Electrical Maintenance Hints

Volume 4

Reference Material, Tables, and Formulas

Electrical Maintenance Hints

Electrical Maintenance Hints

Volume 4

Reference Material, Tables, and Formulas

Complied and Edited by John G. Bishop

Westinghouse Electric Corporation
Printing Division
Trafford, Pennsylvania

Printing Division
Forbes Road
Trafford, PA 15085

Printed in U.S.A.

HB 6001-R

Electrical Maintenance Hints

Volume 4. Reference Material, Tables, and Formulas

Notice to the user of this book

The safe maintenance or repair of any electrical apparatus requires a thorough knowledge of engineering safety and repair techniques, and familiarity with the particular features of the apparatus involved. This book cannot, and does not deal with the numerous details of every manufacturer's apparatus necessary for safe repair or maintenance. The inexperienced electrician or unqualified layman should not expect this book to provide sufficient instructions to permit him to safely repair any electrical apparatus. Use only qualified electrical repair personnel to do any work required, and refer those workers to the manufacturers' warnings and instructions before starting any work.

Severe or fatal electrical shock or burn can result from failure to properly service or repair equipment.

Safety

Disclaimer of Warranties and Limitation of Liability

There are no understandings, agreements, representations, or warranties, express or implied, including warranties of merchantability or fitness for a particular purpose.

The information, recommendations, descriptions, and safety notations in this document are based on Westinghouse experience and judgment with respect to maintenance hints. **This information must not be considered to be all inclusive or covering all contingencies.** If further information is required, the equipment or material manufacturer must be consulted.

This document is furnished in "as is" condition. **No warranties, express or implied, including warranties of fitness for a particular purpose, of merchantability, or warranties arising from course or dealing or usage of trade, are made regarding the information, recommendations, descriptions, and safety notations contained herein.** In no event will Westinghouse be responsible to the user in contract, in tort (including negligence), strict liability or otherwise for any direct, special, indirect, incidental, or consequential damage or loss whatsoever, including but not limited damage or loss of use of equipment, plant or power system, cost of capital, loss of profits or revenues, cost of replacement power, additional expenses in the use of existing power facilities, or claims against the user by its customers resulting from the use of the information, recommendations, descriptions, and safety notations contained herein.

Warning
Warnings, recommendations, and instructions contained in this book may not apply to equipment designed and built after the book was written. The manufacturers' applicable instructions should be consulted in all instances.

Warning: This document is not all inclusive. It does not cover all contingencies. Read and follow the manufacturer's instructions before attempting to handle, store, install, use, or service any equipment. Failure to follow these instructions can result in severe personal injury, death, or damage to property.

Warning: Hazardous voltage, vapor, hot oil, and other hazardous conditions can be present in electrical equipment and related systems. Competent trained personnel are required to handle, store, install, use, or service any equipment. Failure to follow this warning can result in severe personal injury, death, or damage to property.

Warning: Follow the safety instructions given in Volume 1 Chapter 5 and throughout the book. Failure to do so can result in severe personal injury, death, or damage to property.

Preface

This set of books is intended to provide a condensed treatment of acceptable maintenance practice on the most commonly used types of electrical equipment. Where specific references or examples were required, products manufactured by the Westinghouse Electric Corporation or components used in such products have been used.

Since this book is directed to the maintenance of electrical equipment an attempt has been made to make it applicable to older as well as new apparatus and devices.

For the user's convenience the book has been bound in four volumes, 1 General Maintenance, 2 Industrial Equipment Maintenance, 3 Power Apparatus Maintenance, 4 Reference Material and Tables and Formulas. An additional volume entitled Index, is supplied to help you locate specific topics. It consists of a volume/chapter listing, followed by a detailed index.

Page numbering reflects this organization.

1:1.1
The first digit indicates the volume
The second digit the chapter
The third digit the page

Volume 4
Chapter 1

Reference Tables and Formulas

Reference Tables and Formulas

1.1 Units of Measure

A. Metric System Prefixes

Mega – 1,000,000
Kilo – 1,000
Hecto – 100
Deca – 10

Deci – 0.1
Centi – 0.01
Milli – 0.001
Micro – 0.000001

Tera (T) – 10^{12}
Giga (G) – 10^{9}
Nano (N) – 10^{-9}
Pico (P) – 10^{-12}

B. Multiplication Factors

1,000,000,000,000	= 10^{12}	= tera	= T	=	trillion
1,000,000,000	= 10^{9}	= giga	= G	=	billion
1,000,000	= 10^{6}	= mega	= M	=	million
1,000	= 10^{3}	= kilo	= k	=	thousand
100	= 10^{2}	= hecto	= h	=	hundred
10	= 10^{1}	= deka	= da	=	ten
1	= 1				
.1	= 10^{-1}	= deci	= d	=	tenth
.01	= 10^{-2}	= centi	= c	=	hundredth
.001	= 10^{-3}	= milli	= m	=	thousandth
.000,001	= 10^{-6}	= micro	= μ	=	millionth
.000,000,001	= 10^{-9}	= nano		=	billionth
.000,000,000,001	= 10^{-12}	= pico		=	trillionth

C. Conversion Equations

To Metric	From Metric
Linear	
1 inch = .0254 meters	1 meter = 39.37 inches
1 foot = .3048 meters	1 meter = 3.28088 feet
1 yard = .9144 meters	1 meter = 1.09361 yards
1 mile = 1609.35 meters	1 kilometer = .62137 miles
1 mile = 1.60935 kilometers	
Square	
1 sq. inch = 6.4516 sq. centimeters	1 sq. centimeter = .155 sq. inches
1 sq. foot = 9.290 sq. decimeters	1 sq. meter = 10.764 sq. feet
1 sq. yard = .836 sq. meters	1 sq. meter = 1.196 sq. yards
Cubic	
1 cu. inch = 16.387 cu. centimeters	1 cu. centimeter = .0610 cu. inches
1 cu. foot = .02832 cu. meters	1 cu. meter = 35.314 cu. feet
1 cu. yard = .76455 cu. meters	1 cu. meter = 1.308 cu. yards
Weight	
1 grain = 64.7989 milligrams	1 milligram = .01543 grains
1 avoirdupois ounce = 28.3495 grams	1 kilogram = 35.274 oz.
1 troy ounce = 31.10348 grams	1 hectogram = 3.5274 avoirdupois ounces
1 avoirdupois pound = .45359 kilograms	1 kilogram = 2.20462 avoirdupois pounds
Capacity	
1 fluid drachm = 3.7 cu. centimeters	1 milliliter = .27 fluid drachms
1 fluid ounce = 29.57 milliliters	1 centiliter = .338 fluid ounces
1 quart = .94636 liters	1 liter = 1.0567 quarts
1 gallon = 3.78544 liters	1 hectoliter = 26.417 gallons
Pressure	
1 pound per sq. inch = .0703 kilograms per sq. centimeter	1 kilogram per square centimeter = 14.22 pounds per square inch
Temperature	
F = 9/5 (C + 32)	
C = 5/9 (F − 32)	
K = C + 273.15	

