Electrical Applications

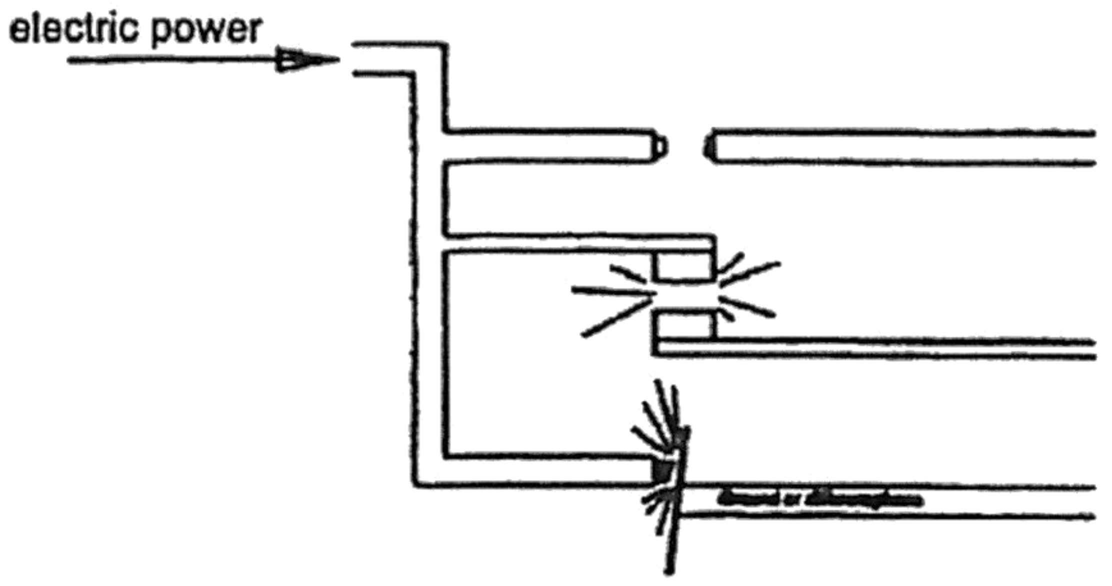
This Section Contains:

- Electrical Fault Types
- Electricity
- Control Circuit
- World Electricity Supplies

Section 5
Electrical Applications

The 3 electrical fault types

Evidence of fault



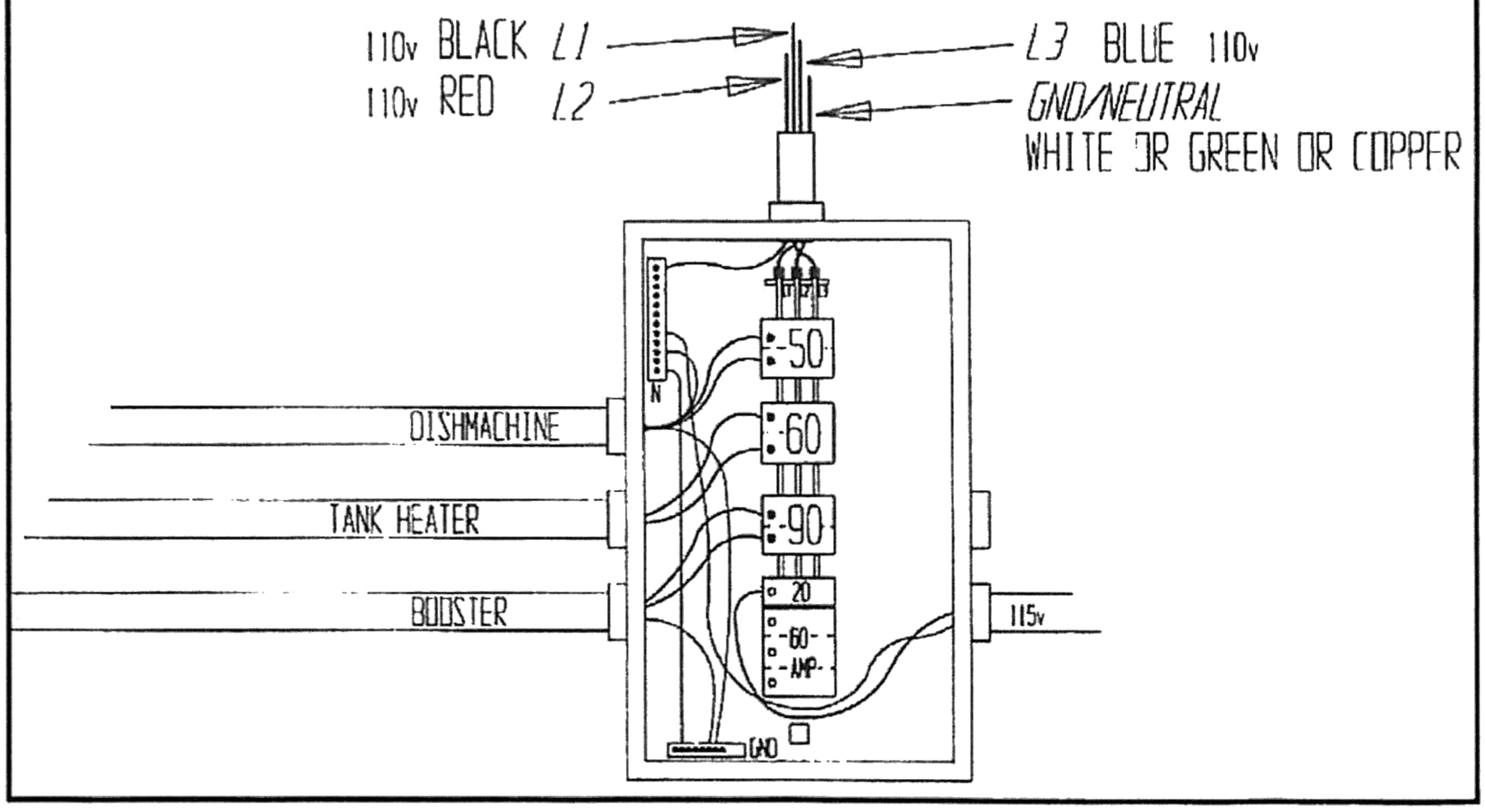
Short (open short)
Connection opened, current stopped
Typical of coil failure or disconnect

