.0**	174.7
27	80	84.2	86.8	**102.0**	143.6	238.4	161.2	**174.0**	180.3
28	82	87.2	90.2	**106.0**	148.4	245.9	166.2	**180.0**	186.0
29	84	90.2	93.6	**109.0**	153.2	253.5	171.4	**185.0**	191.9
30	86	93.3	97.1	**113.0**	158.2	261.2	176.6	**191.0**	197.8
31	88	96.5	100.7	**117.0**	163.2	269.2	181.9	**197.0**	203.9
32	90	99.8	104.4	**121.0**	168.4	277.3	187.4	**203.0**	210.2
33	92	103.1	108.2	**125.0**	173.7	285.5	192.9	**209.9**	216.6
34	94	106.5	112.1	**129.0**	179.1	294.0	198.6	**215.0**	223.1
36	96	110.0	116.1	**133.0**	184.6	302.6	204.3	**222.0**	229.8
37	98	113.5	120.1	**138.0**	190.2	311.4	210.2	**229.0**	236.6
38	100	117.2	124.3	**142.0**	195.9	320.4	216.2	**235.0**	243.5
39	102	120.9	128.5	**146.0**	201.8	329.6	222.3	**242.0**	250.6
40	104	124.7	132.9	**151.0**	207.7	339.0	228.5	**249.0**	257.9
41	106	128.5	137.3	**156.0**	213.8	348.5	234.9	**256.0**	265.3
42	108	132.4	142.8	**160.0**	220.0	358.3	241.3	**264.0**	272.9
43	110	136.4	146.5	**165.0**	226.4	368.2	247.9	**271.0**	280.6
44	112	140.5	151.3	**170.0**	232.8	378.3	254.6	**279.0**	288.6
46	114	144.7	156.1	**175.0**	239.4	388.7	261.5	**286.0**	296.6
47	116	148.9	161.1	**180.0**	246.1	399.2	268.4	**294.0**	304.9
48	118	153.2	166.1	**185.0**	252.9	410.0	275.5	**302.0**	313.3
49	120	157.7	171.3	**191.0**	259.9	420.9	282.7	**311.0**	321.9
50	122	162.2	176.6	**196.0**	267.0	432.1	290.1	**319.0**	330.7
51	124	166.7	182.0	**202.0**	274.3	443.5	297.6	**328.0**	339.7
52	126	171.4	187.5	**207.0**	281.6	455.1	305.2	**336.0**	348.9
53	128	176.2	193.1	**213.0**	289.1	466.9	312.9	**345.0**	358.2
54	130	181.0	198.9	**219.0**	296.8	478.9	320.8	**354.0**	367.8
56	132	185.9	204.7	**225.0**	304.6	491.2	328.9	**364.0**	377.6
57	134	191.0	210.7	**231.0**	312.5	503.7	337.1	**373.0**	387.5
58	136	196.1	216.8	**237.0**	320.6	516.4	345.4	**383.0**	397.7
59	138	201.3	223.0	**243.0**	328.9	529.4	353.9	**392.0**	408.1
60	140	206.6	229.4	**250.0**	337.3	542.5	362.6	**402.0**	418.7
61	142	212.0	235.8	**256.0**	345.8	556.0	371.4	**413.0**	429.6
62	144	217.5	242.4	**263.0**	354.5	569.6	380.4	**423.0**	440.6
63	146	223.1	249.2	**269.0**	363.3	583.6	389.5	**434.0**	451.9
64	148	228.8	256.0	**277.0**	372.3	597.7	398.9	**444.0**	462.0
66	150	234.6	263.0	**283.0**	381.5	612.1	408.4	**449.0**	475.3

The E Class Advantage

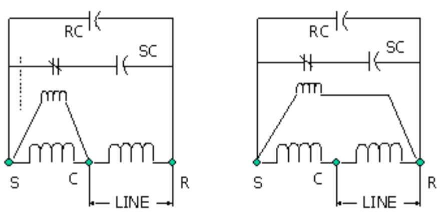
Are Compressor Hard Start Devices Needed?