D. Conversion Formulas

Multiply	By	To Obtain
Atmospheres	33.90	feet of water
	29.92	inches of mercury
	14.69	pounds per sq. in.
Btu	252.	calories (gram) 15°C
	778.3	foot pounds
	.0003929	horsepower-hours
	1054.8	joules
	.0002930	kilowatt-hours
Btu per min.	12.97	foot pounds per sec.
	.02357	horsepower
	17.58	watts
Calories	.003968	BTU
Erg	9.478×10^{-11}	BTU
	1.0	dyne centimeters
	7.376×10^{-8}	foot pounds
Feet of water	.02950	atmospheres
	.8826	inches of mercury
	.4335	pounds per sq. in.
Foot pounds per second	.07712	BTU per min.
	.001818	horsepower
	.001356	kilowatts
Foot candle	10.765	lux
Horsepower	42.41	BTU per minute
	33,000.	foot pounds per min.
	550.	foot pounds per sec.
	.7457	kilowatts
Horsepower-hours	2545.	BTU
	1.98×10^{6}	foot pounds
	2.684×10^{6}	joules
Inches of mercury	.03342	atmospheres
	1.133	feet of water
	.4912	pounds per sq. inch
Joules	.0009478	BTU
	.7376	foot pounds
	.0002778	watt hours
	1.0	watt seconds
Kilowatt-hours	3412.	BTU
	3.6×10^{13}	Ergs
Lux	.0929	foot candles
Meters	100.	centimeters
	39.37	inches
Radians	57.3	degrees
Watts	.05689	BTU per minute
	1.0×10^{7}	Ergs per second
	44.26	foot pounds per min.
	.00134	horsepower

E. Temperature Conversion Table

Fahrenheit (F)	Celsius (C)	Kelvin (K)
−31	−35	+238.15
−22	−30	+243.15
−13	−25	+248.15
−4	−20	+253.15
+5	−15	+258.15
+14	−10	+263.15
+23	−5	+268.15
+32	0	+273.15
+41	+5	+278.15
+50	+10	+283.15
+59	+15	+288.15
+68	+20	+293.15
+77	+25	+298.15
+86	+30	+303.15
+95	+35	+308.15
+104	+40	+313.15
+113	+45	+318.15
+122	+50	+323.15
+131	+55	+328.15
+140	+60	+333.15
+149	+65	+338.15
+158	+70	+343.15
+167	+75	+348.15
+176	+80	+353.15
+185	+85	+358.15
+194	+90	+363.15
+203	+95	+368.15
+212	+100	+373.15

1.2 Equivalents

Linear

1 centimeter = 0.3937 inch = 0.0328 foot
1 meter = 39.37 inches = 1.0936 yards
1 kilometer = 0.62137 mile = 3280 feet
1 inch = 2.54 centimeters
1 foot = 0.3048 meters
1 mil = 0.001 inch

Square

1 sq. cm. = 0.155 sq. in.
1 sq. meter = 1.196 sq. yd. = 10.764 sq. ft.
1 sq. kilometer = 0.386 sq. mile
1 sq. inch = 6.452 sq. centimeters
1 sq. foot = 929.03 sq. cm. = 0.092903 sq. meter
1 sq. yd. = 0.8361 sq. meter
1 sq. mile = 2.59 sq. kilometers
1 circular mil = 0.7854 sq. mil
1 sq. in. = 1,000,000 sq. mils

Cubic

1 cubic centimeter = 0.061 cu. inch
1 cubic inch = 16.39 cu. cm.
1 cubic meter = 1.308 cu. yards = 35.316 cu. feet
1 gallon (US) = 231 cu. inches
1 cubic foot = 7.48 gallons
1 liter = 1000 cu. centimeters

Time

1 day = 86,400 seconds
1 year = 8,760 hours (approx.)

Velocity

1 ft/sec = 0.3048 meter/sec.
1 meter/sec = 3.281 ft/sec.
1 ft/minute = 0.00508 meter/sec.
1 meter/sec = 196.9 ft/min.
1 mile/hr = 0.447 meter/sec.
1 meter/sec = 2.237 mi/hr.
1 kilometer/hr = 0.2778 meter/sec.
1 meter/sec = 3.60 km/hr.

Equivalents (Continued)

Acceleration

1 ft/sec/sec = 0.3048 meter/sec/sec
1 mi/hr/sec = 0.447 meter/sec/sec
1 kilometer/hr/sec = 0.2778 meter/sec/sec
Standard gravitation = 9.806 meter/sec/sec
= 980.6 cm/sec/sec
= 32.2 ft/sec/sec

Mass

1 slug = 32.2 pounds mass = 14.606 kilograms
1 pound mass = 453.6 grams

Force

1 pound force = 1 slug x 1 foot/sec/sec
1 dyne = 1 gram x 1 centimeter/sec/sec
1 newton = 1 kilogram x 1 meter/sec/sec
1 pound force = 4.452 newtons
1 newton = 100,000 dynes = 0.224 pound force
1 gram force = 980.6 dynes