Burned contact point
Black or Green color to copper, charred or bubbled plastic
Happens over time at loose connections

Fault current
Molten metal, vaporized plastic insulation
Occurs rapidly

All electrical faults can be traced by observing the evidence

SERVICE ENTRANCE BOX



TECHNICAL SUPPORT MATERIAL

Burned Wire on Heater or Mercury Relay
(ADC-44, HT-25, ADC-66, B-13 Booster)

Appearance: black or green copper wire, charred wire holders, 3" to 4" of bubbled or melted wire insulation from connection. If this problem is not corrected and the loss of insulation allows wires to come in contact with ground or another phase, there can be immediate catastrophic damage. Often, this eventual damage is misinterpreted as the original cause.
Original Cause: gap between or loose connection of wire to terminal. Burned condition happens over time (weeks or months) rather than immediately. This failure is most commonly found on high-load components such as heaters and large motors (20 – 30 amps).
Prevention: the problem is easily prevented by simply checking the wire connection. See if the wire will move. You can feel the looseness on the terminal. Make sure connection parts are clean bright metal. Burned wire will cause the same problem to happen again.

"BEST WISDOM" FOR ELECTRICAL TROUBLESHOOTING

When dealing with a circuit short, loss of signal, loss of power, or burning points, the trouble will usually be associated with **connection terminals.** The connection is the weak point in any circuit. The problem is seldom found in the wire. Loose terminal connections will cause many problems, which appear to be the fault of other parts. Over time, the loose connection will cause the working device to overheat or fail.

ADS tech support/electricity/April 1998

Terminal Types
There are a number of terminal choices. Slip on (spade), screw post, (ring or eye), crimp (butt connectors), soldered joint, and pressure wire connector (screw or bolted).

Amp loads over 30 amps require screw pressure connections. Pressure wire connectors or screws meet this requirement. Heaters and motors would have field-wiring terminals for replacement purposes.

UL Commercial Electric Dishwashers #921, section 10.20 A field-wiring terminal shall be provided with a solder lug or with a pressure wire connector, firmly bolted or held by a screw. 12.14 A soldered connection shall be made mechanically secure [screw terminal] before being soldered.
12.16 An open-end spade lug is not acceptable unless additional means, such as upturned ends or the like is provided to hold the lug in place should the wire-binding screw or nut become slightly loosened. An open-end lug with a lock washer alone is not acceptable.

TECHNICAL SUPPORT MATERIAL

"ELECTRICITY"

Prepared by Russell Payzant

Electrical problem troubleshooting is one of the greater challenges for the dishmachine industry. *Chemicals* and *result problems* fall into the middle ground. While of the three service areas, *mechanical problems* are generally the easiest to solve. A few companies invest in limited electrical training because they view their primary business as chemicals or foods. One reason electrical problem-solving has continued to elude the industry, is the fear of inadvertent electrocution. This is a real and reasonable fear; injury and damage can occur quickly. Lack of training and inexperience can place the new hire in harmful or even deadly circumstances.

The purpose of this material is to describe the basic elements of electrical power, applications, distributions, capacities, and cautions as they are related to dishmachines. This is practical electricity without the math.

Electricity is an important element of the dishwashing industry. It provides efficient, readily available power to operate complex systems. In fact, this industry would not exist without electrical controls, motors, and heaters. Growth in the dishmachine sector closely parallels developments in centrifugal pumps and electric motors. Over the last 20 years, the focus has been on the reduction of energy demands. Many advanced designs were born out of efficiency projects.

Simple formula: reduced water usage = less time + less gas/electricity + less water treatment

"BLACK MAGIC" MYTHS

Historically, warewashing service people have had to solve electrical problems without suitable training. They just have to do the best they can. While achieving some temporary fix to an electrical issue, the service person often experiences return calls for failure to diagnose the real cause. An electric disruption to the machine requires some type of answer by the owner, eventually the true causes of failure are overshadowed by made-up answers. Over a period of time, legends develop.

Succeeding service generations foster these legends. Once established, those who are less skilled justify the tradition on grounds that it has always been done that way. Many of these myths exist in the dishmachine world: "the mercury relay can hold electricity", "single-phase motors are not good", "1700 RPM motors are not as strong as 3400 RPM motors", "120v power costs less than 240v", "a delta system is used predominately in the South", "change everything, you'll fix the problem", and so forth.

"ELECTRICAL" AND "ELECTRONICS"

The terms electrical and electronics are used interchangeably by the public at large, but the terms are not equal. When troubleshooting machine problems, using the wrong term can give the wrong impression and cause confusion.

"Electronics" is a term that industry applies to very low voltage (milli-volts to 6v), solid-state and printed-board control elements. It includes miniaturized components, shielding, single and multi-layer boards, control circuitry, installed or portable devices, and semiconductor technology. Typical parts would include capacitors, microchips, inductors, transformers, resistors, transistors, diodes, ribbon cables, integrated circuits, and filters. The actual term "electronics" is a branch of physics dealing with the behavior of electrons.

"Electrical" is a broad term but in the trades has come to mean low voltage (50v to 600v) domestic and commercial control and power circuits. It includes equipment consisting of wire, conduit, lighting, electro-mechanical devices, circuit breakers, generators, motors and heaters.