Compressor hard start devices are a luxury item for service technicians to use in rectifying a myriad of compressor start problems. It is true that the majority of hard start device applications result from the marginal voltages delivered by electric utilities during peak demand periods. As the predominant application is air conditioning, the hard start device can serve as an insurance policy for compressor starts when voltages drop to 90% of rated line conditions. The ability to ensure a compressor start under low voltage conditions can serve to minimize the number of “nuisance” service calls and allow a service contractor to focus on true problem events.

As the air conditioning industry has expanded and diversified, numerous types and models of air conditioning units and compressors have entered the marketplace. This diverse proliferation has resulted in the need to provide a one-size-fits-all compressor start device. Investigations recently undertaken by SUPCO indicate that a start device should be closely matched to the compressor, and a one size for all approach may actually cause damage to a compressor if applied incorrectly. All SUPCO technology employs the appropriate safeguards to ensure against compressor damage due to misapplied start devices. This situation does not exist for most other start device manufacturers.

General Function

It is pertinent to discuss the general application and function of a hard start device. A capacitor in conjunction with a switching device (typically a relay) is introduced across the start windings of a single-phase compressor. Figure 1. illustrates the typical wiring arrangement for a 2-wire and a 3-wire connection.



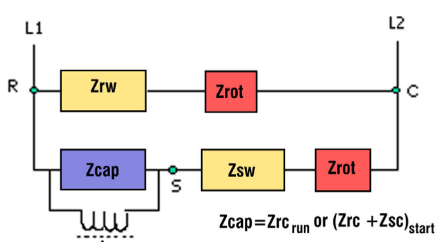
3 Wire Connection 2 Wire Connection

Figure 1. Wiring Configurations

When the compressor is called upon to start, the start capacitor provides a voltage boost to the start winding of the motor (effectively simulating the phasor lead/lag of a three-phase motor) and causes the motor rotor to turn. At some point, when the capacitor is released from the start winding, the motor continues to run.

In a 3 wire configuration, the potential relay opens at a manufacturer’s specified voltage across the start winding of the motor, effectively removing the start capacitor from the circuit. A third wire is necessary to connect to the run winding. In a 2 wire configuration, the potential relay and start capacitor are connected across the run and start winding. The potential relay opens at a specified increment above line voltage, thus removing the start capacitor from the circuit. There is no need for a third wire.

The size of the capacitor significantly impacts the characteristics of the start winding. Figure 2. shows the generalized impedances for the compressor motor and start devices. As such, the start capacitor should be carefully matched to the specific compressor.



$Zcap = Zrc_{run}$ or $(Zrc + Zsc)_{start}$

Figure 2.
2 Wire Potential Relay Equivalent Circuit

Hard Start Technology

Two main types of start devices exist in the marketplace today. SUPCO has developed a full range of products in both types to provide a customer with all applicable choices. Both types have their own desirable applications and each have specific advantages. The two types of start devices discussed below are

1. PTC – Positive Temperature Coefficient devices
2. Potential Relay devices – voltage sensing and current sensing

PTC Devices

The PTC device has been successfully employed in a number of applications for many years. SUPCO models SPP, SPP5, SPP6, SPP7S employ PTC technology to ensure that the start capacitor has dropped from the start circuit after an appropriate amount of time has elapsed. This device utilizes a ceramic element with a predictable thermal response to the introduction of electric current. As current is introduced across the start windings, the PTC element begins to warm. When the PTC device reaches approximately 250º F (corresponding to 0.6-0.8 seconds), the resistance in the element increases and creates an open switch that releases the start winding from the circuit. The 0.6-0.8 seconds that the PTC device allows the start windings to be engaged is generally enough time to enable the compressor to start. The advantage of this device is its simplicity. A two-wire connection between the run and start terminals on the compressor is all that is required to provide reliable starts in most cases.