Pressure

1 atmosphere = 14.69 pounds/sq. in. = 29.92 inches mercury
= 76 cm mercury = 33.9 ft. water
1 inch mercury = 0.491 pounds/sq. inch
water pressure in pounds/sq. inch = head in feet x 0.434
Torque – The product of force and perpendicular distance
1 pound-foot = 1.356 newton-meter = 1.356 joule/radian
1 pound-foot = 1.356 x 10^7 dynes-centimeter
1 pound-foot = 1.383 x 10^4 grams-centimeter
1 pound-foot = 192 ounce-inches

Work and Energy – Mechanical

1 erg = 1 dyne x 1 centimeter
1 joule = 1 newton x 1 meter = 10^5 dynes x 10^2 centimeters = 10^7 ergs
1 foot-pound = 1 pound force x 1 foot = 1.356 joules

Work and Energy – Heat Equivalent

1 British termal unit raises 1 pound of water 1 degree Fahrenheit
1 gram calorie raises 1 gram of water 1 degree Celcius
1 Btu = 252 gram calories = 778.3 foot pounds = 1054.8 joules
1 horsepower = 2545 British thermal unit

Equivalents (Continued)

Work and Energy – Electrical Equivalent

1 joule = 1 watt x 1 second = 1 ampere (dc) x 1 volt (dc) x 1 second
W (joules) = 1/2 L (henries) x 1 (amperes)^2
W (joules) = 1/2 C (farads) x E (volts)^2
1 kilowatt hour = 3,600,000 joules

Power

1 watt = 1 joule/sec
1 horsepower = 550 foot pounds/second = 746 watts
1 watt = 3.413 British thermal units/hour = 0.239 gram calorie/sec.
P (watts) $\times$ R (ohms) x I (amperes)^2

$$P \text{ (watts)} = \frac{E \text{ (Volts)}^2}{R \text{ (Ohms)}}$$

Angles

1 circle = 2 π radians = 360 degrees
1 radian = 57.3 degrees
1 degree = 0.01745 radians

Geometric Figures

Circle, area = Diameter^2 x 0.7854 = π x radius = $2(\pi r^2)$
Circle, circumference = $\pi D = 2\pi$radius
Sphere, volume = D^3 x 0.5236 = 4/3 π radius^3
Triangle, area = 1/2 altitude x base
Cone, volume = area of base x 1/3 altitude
Trapezoid, area = 1/2 (sum of parallel sides) x altitude
Pyramid, volume = area of base x 1/3 altitude

Miscellaneous Constant Equivalents

π = 3.14159 e = 2.71828
$\text{Log}_e\, x = 2.3059 \log_{10} x$
Electronic charge = 4.8×10^{-10} e.s.u. = 1.60×10^{-20} e.m.u.
Mass Units = 1.07×10^{-3} x Mev = 6.71×10^2 ergs
Speed of light = 3×10^8 meters/second
Speed of sound (in air at sea level) = 1100 feet/second

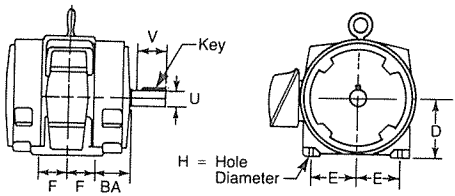
1.3 Electric Motor Data

A. Motor Terminal Amperes at Full Load①
Average Values for All Speeds and Frequencies
(source NEC)

Hp	Single Phase Ac		Polyphase Ac Induction Type Squirrel Cage and Wound Rotor									3 Phase Synchronous Unity Power Factor④				Direct-Current		
	115v	230v②	115v		230v		460v		575v		2300v	240v	440v	550v	2300v	120v	240v	500v
			3 ph	2 ph③ 4 wire	3 ph	2 ph② 4 wire	3 ph	2 ph 4 wire	3 ph	2 ph 4 wire								
¼	5.8	2.9														2.9	1.5	
⅓	7.2	3.6														3.6	1.8	
½	9.8	4.9	4	4	2	2	1	1	.8	.8						5.2	2.6	
¾	13.8	6.9	5.6	4.8	2.8	2.4	1.4	1.2	1.1	1.0						7.4	3.7	
1	16	8	7.2	6.4	3.6	3.2	1.8	1.6	1.4	1.3						9.4	4.7	
1½	20	10	10.4	9	5.2	4.5	2.6	2.3	2.1	1.8						13.2	6.6	
2	24	12	13.6	11.8	6.8	5.9	3.4	3	2.7	2.4						17	8.5	
3	34	17			9.6	8.3	4.8	4.2	3.9	3.3						25	12.2	
5					15.2	13.2	7.6	6.6	6.1	5.3						39	19.5	
7½	80	40			22	19	11	9	9	8						58	29	
10	100	50			28	24	14	12	11	10						76	38	18
15					42	36	21	18	17	15							54	26
20					54	47	27	23	22	19							73	35
25					68	59	34	29	27	24		54	27	22			89	43
30												65	33	26			111	53
40					104	90	52	45	41	36		86	43	35			143	69
50					130	113	65	56	52	45		108	54	44			175	84
60					154	134	77	67	62	54	16	128	64	51	12		207	99
75					192	166	96	83	77	66	20	161	81	65	15		261	125
100					248	218	124	109	99	87	26	211	106	85	20		343	165
125					312	270	156	135	125	108	31	264	132	106	25		420	202
150					360	312	180	156	144	125	37		158	127	30		510	245
200					480	416	240	208	192	166	49		210	168	40		690	331

① These values for full-load current are for motors running at speeds usual for belted motors and motors with normal torque characteristics. Motors built for especially low speeds or high torques may require more running current. Multi-speed motors will have full-load current varying with speed, in which case the name plate rating should be used.
② For full-load currents of 208-volt and 200-volt motors increase the corresponding 230-volt motor full-load current by 10% and 15% respectively.
③ Current in common conductor of 2-phase, 3-wire system will be 1.41 times the value given.