IMPORTANT voltage designations: **"high voltage"** is a term used for voltage supplies above >600v. All 600v enclosures must be labeled: "Danger High Voltage-Keep Out" (NEC 710.2); **"low voltage"** is a term for values below <600 volts (but are commonly misrepresented as *high*-voltage); and voltages below 50 volts are used for control and information purposes such as land-line telephones.

POWER & CONTROL

"Power" circuits provide electrical energy to *do work*, such as turning a motor or powering a heater. "Control" circuits provide the electric signal, which *tells* a power circuit to energize. The controls of most commercial dishwashers are voltages of 120v or 240v.

TYPICAL VOLTAGES

The 110v, 115v, and 120v designations are variations of domestic single phase power; where 208v, 220v, 230v, and 240v are variations of light industry poly-phase power; and 277v is a power used mainly for lighting fixtures. 440v, 460v, and 480v are poly-phase, commercial voltages (Lenk 5).
Informational Note: Today, the 120v and 240v designations are used in calculations for code. The terms 110v and 220v are still used by people but these voltage classifications come from many years ago and are no longer used in calculations. However, for motor calculations, the terms 115v and 230v are still used (Richter 41).
Generating stations (hydroelectric, coal, or nuclear power plants) will produce voltages typically around 13,800 volts, which are stepped up for long distance transmission (46,000 to 345,000v). Power transmission lines from substations will carry 4160 volts and then step-down to utilization voltages prior to the service drop [panel box] (Richter 56 and Kurtz 3).

ELECTRIC POWER SUPPLY INTO THE BUILDING

(color designations)

Phase 1, GRID, SUPPLY SIDE-------------L1 BUSS in access panel, usually black---------CIRCUIT BKR
Phase 2, GRID, SUPPLY SIDE-------------L2 BUSS in access panel, usually red------------CIRCUIT BKR
Phase 3, GRID, SUPPLY SIDE-------------L3 BUSS in access panel, usually blue-----------CIRCUIT BKR
NEUTRAL--always White "n" bar
Earth Grounding Electrode---always Green GND bar

PHASE PATH TO MOTORS FOR VARIOUS VOLTAGE SUPPLIES

Each line (L1, L2, L3 or N) represents a wire path to the motor
120v Single (Ø) phase motor power supply (domestic)
L1 supply side voltage 120v--------------circuit breaker-----------machine------relay----------120v
N supply side grounded neutral------------neutral bar-------------machine----------------------motor
(Rotational aspect, motor specific)
208v Single (Ø) Phase motor power supply (household appliance)
L1 supply side voltage 120v--------------circuit breaker-----------machine------contactor-----208v
L2 supply side voltage 120v--------------circuit breaker-----------machine------contactor-----motor
(Rotational aspect is reversed by an internal motor wire change)
208Y 3 (Ø) Phase motor power supply (wye circuit, commercial)
L1 supply side voltage 120v--------------circuit breaker----------machine-------contactor----3-ph
L2 supply side voltage 120v--------------circuit breaker----------machine-------contactor----motor
L3 supply side voltage 120v--------------circuit breaker----------machine-------contactor---
(Rotational aspect is reversed by a phase supply wire change)
230 "B" Phase, 2 (Ø) Phase motor power supply (rural farm or streetcar origins, K8.1)
L1 supply side voltage 230v--------------circuit breaker-----------machine-------contactor----B-ph
L2 supply side voltage 230v--------------circuit breaker-----------machine-------contactor----motor
N supply side grounded neutral------------circuit breaker-----------machine-------contactor---
(Rotational aspect is reversed by a phase supply wire change)
240v Delta 3 (Ø) Phase motor power supply (commercial)
L1 supply side voltage 120v--------------circuit breaker------------machine-------contactor----3-ph
L2 supply side voltage 120v--------------circuit breaker------------machine-------contactor----motor
L3 supply side voltage 210v--------------circuit breaker------------machine-------contactor----
(Rotational aspect is reversed by a phase supply wire change)

HEATER POWER SUPPLIES

Same as motors, exception: there is no rotational aspect

120v Single (Ø) Phase heater power supply

L1 supply side voltage 120v---------------circuit breaker-----------machine------relay----------
N supply side grounded neutral------------neutral bar--------------machine-----------------------heater

208Y 3 (Ø) Phase heater power supply

L1 supply side voltage 120v---------------circuit breaker-----------machine------relay-----------
L2 supply side voltage 120v---------------circuit breaker-----------machine------relay-----------heater
L3 supply side voltage 120v---------------circuit breaker-----------machine------relay-----------
(No rotational aspect, no wire-specific requirements)

CONTROL CIRCUITS

This is the circuit that communicates *information*. The circuit is made up of switches, lights, buzzers, relays, thermostats, and timers. It tells power devices to come "on" or "turn off".

TYPICAL CONTROL PATH

L1 supply side voltage 120v---------------circuit breaker-----------machine---POWER WIRE---relay----*mtr/htr*
\-----switch------/
(or thermostat)

NEUTRAL

The Neutral conductor is grounded at the generating source and the service drop, but it is considered a current carrier. For safety reasons, a grounded neutral wire is never interrupted by a circuit breaker, fuse, switch or other device. It is always designated by white or gray. In a two wire 120v circuit, the grounded wire (green), even if the grounded wire is attached to the neutral in the service, it is <u>not</u> a neutral wire; it is just the grounded wire, although it is commonly called a "neutral" (Richter 144). A ground wire cannot be used as a neutral. Neutral must come from the generating source.

"RELAYS"

Relays are devices that act as a gate. Voltage will pass through the gate when the relay closes the contact points. Relays are activated by mechanical, manual, electrical, or other means. A small economical voltage can control large power voltages. They usually transfer power voltages to motors, heaters, or other powered devices. They can be considered purpose-specific switches. In electrical relays, a coil of wire will magnetically influence the metallic (moveable) member of the relay, which causes the circuit points to make contact. Applying control voltage to the relay coil is the way a machine receives a signal to operate one of the systems.