However, this device has several limitations that should be considered if the application is critical.

- The PTC device has no ability to sense whether the compressor has actually started.
- The amount of time provided for a start boost is dictated solely by the temperature of the ceramic device, which has warmed due to the introduction of the starting current.
- If the compressor does not start before the temperature threshold has been reached, it will not start until the PTC device cycles through a cool-down period (usually 2 - 3 minutes). Many view this start approach as an appropriate safety measure. The PTC effectively limits the continued unsuccessful cycling of the start windings that can often result in a motor burnout. Others will argue that a start device should be able to re-cycle immediately. If this feature is desired, a PTC is not the correct start device application.

Potential Relay Devices

The Potential Relay start device has recently been the subject of considerable attention in the market place. Several manufacturers are promoting products with a variety of technologies. The primary distinction between the potential relay devices relates to a voltage sensing or current sensing capability.

The voltage sensing method monitors start winding developed voltage and actuates a mechanical or electronic potential relay to disengage the start capacitor. The electronic potential relay is inherently more reliable and precise than the older type mechanical potential relay. SUPCO employs voltage sensing technology with an electronic potential relay.

The current sensing approach senses current through the run winding and drops the start capacitor out of the circuit based upon a threshold value. Both methods have proven effective in providing devices that are able to “sense” when a compressor has started and thus providing more reliable compressor starts in marginal conditions. However, the current sensing method must employ an internal fuse to protect the motor from potential damage and is more difficult to connect than the 2-wire voltage sensing approach.

Capacitor Size

The proliferation of potential relay type devices has resulted in the notion that one capacitor can be employed to start all compressors. That is, use the biggest capacitor and give the compressor a “big kick” to get it started. The sensing characteristic will drop the capacitor out of the start circuit when necessary and thus the compressor will not be harmed. This idea, however, is flawed. The use of a capacitor that is too large for the impedance characteristics of the windings in some compressors can actually result in significant compressor damage. Recent investigations indicate that this situation is particularly evident in voltage sensing devices.

Figure 3. shows a successful compressor start. The run-start and start-common voltages increase to a maximum value and the total supply current drops to operating conditions when the start device is dropped from the circuit. While Figure 4. shows an unsuccessful (locked rotor) compressor start. In this figure, the run-start voltage never increases to a point indicating a motor start. The total supply current remains at a maximum and the motor never starts.

Figure 3. Good Start

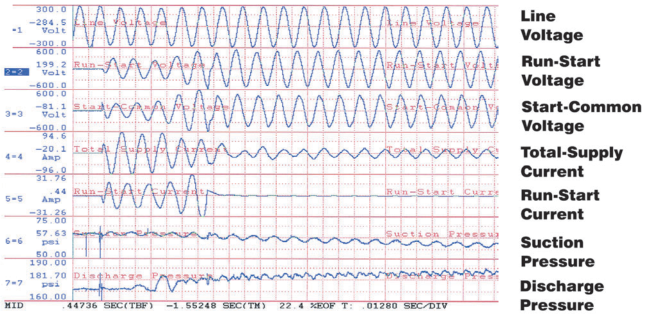
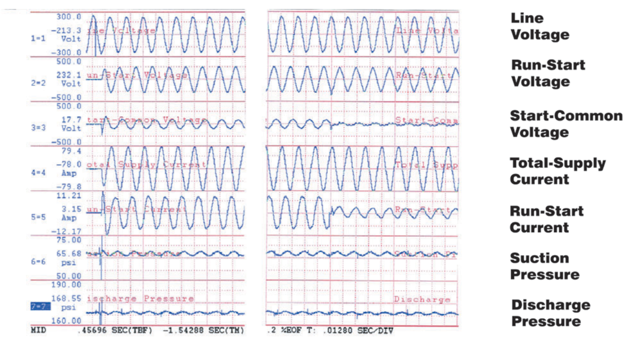
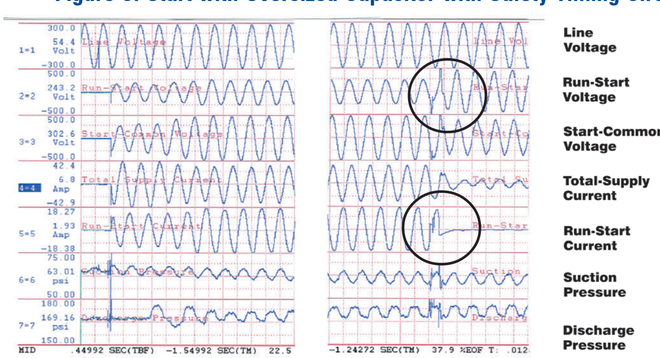