B. Motor Frame Dimensions and Weights



1. Motor Frame Dimensions – Inches

Frame	D	E	F	H	U	BA	V Min.
143	3½	2¾	2	11/32	¾	2¼	1¾
143T	3½	2¾	2	11/32	⅞	2¼	2
145	3½	2¾	2½	11/32	¾	2¼	1¾
145T	3½	2¾	2½	11/32	⅞	2¼	2
182	4½	3¾	2¼	13/32	⅞	2¾	2
182T	4½	3¾	2¼	13/32	1⅛	2¾	2½
184	4½	3¾	2¾	13/32	⅞	2¾	2
184T	4½	3¾	2¾	13/32	1⅛	2¾	2½
203	5	4	2¾	13/32	¾	3⅛	2
204	5	4	2¼	13/32	¾	3⅛	2
213	5¼	4¼	2¾	13/32	1⅛	3½	2¾
213T	5¼	4¼	2¾	13/32	1⅜	3½	3⅛
215	5¼	4¼	3½	13/32	1⅛	3½	2¾
215T	5¼	4¼	3½	13/32	1⅜	3½	3⅛
224	5½	4½	3⅜	13/32	1	3½	1¾
225	5½	4½	3¾	13/32	1	3½	2¾
254	6¼	5	4⅛	17/32	1⅛	4¼	1¾
254U	6¼	5	4⅛	17/32	1⅜	4¼	1¾
254T	6¼	5	4⅛	17/32	1⅝	4¼	1¾
256U	6¼	5	5	17/32	1⅜	4¼	3½
256T	6¼	5	5	17/32	1⅝	4¼	3¾
284	7	5½	4¾	17/32	1¼	4¾	3½
284U	7	5½	4¾	17/32	1⅝	4¾	4⅝
284T	7	5½	4¾	17/32	1⅞	4¾	4⅜
284TS	7	5½	4¾	17/32	1⅝	4¾	3
286U	7	5½	5½	17/32	1⅝	4¾	4⅝
286T	7	5½	5½	17/32	1⅞	4¾	4⅜
286TS	7	5½	5½	17/32	1⅝	4¾	3
324	8	6¼	5¼	21/32	1⅝	5¼	4⅜
324U	8	6¼	5¼	21/32	1⅞	5¼	4⅜
324S	8	6¼	5¼	21/32	1⅝	5¼	3
324T	8	6¼	5¼	21/32	2⅛	5¼	5
324TS	8	6¼	5¼	21/32	1⅞	5¼	3½
326	8	6¼	6	21/32	1⅝	5¼	4⅝
326U	8	6¼	6	21/32	1⅞	5¼	5⅜
326S	8	6¼	6	21/32	1⅝	5¼	3
326T	8	6¼	6	21/32	2⅛	5¼	5
326TS	8	6¼	6	21/32	1⅞	5¼	3½
364	9	7	5⅝	21/32	1⅞	5⅞	5⅜
364S	9	7	5⅜	21/32	1⅝	5⅞	3
364U	9	7	5⅝	21/32	2⅛	5⅞	6⅛
364US	9	7	5⅝	21/32	1⅞	5⅞	3½
364T	9	7	5⅝	21/32	2⅜	5⅞	5⅝
364TS	9	7	5⅝	21/32	1⅞	5⅞	3½
365	9	7	6⅛	21/32	1⅞	5⅞	5⅜
365S	9	7	6⅛	21/32	1⅝	5⅞	3
365U	9	7	6⅛	21/32	2⅛	5⅞	6⅛
365US	9	7	6⅛	21/32	1⅞	5⅞	3½
365T	9	7	6⅛	21/32	2⅜	5⅞	5⅝
365TS	9	7	6⅛	21/32	1⅞	5⅞	3½
404	10	8	6⅛	13/16	2⅛	6⅝	6⅛
404S	10	8	6⅛	13/16	1⅞	6⅝	3½
404U	10	8	6⅛	13/16	2⅜	6⅝	6⅞
404US	10	8	6⅛	13/16	2⅛	6⅝	4
404T	10	8	6⅛	13/16	2⅞	6⅝	7
404TS	10	8	6⅛	13/16	2⅛	6⅝	4
405	10	8	6⅞	13/16	2⅛	6⅝	6⅛
405S	10	8	6⅞	13/16	1⅞	6⅝	3½
405U	10	8	6⅞	13/16	2⅜	6⅝	6⅞
405US	10	8	6⅞	13/16	2⅛	6⅝	4
405T	10	8	6⅞	13/16	2⅞	6⅝	7
405TS	10	8	6⅞	13/16	2⅛	6⅝	4
444	11	9	7¼	13/16	2⅜	7½	6⅞
444S	11	9	7¼	13/16	2⅛	7½	4
444U	11	9	7¼	13/16	2⅞	7½	8⅜
444US	11	9	7¼	13/16	2⅛	7½	4
444T	11	9	7¼	13/16	3⅜	7½	8¼
444TS	11	9	7¼	13/16	2⅜	7½	4½
445	11	9	8¼	13/16	2⅜	7½	6⅞
445S	11	9	8¼	13/16	2⅛	7½	4
445U	11	9	8¼	13/16	2⅞	7½	8⅜
445US	11	9	8¼	13/16	2⅛	7½	4
445T	11	9	8¼	13/16	3⅜	7½	8¼
445TS	11	9	8¼	13/16	2⅜	7½	4½
504U	12½	10	8	15/16	2⅞	8½	8⅜
504S	12½	10	8	15/16	2⅛	8½	4
505	12½	10	9	15/16	2⅞	8½	8⅜
505S	12½	10	9	15/16	2⅛	8½	4