VOLTS, AMPS, WATTS, CURRENT

(Rule: no amps means no work)

Current can be explained easily by using a river canal as an example. A canal has a strong *current* of water, whenever the down-river floodgates are opened, flow increases. Electrical current in a circuit means the same thing. The wire is the canal; voltage pressurizes the circuit or canal. Amps are measured when a device is at work, work creates a flow of current (or electrical energy) towards the working device when the gate (switch) is operated.

Volts can represent the pressure on the electricity, which pushes the flow; water moving in a channel represents electrical current. Amps will be similar to the measurement of a water volume going past a certain point for a given time. If the gate is closed the water stops moving, no current, no amp measurement. But the pressure (volts) is still there and the current will flow (amps) whenever the gate is opened again.

How do you measure the amount of energy (pressure x flow) being consumed? That measurement is called watts or in our case, kilowatts (1000 x watts).

Voltage = the pressure to push electrons, it pressurizes the system
Current = flow, speed of the flow is always the same 186,000 miles/sec.
Amps = measurement of flow over time (1 amp = 1 coulomb per second)
Watts = volts x amps measures the amount of energy used
Ohms = resistance in the conductor (push electrons through wire)

Background on Electrical Terms
The Volt was named after Italian physicist Count Alessandro Volta (1745 – 1827)
Ampere is named after French physicist André Marie Ampere (1775 – 1836)
The Watt is named for James Watt, Scottish engineer (1736 – 1819)
The Ohm is named after George Simon Ohm, German physicist (1789 – 1854)
Theory of the nature of electricity, Benjamin Franklin, American scientist (1706 – 1790)

Interesting side note, all of these remarkable scientists appeared in world history during a brief window of less than a hundred years. The dawn of 1700 was prelude to the extraordinary gifts of light and knowledge.

ELECTRICAL TESTING

This river analogy provides a distinct advantage in explaining electrical testing. If a motor were working, the amp draw would be indicated when your amp meter is clamped around the wire. If the motor were *not working at full capacity* (less efficiency), the amps would read less than the rated load of the motor. If the motor were *working too hard* (increased resistance) the amp draw would be **greater** than the rated amp load of the motor.
Example:
Supply side---no amp draw--------MOTOR @ REST
Supply side-------------------->>>rated amps are drawn by the motor or heater--------MOTOR @ WORK
Supply side-------------------->>>less amps are drawn by the motor or heater----------MOTOR reduced eff.
Supply side-------------------->>>more amps are drawn by the motor or heater--------MOTOR increased res.

TEST METERS

So, a voltage meter will tell you electric energy is present, or how much pressure. An amp meter will tell you if work is being done, and if it is *more* or *less* than the motor rating. An ohm meter will describe connectedness. It will tell you if one end of the conductor (wire) is connected to the other end and if there is too much resistance or interference to flow. Too much resistance equals heat over time.

"BEST WISDOM" FOR ELECTRICAL TROUBLESHOOTING

When dealing with a short, loss of signal, loss of power, or burning points, the trouble will usually be associated with **connection terminals**. The connection is the weak point in any circuit. The problem is seldom found in the wire run. Loose terminal connections will cause many problems, which appear to be the fault of other parts. Over time, the loose connection will cause the working device to overheat or fail.

WIRE SIZE AND AMPACITY (NEC 70.857 / Kurtz 4.36)

American Wire Gauge (AWG)

Types THHW, THW, RH, RHW, FEPW, XHHW, ZW at 75C. or 167F.

18 AWG = .040" dia.	10 amp
16 AWG = .050" dia.	15 amp
14 AWG = .064" dia.	20 amp
12 AWG = .081" dia.	25 amp
10 AWG = .102" dia.	35 amp
8 AWG = .128" dia.	50 amp
6 AWG = .162" dia.	65 amp
4 AWG = .204" dia.	85 amp
3 AWG = .229" dia.	100 amp
2 AWG = .257" dia.	115 amp
1 AWG = .289" dia.	130 amp
1/0 AWG = .324" dia.	150 amp
2/0 AWG = .364" dia.	175 amp
3/0 AWG = .409" dia.	200 amp

STANDARD BREAKER AND FUSE RATINGS

15, 20, 25, 30, 35, 40, 45, 50, 60, 70, 80, 90, 100, 110, 125, 150, 175, 200 amps (Richter 92)

Is it "SERIES" OR "PARALLEL"?

Typical circuit for one device

□power generation----------------120v power-------------→⊗motor

^--------------------------------Neutral--------------------------/

<u>The simplest circuit is a series</u> (current path flows through all devices)

□power generation---120v----------------→⊗motor----→⊗motor----→⊗motor

^---------------------------------------Neutral---/

<u>The independent-multiple-device circuit is a parallel</u>

□power generation-----------120v--------------\------------\---------------\--------

⊗motor ⊗motor ⊗motor

^--------------------------------Neutral---------- --/-----------/---------------/--------

Most **power** wiring is done in parallel circuits, because of the advantage of not losing power when one motor fails (Kurtz 1.9). However, **control** circuits are usually wired in series.

DEFINITION OF TERMS

<u>Continuous Loads</u> are defined as 3 hours or longer. Maximum load on any circuit must not exceed 80% of the rating for breaker or fuse. A 20-amp breaker may not exceed 16 amps. Greater *continuous* loads will cause breakers to trip and fuses to blow (Richter 125).

<u>Resistance of Wires</u>, current flows at a uniform density throughout the diameter of a wire in dc circuits. In ac circuits, with larger wire, current flows mostly in the outer layer of the wire. This is known as skin effect. The importance of this effect is higher resistance in larger wires used for ac circuits.