Figure 4. No Start



If the start capacitor is too large for the application, the capacitor can actually mask the developed voltage in the start windings and keep the start capacitor in the circuit continuously. Figure 5. illustrates a compressor start with a capacitor that is too large. The motor is actually running, but the run-start voltage is suppressed below the trigger voltage of the start device. As a result, the start capacitor remains in the circuit as the motor runs. A secondary, fail-safe method is necessary to ensure that the start device is ultimately removed from the circuit. This event can be seen at the end of the time duration of the run-start current highlighted in Figure 5.

Figure 5. Start with Oversized Capacitor with Safety Timing Circuit



A start device that fails to remove the start capacitor from the circuit has the potential to cause premature failure of the start windings in the compressor.

Figure 6 shows the same compressor start using and oversized capacitor without a safety timing circuit. The run – start voltage is suppressed by the combined characteristics of the motor windings and the extra large capacitor. It never reaches the prescribed threshold voltage defined by the potential relay for removing the start capacitor from the circuit. The total supply current remains near the locked rotor value even after the motor has started (as highlighted in Figure 6).

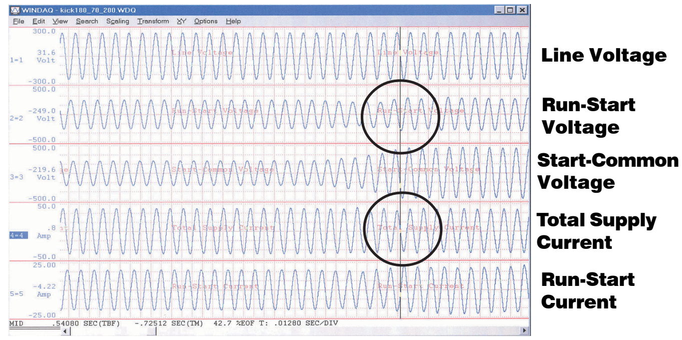


Figure 6. Start with Oversized Capacitor with out Safety Timing Circuit

If the capacitor is never removed from the start windings, premature winding failure could occur. As such, care should be taken when selecting capacitor sizes for an application. Care should also be taken regarding products that tout a “bigger capacitor is better” approach to compressor starting. SUPCO E-Class devices provide a secondary timing safety device to ensure that the start capacitor is dropped from the circuit in a fail-safe mode. Figure 5. also shows that the start winding voltage drops appropriately after the start capacitor has been removed in a SUPCO E-Class device.

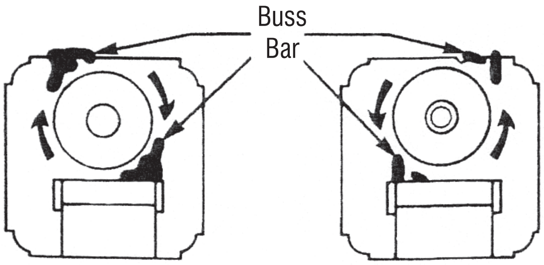
The E Class Advantage

Compressor start devices are available in a variety of forms. Specific applications call for specific products. SUPCO is one of very few manufacturers in the marketplace who provide a complete line of start devices to fit any application. PTC devices fulfill and will continue to fulfill specific needs in the industry. Potential relay devices can be found in a wide assortment. Care should be employed in selecting potential relay devices to ensure that all state-of-the-art developments are included in the product. The SUPCO E-Class Series comprise the most advanced developments in start device technology:

1. Voltage sensing technology that monitors for motor start (current sensing devices require internal fuse protection).
2. A 2-wire connection that simplifies installation
3. A secondary timing circuit that ensures that the capacitor is not permanently left in the start winding circuit
4. A fully electronic device – minimizing the limitations of mechanical devices and secondary fusing associated with triac devices
5. A start device matched with an appropriately sized capacitor to cover the range of compressors for the intended application (one size does not fit all)

The use of compressor start devices results from a need to ensure that a compressor (usually air conditioning) will start under voltage conditions that are less than ideal. As discussed, several options exist in the market to address compressor start concerns. Start devices exist in many forms for specific applications. SUPCO provides a full range of products in all relevant technologies to effectively match the proper start device to the application. Care should be taken to utilize a device that meets the requirements of the job. Extra caution should be observed when employing the “one-size-fits-all” and “a bigger capacitor is better” approach to applying a start device. Consult SUPCO, a manufacturer with a complete product range, to ensure the greatest success in the start device application.

Motor Rotation as viewed facing Shaft
CW - Clockwise Rotation
CCW - Counter Clockwise



CW
Upper buss bar on left
Lower buss bar on right

CCW
Upper buss bar on right
Lower buss bar on left

Motor Rotation

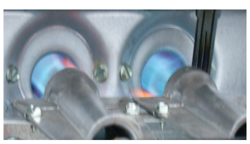
To determine motor rotation:
CW - Clockwise CCW - Counter Clockwise

A. Facing shaft end of motor, locate the copper Buss Bar as indicated in illustration.
B. The Buss Bar location determines shaft rotation.

APPLICATIONS

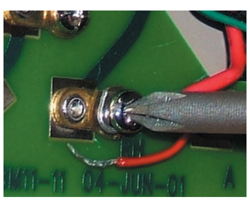
Micro Amp Display

This information indicates current flame circuit conditions and possible future failure.



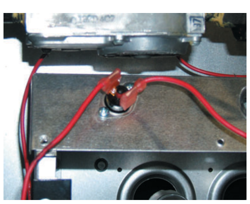
Gas Valve

LED is lit when all operating controls have been satisfied and shows that power is being sent to the valve.



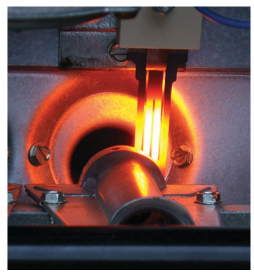
Thermostat

When the green thermostat closed LED is lit, it indicates that the control system is receiving a “call for heat” signal from the thermostat.



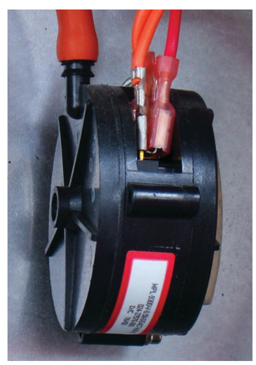
Open Circuit

This red LED indicates a problem and directs the technician to check the limit circuits and make the appropriate repairs.



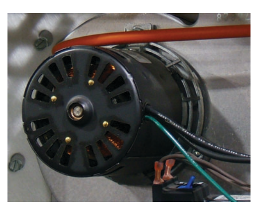
Ignitor Circuit

When the green igniter LED is lit, it indicates power is being sent to the igniter.



Pressure Switch

This red LED is an indicator of an erratic, stuck closed pressure switch and other problems in the flue gas venting.



Identifying Venting Problems

The green inducer LED is a confirmation of power being supplied to the inducer. This can be used to diagnose problems with power ventors, boards and valves.