2. Motor Shaft Key Dimensions – Inches

Frame	Width	Thick.	Length
143	3/16	3/16	1 3/8
143T	3/16	3/16	1 3/8
145	3/16	3/16	1 3/8
145T	3/16	3/16	1 3/8
182	3/16	3/16	1 3/8
182T	1/4	1/4	1 3/4
184	3/16	3/16	1 3/8
184T	1/4	1/4	1 3/4
203	3/16	3/16	1 1/2
204	3/16	3/16	1 1/2
213	1/4	1/4	2
213T	5/16	5/16	2 3/8
215	1/4	1/4	2
215T	5/16	5/16	2 3/8
224	1/4	1/4	2
225	1/4	1/4	2
254	1/4	1/4	2
254U	5/16	5/16	2 3/4
254T	3/8	3/8	2 7/8
256U	5/16	5/16	2 3/4
256T	3/8	3/8	2 7/8
284	1/4	1/4	2
284U	3/8	3/8	3 3/4
284T	1/2	1/2	3 1/4
284TS	3/8	3/8	1 7/8
286U	3/8	3/8	3 3/4
286T	1/2	1/2	3 1/4
286TS	3/8	3/8	1 7/8
324	3/8	3/8	3 3/4
324U	1/2	1/2	4 1/4
324S	3/8	3/8	1 7/8
324T	1/2	1/2	3 7/8
324TS	1/2	1/2	2
326	3/8	3/8	3 3/4
326U	1/2	1/2	4 1/4
326S	3/8	3/8	1 7/8
326T	1/2	1/2	3 7/8
326TS	1/2	1/2	2
364	1/2	1/2	4 1/4
364S	3/8	3/8	1 7/8
364U	1/2	1/2	5
364US	1/2	1/2	2
364T	5/8	5/8	4 1/4
364TS	1/2	1/2	2
365	1/2	1/2	4 1/4
365S	3/8	3/8	1 7/8
365U	1/2	1/2	5
365US	1/2	1/2	2
365T	5/8	5/8	4 1/4
365TS	1/2	1/2	2
404	1/2	1/2	5
404S	1/2	1/2	2
404U	5/8	5/8	5 1/2
404US	1/2	1/2	2 3/4
404T	3/4	3/4	5 5/8
404TS	1/2	1/2	2 3/4
405	1/2	1/2	5
405S	1/2	1/2	2
405U	5/8	5/8	5 1/2
405US	1/2	1/2	2 3/4
405T	3/4	3/4	5 5/8
405TS	1/2	1/2	2 3/4
444	5/8	5/8	5 1/2
444S	1/2	1/2	2 3/4
444U	3/4	3/4	7
444US	1/2	1/2	2 3/4
444T	7/8	7/8	6 7/8
444TS	5/8	5/8	3
445	5/8	5/8	5 1/2
445S	1/2	1/2	2 3/4
445U	3/4	3/4	7
445US	1/2	1/2	2 3/4
445T	7/8	7/8	6 7/8
445TS	5/8	5/8	3
504U	3/4	3/4	7 1/4
504S	1/2	1/2	2 3/4
505	3/4	3/4	7 1/4
505S	1/2	1/2	2 3/4

3. Motor Estimating Weights-Pounds

Frame	DP	TEFC
143	40	40
143T	40	40
145	45	45
145T	45	45
182	56	63
182T	72	82
184	62	70
184T	80	90
203	52	55
204	60	62
213	110	120
213T	130	145
215	135	135
215T	145	160
224	120	135
225	140	155
254	155	175
254U	180	180
254T	220	230
256U	210	220
256T	240	250
284	250	255
284U	285	290
284T	330	355
284TS	330	355
286U	325	330
286T	370	390
286TS	370	390
324	400	395
324U	420	480
324S	420	480
324T	475	690
324TS	475	690
326	405	590
326U	470	540
326S	470	540
326T	525	610
326TS	525	610
364	575	700
364S	550	690
364U	550	690
364US	550	690

Frame	DP	TEFC
364T	630	835
364TS	630	835
365	570	725
365S	610	775
365U	610	775
365US	610	775
365T	690	920
365TS	690	920
404	675	945
404S	655	980
404U	780	980
404US	780	980
404T	830	1145
404TS	830	1145
405	780	1140
405S	865	1110
405U	865	1110
405US	865	1110
405T	915	1260
405TS	915	1260
444	890	1260
444S	975	1250
444U	975	1250
444US	975	1250
444T	1095	1515
444TS	1095	1515
445	1035	1585
445S	1015	1585
445U	1300	1585
445US	1300	1585
445T	1250	1785
445TS	1250	1785
504U	1600	1780
504S	1580	1780
505	1785	1855
505S	1765	1855

C. Full Load Current①
Three Phase A-c Motors
(NEC Table 430-150, with permission)

	Induction Type Squirrel-Cage and Wound-Rotor Amperes					Synchronous Type Unity Power Factor② Amperes			
Hp	115v	230v	460v	575v	2300v	230v	460v	575v	2300v
½	4	2	1	.8					
¾	5.6	2.8	1.4	1.1					
1	7.2	3.6	1.8	1.4					
1½	10.4	5.2	2.6	2.1					
2	13.6	6.8	3.4	2.7					
3		9.6	4.8	3.9					
5		15.2	7.6	6.1					
7½		22	11	9					
10		28	14	11					
15		42	21	17					
20		54	27	22					
25		68	34	27		53	26	21	
30		80	40	32		63	32	26	
40		104	52	41		83	41	33	
50		130	65	52		104	52	42	
60		154	77	62	16	123	61	49	12
75		192	96	77	20	155	78	62	15
100		248	124	99	26	202	101	81	20
125		312	156	125	31	253	126	101	25
150		360	180	144	37	302	151	121	30
200		480	240	192	49	400	201	161	40

For full-load currents of 208- and 200-volt motors, increase the corresponding 230-volt motor full-load current by 10 and 15 percent, respectively.

① These values of full-load current are for motors running at speeds usual for belted motors and motors with normal torque characteristics. Motors built for especially low speeds or high torques may require more running current, and multispeed motors will have full-load current varying with speed, in which case the nameplate current rating shall be used.

② For 90 and 80 percent power factor the above figures shall be multiplied by 1.1 and 1.25 respectively.

The voltages listed are rated motor voltages. The currents listed shall be permitted for system voltage ranges of 110 to 120, 220 to 240, 440 to 480, and 550 to 600 volts.