<u>Aluminum Wire</u>, these are the problems associated with this product. Aluminum has a higher resistance than copper. A larger wire size (two number sizes) must be used when replacing copper wire with aluminum. Also, connections are a real problem. When heated, aluminum expands much more, and faster than copper. At the connection point of a screw clamp, the expansion will cause the aluminum wire to cold-flow out of the connector. Over time, this will cause overheating and failure. For devices over 200 amps, only copper should be used (36).

kilowatt-hour (kWh) is 1000 watts acting for 1 hour.
kilovolt-ampere (kVA) if the power factor is 100%, then one kilovolt-ampere is the same as one kilowatt (kW). Volt-amperes = volts x amperes, for single phase. Volt-amperes = 1.732 x volts x amperes, for 3 phase (51).
Watt (W) the pressure (voltage) times the current (ampere) – electrical power (watt).
Volt (V) is the pressure required to force one ampere through a resistance of one ohm.
Ampere (A) the electric current that will flow through one ohm under a pressure of one volt.
Ohm (□) is the resistance through which one volt will force one ampere.
Hertz is the number of cycles (alternating current) in one second.
1 Horsepower = 746 watts
BTU = 0.29 watt
Alternating Current is measured in a cycle: 1/60 of a second when voltage goes from zero to (+) max, to zero to (-) max, and back to zero. The number of these cycles (frequency) in sixty seconds is called Hertz (49/615).
Starting Current or "locked-rotor" is the high in-rush of current consumed by the motor before it comes to speed. It may run as high as 600% of running current, but only lasts for a second or two. This is normal and designated by the Code letter on the nameplate (554). A heater has no rotation, therefore, no high in-rush of current to begin work.

WORKS CITED

American National Standard Institute / National Fire Protection Association. National Electrical Code. Quincy, Maryland. 14 August 1992: ANSI/NFPA 7.0.

Kurtz, Edwin B. The Lineman's and Cableman's Handbook. 4th ed. New York: McGraw-Hill, 1964.

Lenk, John D. Handbook of Simplified Electrical Wiring Design. Englewood, New Jersey: Prentice-Hall, 1975.

McPartland, J.F. Handbook of Practical Electrical Design. New York: McGraw-Hill, 1984.

Oppenheimer, Samuel L. Direct and Alternating Currents. 2nd ed. New York: McGraw-Hill, 1973.

Richter, Herbert P. Practical Electrical Wiring. 15th ed. New York: McGraw-Hill, 1990.

Product Data

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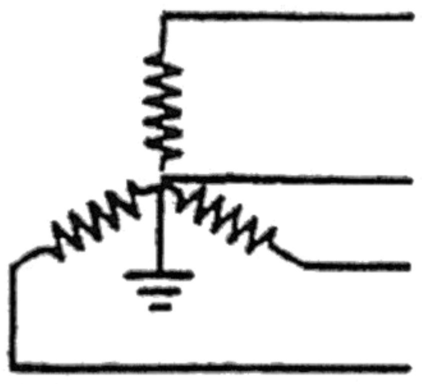
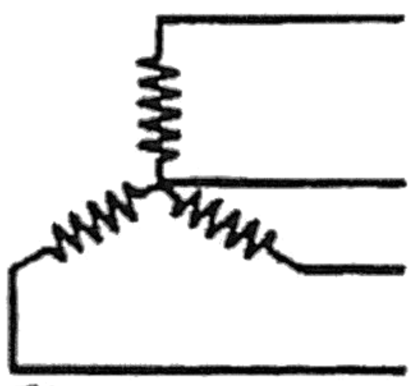
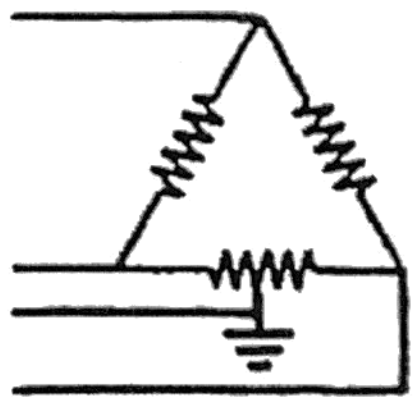
Subject WORLD ELECTRICITY SUPPLIES
A SURVEY OF SUPPLY VOLTAGES IN 172 COUNTRIES AND PROVINCES



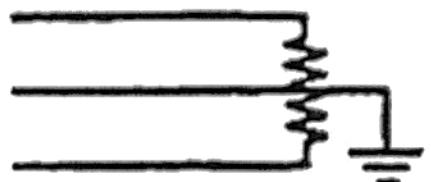
(A)
Three-Phase Star;
Four-Wire; Earthed
Neutral



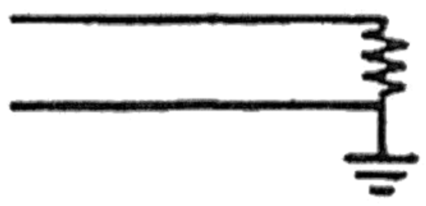
(D)
Three-Phase Star;
Four-Wire; Non-
Earthed Neutral



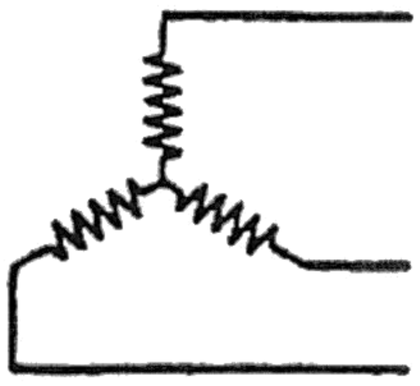
(G)
Three-Phase Delta;
Four-Wire; Earthed
Mid Point of Phase



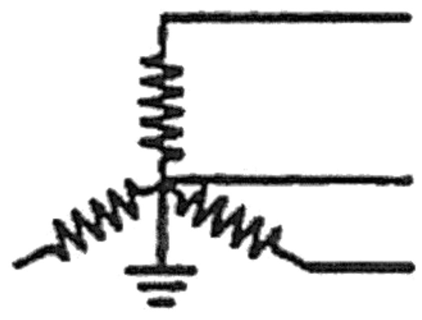
(K)
Single-Phase; Three-
Wire; Earthed Mid
Point



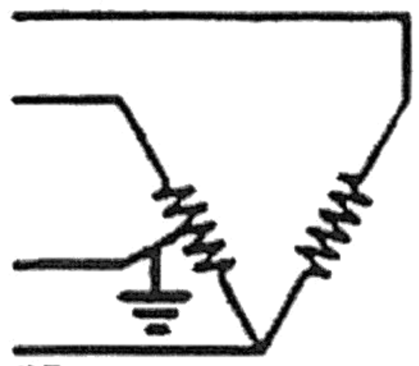
(L)
Single-Phase; Two-
Wire; Earthed End
of Phase



(B)
Three-Phase Star;
Three-Wire

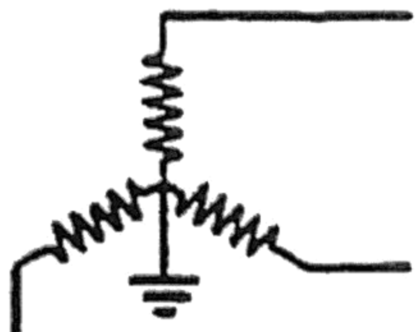


(E)
Two-Phase Star;
Three-Wire; Earthed
Neutral

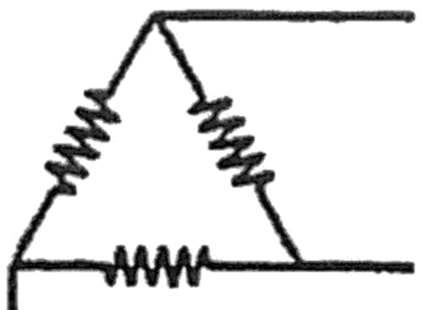


(H)
Three-Phase Open
Delta; Four-Wire;
Earthed Mid Point
of Phase

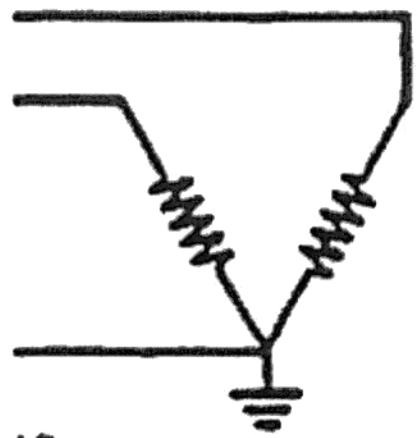
(M)
Single-Phase; Two-
Wire; Non-Earthed
Neutral



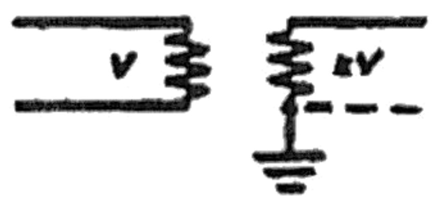
(C)
Three-Phase Star;
Three-Wire; Earthed
Neutral Point



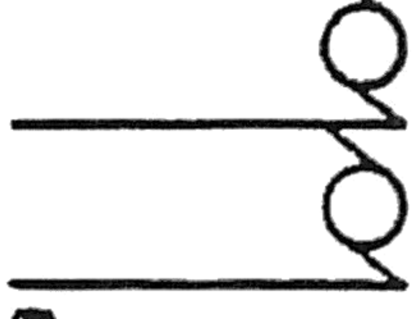
(F)
Three-Phase Delta;
Three-Wire



(J)
Three-Phase Open
Delta; Four-Wire;
Earthed Junction
of Phases



(N)
Single-Wire; Earthed
Return (SWER)