D. Maximum Rating or Setting of Motor Branch-Circuit Short Circuit and Ground Fault Protective Devices②

Type of Motor	Percent of Full-Load Current			
	Nontime Delay Fuse	Dual-Element (Time-Delay) Fuse	Instantaneous Trip Breaker	Inverse Time Breaker
Single-phase, all types				
No code letter	300	175	700	250
All Ac single-phase and polyphase squirrel-cage and synchronous motors① with full-voltage, resistor or reactor starting:				
No code letter	300	175	700	250
Code letter F to V	300	175	700	250
Code letter B to E	250	175	700	200
Code letter A	150	150	700	150
All Ac squirrel-cage and synchronous motors① with autotransformer starting:				
Not more than 30 amps				
No code letter	250	175	700	200
More than 30 amps				
No code letter	200	175	700	200
Code letter F to V	250	175	700	200
Code letter B to E	200	175	700	200
Code letter A	150	150	700	150
High-reactance squirrel-cage				
Not more than 30 amps				
No code letter	250	175	700	250
More than 30 amps				
No code letter	200	175	700	200
Wound-rotor – No code letter	150	150	700	150
Direct-current (constant voltage)				
No more than 50 Hp				
No code letter	150	150	250	150
More than 50 Hp				
No code letter	150	150	175	150

Locked-Rotor Indicating Code Letters

Code Letter	Kilovolt-Amperes per Horsepower with Locked Rotor
A	0 – 3.14
B	3.15 – 3.54
C	3.55 – 3.99
D	4.0 – 4.49
E	4.5 – 4.99
F	5.0 – 5.59
G	5.6 – 6.29
H	6.3 – 7.09
J	7.1 – 7.99
K	8.0 – 8.99
L	9.0 – 9.99
M	10.0 – 11.19
N	11.2 – 12.49
P	12.5 – 13.99
R	14.0 – 15.99
S	16.0 – 17.99
T	18.0 – 19.99
U	20.0 – 22.39
V	22.4 – and up

The values given in the last column also cover the ratings of nonadjustable inverse time types of circuit breakers that may be modified.

① Synchronous motors of the low-torque, low-speed type (usually 450 rpm or lower), such as are used to drive reciprocating compressors, pumps, etc. that start unloaded, do not require a fuse rating or circuit-breaker setting in excess of 200 percent of full-load current.

② 1981 NEC table 430-152 re-printed with permission.

E. Maximum Permissible Capacitor kVAR for use with Open, 3-Phase, 60 Hz, Induction Motors

Motor Rating Hp	3600 rpm		1800 rpm		1200 rpm		900 rpm		720 rpm		600 rpm	
	Max. Capacitor kVAR	Reduction in Line Current %	Max. Capacitor kVAR	Reduction in Line Current %	Max. Capacitor kVAR	Reduction in Line Current %	Max. Capacitor kVAR	Reduction in Line Current %	Max. Capacitor kVAR	Reduction in Line Current %	Max. Capacitor kVAR	Reduction in Line Current %
10	3	10	3	11	3.5	14	5	21	6.5	27	7.5	31
15	4	9	4	10	5	13	6.5	18	8	23	9.5	27
20	5	9	5	10	6.5	12	7.5	16	9	21	12	25
25	6	9	6	10	7.5	11	9	15	11	20	14	23
30	7	8	7	9	9	11	10	14	12	18	16	22
40	9	8	9	9	11	10	12	13	15	16	20	20
50	12	8	11	9	13	10	15	12	19	15	24	19
60	14	8	14	8	15	10	18	11	22	15	27	19
75	17	8	16	8	18	10	21	10	26	14	32.5	18
100	22	8	21	8	25	9	27	10	32.5	13	40	17
125	27	8	26	8	30	9	32.5	10	40	13	47.5	16
150	32.5	8	30	8	35	9	37.5	10	47.5	12	52.5	15
200	40	8	37.5	8	42.5	9	47.5	10	60	12	65	14

NOTE: If capacitors of a lower rating than the values given in the table are used, the percentage reduction in line current given in the table should be reduced proportionally.

rpm shown are synchronous speed

F. Power-Factor Correction

Table values x kW load = kVA of capacitors needed to correct from existing to desired power factor.

Existing Power Factor %	Corrected Power Factor 100%	95%	90%	85%	80%	75%
50	1.732	1.403	1.247	1.112	0.982	0.850
52	1.643	1.314	1.158	1.023	0.893	0.761
54	1.558	1.229	1.073	0.938	0.808	0.676
55	1.518	1.189	1.033	0.898	0.768	0.636
56	1.479	1.150	0.994	0.859	0.729	0.597
58	1.404	1.075	0.919	0.784	0.654	0.522
60	1.333	1.004	0.848	0.713	0.583	0.451
62	1.265	0.936	0.780	0.645	0.515	0.383
64	1.201	0.872	0.716	0.581	0.451	0.319
65	1.168	0.839	0.683	0.548	0.418	0.286
66	1.139	0.810	0.654	0.519	0.389	0.257
68	1.078	0.749	0.593	0.458	0.328	0.196
70	1.020	0.691	0.535	0.400	0.270	0.138
72	0.964	0.635	0.479	0.344	0.214	0.082
74	0.909	0.580	0.424	0.289	0.159	0.027
75	0.882	0.553	0.397	0.262	0.132	
76	0.855	0.526	0.370	0.235	0.105	
78	0.802	0.473	0.317	0.182	0.052	
80	0.750	0.421	0.265	0.130		
82	0.698	0.369	0.213	0.078		
84	0.646	0.317	0.161			
85	0.620	0.291	0.135			
86	0.594	0.265	0.109			
88	0.540	0.211	0.055			
90	0.485	0.156				
92	0.426	0.097				
94	0.363	0.034				
95	0.329					

Typical Problem: With a load of 500 kW at 70% power factor, it is desired to find the kVA of capacitors required to correct the power factor to 85%.
Solution: From the table select the multiplying factor 0.400 corresponding to the existing 70%, and the corrected 85% power factor. 0.400 x 500 = 200 kVA of capacitors required.