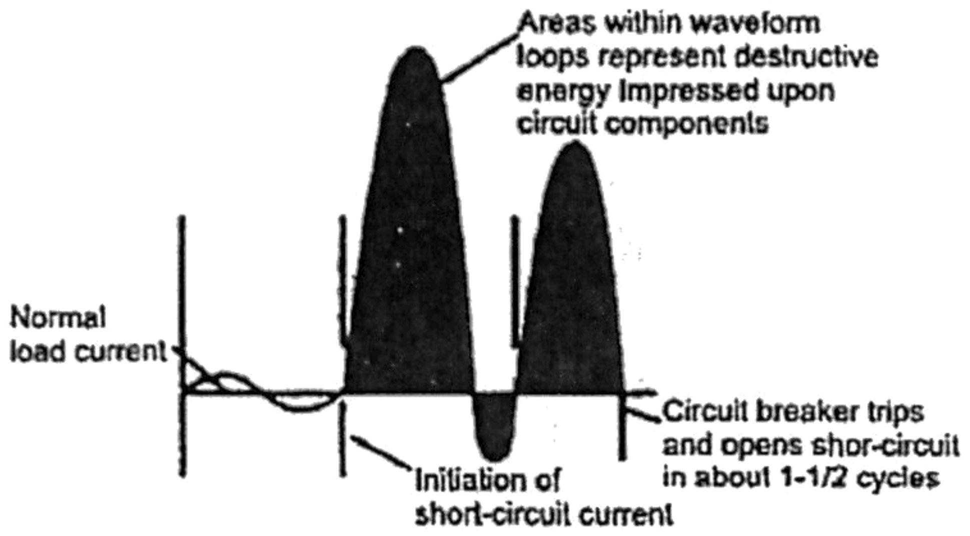


(P)
d.c.; Three-Wire

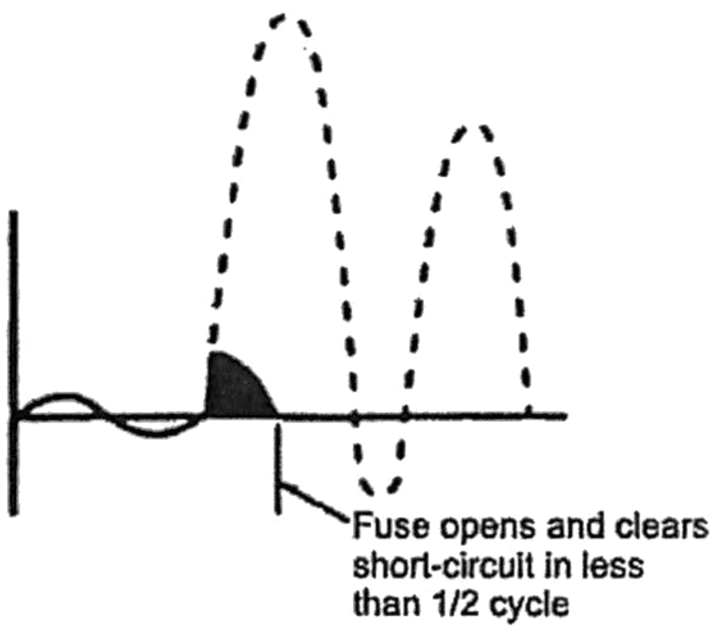
Reference: U.S. Department of Commerce Publication "Electric Current Abroad", 1975 Edition

Definition of Current-Limiting Overcurrent Protective Devices

What is the importance of this Section?



ACTION OF NON-CURRENT-LIMITING CIRCUIT BREAKER



ACTION OF CURRENT-LIMITING FUSE

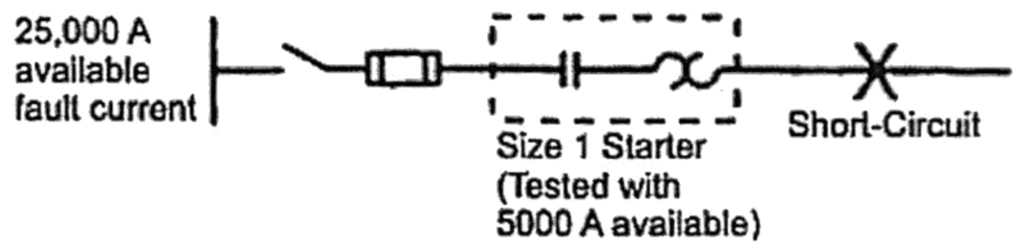
Simply stated, a current-limiting protective device is one which cuts off a fault current in less than one-half cycle. It thus prevents short-circuit currents from building up to their full available values.

The greatest damage done to components by a fault current occurs in the first half-cycle (or more precisely, "the first major loop" of the sinewave). Heating of components to very high temperatures can cause deterioration of insulation, or even explosion. Tremendous magnetic forces between conductors can crack insulators and loosen or rupture bracing structures.

The levels of both thermal energy and magnetic forces are proportionate to the square of current. Thermal energy is proportionate to the square of "RMS" current: maximum magnetic fields to the square of "peak" current. If a fault current is 100 times higher than normal current, it's increased heating effects equals $(100)^2$ or 10,000 times higher than that of the normal current. Thus, to prevent circuit component damage, the use of current-limiting protective devices is extremely important, particularly since present-day distribution systems are capable of delivering high level fault currents.

To further appreciate current-limitation, assume for example that the available prospective short-circuit current in a circuit is 50,000 amperes. If a 200 ampere LOW-PEAK YELLOW fuse is used to protect the circuit, the current let-thru by the fuse will be only 6500 amperes instead of 50,000 amperes. Thus, in this particular example, currents are limited to only 13% of the available short-circuit values.

As is true of fuse application in general, the application of current-limiting fuses in respect to current-limitation and component protection (110 -10) is quite simple. Graphs or tables such as the one shown below permit easy determination of the "let-thru" currents that a fuse will pass for various levels of prospective short-circuit currents. For example, the table below shows that the 200 ampere LOW-PEAK YELLOW fuse will let-thru 6500 amperes when prospective short-circuit current is 50,000 amperes.



For the above circuit, the Size 1 Starter has a short circuit withstand rating of 5000 amperes. The question is, with the 25,000 ampere available short-circuit current, will a LOW-PEAK YELLOW fuse provide adequate protection of the starter? By referring to the table below, it can easily be seen that for a prospective short-circuit current of 25,000 amperes, fuses with ratings less 100 amperes will limit fault currents to below the 5000 ampere withstand of the starter and, thus, provide adequate protection.

Current-Limiting Effects of RK1 LOW-PEAK YELLOW Fuses

Prospective Short – Circuit	Let-Thru Current (Apparent RMS Symmetrical) LPS-RK_SP (600V) Fuse Ratings					
Current	30A	60A	100A	200A	400A	500A
5,000	980	1,600	2,100	3,200	5,000	5,000
10,000	1,200	2,000	2,550	4,000	6,750	9,150
15,000	1,400	2,300	2,900	4,800	7,850	10,200
20,000	1,500	2,500	3,150	5,200	8,250	11,300
25,000	1,600	2,650	3,400	5,450	9,150	12,200
30,000	1,650	2,850	3,550	5,650	9,550	12,800
35,000	1,750	2,950	3,750	5,850	10,000	13,500
40,000	1,850	3,100	3,900	6,100	10,450	13,900
50,000	1,950	3,300	4,150	6,500	11,300	15,000
60,000	2,050	3,500	4,350	6,950	11,950	16,100
80,000	2,250	3,850	4,800	7,850	13,000	17,400
100,000	2,450	4,050	5,200	8,250	13,900	18,700
150,000	2,750	4,800	6,100	9,550	15,900	21,300
200,000	3,000	5,200	6,500	10,000	17,400	23,500
RMS Symmetrical Amperes						

The reader should note that much of the current-limitation claimed by small ampere circuit breakers is actually the result of the significant impedance added to the circuit breaker test circuit *after* the circuit has been calibrated.

2/20/2006	Chart of Usable kW, Across Range of Voltages							
					Heater	Heater	D/Machine	Supply
ADS P/N	Usable 3/ph voltage	Actual kW	Watt/density	Amp Draw	Wire	Bkr size	Main Bkr	Wire
291-9009	**12kW / 208v (6-29-148-3)**							
22 pcs	200 volts	11.1 kW	49.3 w/sq in	32.0 Amps	8 ga	40a	60a	6 ga
	208 volts	12.0 kW	53.3 w/sq in	33.4 Amps	8 ga	40a	60a	6 ga
	240 volts	15.9 kW	70.9 w/sq in	38.4 Amps	8 ga	50a	70a	4 ga
291-9001	**12kW / 220v (6-29-148-1)**							
396 pcs	200 volts	9.9 kW	44.0 w/sq in	28.6 Amps	8 ga	40a	60a	6 ga
	208 volts	10.7 kW	47.6 w/sq in	29.7 Amps	8 ga	40a	60a	6 ga
	220 volts	12.0 kW	53.3 w/sq in	33.4 Amps	8 ga	40a	60a	6 ga
	240 volts	14.3 kW	53.3 w/sq in	34.4 Amps	8 ga	50a	60a	6 ga
291-9008	**14kW / 208v (6-29-231-3)**							
17 pcs	200 volts	12.9 kW	35.9 w/sq in	37.4 Amps	8 ga	40a	70a	4 ga
	208 volts	14.0 kW	38.8 w/sq in	38.9 Amps	8 ga	50a	70a	4 ga
	240 volts	18.6 kW	51.6 w/sq in	44.8 Amps	6 ga	60a	70a	4 ga
291-9007	**18 kW / 220v (6-29-231-1)**							
34 pcs	200 volts	14.8 kW	41.2 w/sq in	42.9 Amps	6 ga	60a	90a	3 ga
	208 volts	16.1 kW	44.6 w/sq in	44.7 Amps	6 ga	60a	90a	3 ga
	220 volts	18 kW	49.9 w/sq in	47.3 Amps	6 ga	60a	90a	3 ga
	240 volts	21.4 kW	59.4 w/sq in	51.5 Amps	4 ga	70a	90a	3 ga
291-9003	**2.25 kW /208 (2-29-99-1) U019HN3S Rinse tank heater**							
257 pcs	200 volts	2.079 kW	56.9 w/sq in	6.0 Amps	14 ga	15a		
	208 volts	2.250 kW	61.6 w/sq in	6.2 Amps	14 ga	15a		
	220 volts	2.515 kW	68.9 w/sq in	6.6 Amps	14 ga	15a		
	240 volts	2.993 kW	82 w/sq in	7.2 Amps	14 ga	15a		
	NEC Recommended breaker size: above 24a:30, above 32a:40, above 40a:50, above 48a:60, above 56a:70, above 64a:80, above 72a:90							
	Wattage: W2=W1(E2/E1)2 Amperage: 3PH Amps = W/E x 1.73 Watt Density: W/in2 sq. = W/in1 sq. (E2/E1)sq.							
391-9002	**8 kW/208 single-phase (6-29-217-1)**							
61 pcs	**200 volts**	**7.4 kW**	**50.3 w/sq in**	**37.0 amps**	8 ga	50a		
	208 volts	**8.0 kW**	**54.4 w/sq in**	**38.5 amps**	8 ga	50a		
	220 volts	**8.95 kW**	**60.8 w/sq in**	**40.7 amps**	8 ga	50a		
	240 volts	**10.6 kW**	**72.4 w/sq in**	**44.4 amps**	8 ga	50a		
391-9005	**8 kW/240 single-phase (6-29-217-2)**							
12 ordered	**200 volts**	**5.56 kW**	**37.8 w/sq in**	**27.8 amps**	8 ga	40a		
	208 volts	**6.01 kW**	**40.8 w/sq in**	**28.9 amps**	8 ga	40a		

	220 volts	6.72 kW	45.7 w/sq in	30.5 amps	8 ga	40a
	240 volts	8 kW	54.4 w/sq in	33.3 amps	8 ga	50a
291-9002	12 kW/220 single-phase (6-29-215-1)					
17 pcs	200 volts	9.92 kW	44 w/sq in	49.6 amps	6 ga	60a
	208 volts	10.73 kW	47.6 w/sq in	51.6 amps	6 ga	70a
	220 volts	12.0 kW	53.3 w/sq in	54.5 amps	6 ga	70a
	240 volts	14.28 kW	63.4 w/sq in	59.5 amps	6 ga	80a
391-9001	8 kW /208 3-Phase (6-29-198-1)					
HT-25	200 volts	7.4 kW	50.3 w/sq in	21.4 amps		
	208 volts	8 kW	54.4 w/sq in	22.2 amps		
	220 volts	8.9 kW	60.8 w/sq in	23.4 amps		
	240 volts	10.6 kW	72.4 w/sq in	25.5 amps		
291-9004	2.25 kW /208 1-Phase (2-29-99-3)					
ADC 44	200 volts	2.09 kW	56.9 w/sq in	10.4 amps		
	208 volts	2.25 kW	61.6 w/sq in	10.8 amps		
	220 volts	2.51 kW	68.9 w/sq in	11.4 amps		
	240 volts	3 kW	82.0 w/sq in	12.5 amps		