A. Allowable Ampacities of Insulated Conductors Rated 0-2000 Volts, 60° to 90°C③

Not More Than Three Conductors in Raceway or Cable or Earth (Directly Buried), Based on Ambient Temperature of 30°C (86°F)

Size	Temperature Rating of Conductor. See Table 310-13								Size
	60°C (140°F)	75°C (167°F)	85°C (185°F)	90°C (194°F)	60°C (140°F)	75°C (167°F)	85°C (185°F)	90°C (194°F)	
AWG MCM	Types RUW, T, TW, UF ①	Types FEPW, RH, RHW, RUH, THW, THWN, XHHW, USE, ZW ①	Types V, MI	Types TA, TBS, SA, AVB, SIS, ①FEP, ①FEPB, ①RHH, ①THHN, ①XHHW②	Types RUW, T, TW, UF ①	Types RH, RHW, RUH, THW, THWN, XHHW, USE ①	Types V, MI	Types TA, TBS, SA, AVB, SIS, ①RHH, ①THHN, ①XHHW②	AWG MCM
	Copper				Aluminum or Copper-Clad Aluminum				
18	...	...	...	21	...	...	...	...	....
16	...	...	22	22	...	...	...	...	....
14	15	15	25	25	...	...	...	...	....
12	20	20	30	30	15	15	25	25	12
10	30	30	40	40	25	25	30	30	10
8	40	45	50	50	30	40	40	40	8
6	55	65	70	70	40	50	55	55	6
4	70	85	90	90	55	65	70	70	4
3	80	100	105	105	65	75	80	80	3
2	95	115	120	120	75	90	95	95	2
1	110	130	140	140	85	100	110	110	1
0	125	150	155	155	100	120	125	125	0
00	145	175	185	185	115	135	145	145	00
000	165	200	210	210	130	155	165	165	000
0000	195	230	235	235	155	180	185	185	0000
250	215	255	270	270	170	205	215	215	250
300	240	285	300	300	190	230	240	240	300
350	260	310	325	325	210	250	260	260	350
400	280	335	360	360	225	270	290	290	400
500	320	380	405	405	260	310	330	330	500
600	355	420	455	455	285	340	370	370	600
700	385	460	490	490	310	375	395	395	700
750	400	475	500	500	320	385	405	405	750
800	410	490	515	515	330	395	415	415	800
900	435	520	555	555	355	425	455	455	900
1000	455	545	585	585	375	445	480	480	1000
1250	495	590	645	645	405	485	530	530	1250
1500	520	625	700	700	435	520	580	580	1500
1750	545	650	735	735	455	545	615	615	1750
2000	560	665	775	775	470	560	650	650	2000

Correction Factors

Ambient Temp. °C	For ambient temperature over 30°C, multiply the ampacities shown above by the appropriate correction factor to determine the maximum allowable load current.								Ambient Temp. °F
31-40	.82	.88	.90	.91	.82	.88	.90	.91	86-104
41-50	.58	.75	.80	.82	.58	.75	.80	.82	105-122
51-60	...	.58	.67	.71	...	.58	.67	.71	123-141
61-70	...	.35	.52	.58	...	.35	.52	.58	142-158
71-80	...	...	.30	.41	...	...	.30	.41	159-176

① The load current rating and the overcurrent protection for these conductors shall not exceed 15 amperes for 14 AWG, 20 amperes for 12 AWG, and 30 amperes for 10 AWG copper; or 15 amperes for 12 AWG and 25 amperes for 10 AWG aluminum and copper-clad aluminum.

② For dry locations only. See 75°C column for wet locations.

③ 1978 NEC Table 310-16 reprinted with permission.

B. Maximum Number of Conductors in Trade Sizes of Conduit or Tubing

Conduit Trade Size (Inches)		½	¾	1	1¼	1½	2	2½	3	3½	4	4½	5	6
Type Letters	Conductor Size AWG, MCM													
TW, T, RUH,	14	9	15	25	44	60	99	142						
RUW,	12	7	12	19	35	47	78	111	171					
XHHW (14 thru 8)	10	5	9	15	26	36	60	85	131	176				
	8	2	4	7	12	17	28	40	62	84	108			
RHW and RHH	14	6	10	16	29	40	65	93	143	192				
(without outer	12	4	8	13	24	32	53	76	117	157				
covering),	10	4	6	11	19	26	43	61	95	127	163			
THW	8	1	3	5	10	13	22	32	49	66	85	106	133	
TW,	6	1	2	4	7	10	16	23	36	48	62	78	97	141
T,	4	1	1	3	5	7	12	17	27	36	47	58	73	106
THW,	3	1	1	2	4	6	10	15	23	31	40	50	63	91
RUH (6 thru 2),	2	1	1	2	4	5	9	13	20	27	34	43	54	78
RUW (6 thru 2),	1		1	1	3	4	6	9	14	19	25	31	39	57
FEPB (6 thru 2),														
RHW and	0		1	1	2	3	5	8	12	16	21	27	33	49
RHH (without	00		1	1	1	3	5	7	10	14	18	23	29	41
outer covering)	000		1	1	1	2	4	6	9	12	15	19	24	35
	0000			1	1	1	3	5	7	10	13	16	20	29
	250			1	1	1	2	4	6	8	10	13	16	23
	300			1	1	1	2	3	5	7	9	11	14	20
	350				1	1	1	3	4	6	8	10	12	18
	400				1	1	1	2	4	5	7	9	11	16
	500				1	1	1	1	3	4	6	7	9	14
	600					1	1	1	3	4	5	6	7	11
	700					1	1	1	2	3	4	5	7	10
	750					1	1	1	2	3	4	5	6	9

C. Conductor Sizes and Overcurrent Protection

Full Load Current Rating of Motor	Minimum Size Wire and Conduit						For Running Protection of Motors		Maximum With Code Letters Single-phase, Squirrel Cage and Synchronous Full Voltage, Resistor or Reactor Starting Code Letters F to V Inc. Without Code Letters Same as Above	
	Type R and T			Type RH			Maximum Rating of Non-adjustable Protective Device	Maximum Setting of Adjustable Protective Device	Amps	
		Conduit Size			Conduit Size					
Amperes	Wire Size	2 Wire	3 Wire	Wire Size	2 Wire	3 Wire	Amps	Amps	Fuse	Breaker
1	14	½	½	14	½	½	2	1.25	15	15
2	14	½	½	14	½	½	3	2.50	15	15
4	14	½	½	14	½	½	6	5.00	15	15
6	14	½	½	14	½	½	8	7.50	20	15
8	14	½	½	14	½	½	10	10.0	25	20
10	14	½	½	14	½	½	15	12.5	30	30
12	14	½	½	14	½	½	15	15.0	40	30
14	12	½	½	12	½	½	20	17.5	45	40
16	12	½	½	12	½	½	20	20.0	50	40
18	10	¾	¾	10	¾	¾	25	22.5	60	50
20	10	¾	¾	10	¾	¾	25	25.0	60	50
24	10	¾	¾	10	¾	¾	30	30.0	80	70
28	8	¾	¾	8	¾	¾	35	35.0	90	70
32	8	¾	¾	8	¾	¾	40	40.0	100	100
36	6	1	1	8	¾	¾	45	45.0	110	100
40	6	1	1	6	1	1	50	50.0	125	100
44	6	1	1	6	1	1	60	55.0	125	125
48	4	1¼	1¼	6	1	1	60	60.0	150	125
52	4	1¼	1¼	6	1	1	70	65.0	175	150
56	4	1¼	1¼	4	1¼	1¼	70	70.0	175	150
60	3	1¼	1¼	4	1¼	1¼	80	75.0	200	150
64	3	1¼	1¼	4	1¼	1¼	80	80.0	200	175
68	2	1¼	1¼	4	1¼	1¼	90	85.0	225	175
72	2	1¼	1¼	3	1¼	1¼	90	90.0	225	200
76	2	1¼	1¼	3	1¼	1¼	100	95.0	250	200
80	1	1½	1½	3	1¼	1¼	100	100.0	250	200
84	1	1½	1½	2	1¼	1¼	110	105.0	250	225
92	0	1½	2	2	1¼	1¼	125	115.0	300	250
96	0	1½	2	1	1½	1½	125	120.0	300	250
100	0	1½	2	1	1½	1½	125	125.0	300	250
120	000	2	2	0	1½	2	150	150.0	400	300
130	000	2	2	00	2	2	175	162.5	400	350
140	4/0	2	2½	00	2	2	175	175.0	450	350
150	4/0	2	2½	000	2	2	200	187.5	450	400
160	250	2½	2½	000	2	2	200	200.0	500	400
170	250	2½	2½	4/0	2	2½	225	213.0	500	500
180	300	2½	2½	4/0	2	2½	225	225.0	600	500
200	350	3	3	250	2½	2½	250	250.0	600	500
240	500	3	3	350	3	3	300	300.0	...	600
300	700	3½	3½	500	3	3	400	375.0	...	...

D. Short Circuit Protection for Trailing Mine Cables

Maximum permissible breaker overload settings, instantaneous trip, for various sizes of mine trailing cable (from Federal Register).

Circuit breakers providing short circuit protection for trailing cables shall be set so as not to exceed the maximum allowable instantaneous settings specified in this section; however, higher settings may be permitted by an authorized representative of the Secretary when he has determined that special applications are justified:

Conductor Size AWG or MGM	Maximum Allowable Circuit Breaker Instantaneous Setting (Amperes)
14	50
12	75
10	150
8	200
6	300
4	500
3	600
2	800
1	1,000
1/0	1,250
2/0	1,500
3/0	2,000
4/0	2,500
250	2,500
300	2,500
350	2,500
400	2,500
450	2,500
500	2,500

E. Dimensions, Weight, and Resistance of Pure Copper

Gauge A. W. G.	Dia. In.	Area Circular Mils (d^2) 1 Mil = .001 in.	Lb. per 1000 Feet Bare Wire	Length Feet per lb.	Resistance at 77°F. Ohms per 1000 ft.
Stranded					
	1.151	1000000.	3090.	.3235	.0108
	1.029	800000.	2470.	.4024	.0135
	.963	700000.	2160.	.4628	.0154
	.891	600000.	1850.	.5400	.0180
	.814	500000.	1540.	.6488	.0216
	.726	400000.	1240.	.8060	.0270
	.574	250000.	772.	1.30	.0431
Solid					
0000	.4600	211600.	640.5	1.55	.0500
000	.4096	167800.	507.9	1.97	.0630
00	.3648	133100.	402.8	2.48	.0795
0	.3248	105500.	319.5	3.13	.1002
1	.2893	83690.	253.3	3.95	.1264
2	.2576	66370.	200.9	4.98	.1593
3	.2294	52640.	159.3	6.28	.2009
4	.2043	41740.	126.4	7.91	.2533
6	.1620	26250.	79.46	12.58	.4028
8	.1284	16510.	49.98	20.01	.6405
10	.1018	10380.	31.43	31.82	1.018
12	.0808	6530.	19.77	50.59	1.619
14	.0640	4107.	12.43	80.44	2.575
16	.0508	2583.	7.82	127.90	4.094
18	.0403	1624.	4.92	203.40	6.510
20	.0319	1022.	3.09	323.4	10.35
22	.0254	642.	1.95	514.2	16.46
24	.0201	404.	1.22	817.7	26.17
26	.0159	254.	.77	1300.	41.62
28	.0126	159.8	.48	2067.	66.17
30	.0100	100.5	.30	3287.	105.2
32	.0080	63.2	.19	5227.	167.3
34	.0063	39.7	.12	8310.	266.0
36	.0050	25.0	.076	13210.	423.0
38	.0040	15.7	.047	21010.	672.6
40	.0031	9.89	.030	33410.	1069.0
42	.0025	6.22	.019	52800.	1701.
44	.0020	3.91	.012	82500.	2703.
46	.0016	2.46	.008	128800.	4299.
48	.0012	1.55	.004	229600.	6833.
50	.0010	0.97	.003	330000.	10870.

F. Aluminum Wire – Property Limits – Conductivity

Alloy and Temper	Specified Dia. Inches	Elongation Percent Min. in 10 Inches		Electrical Conductivity Min. Percent 1ACS at 20°C (68°F)
		Individual	Average	
1350-H19	0.0105-0.0500	...	...	61.0
	0.0501-0.0600	1.2	1.4	
	0.0601-0.0700	1.3	1.5	
	0.0701-0.0800	1.4	1.6	
	0.0801-0.0900	1.5	1.6	
	0.0901-0.1000	1.5	1.6	
	0.1001-0.1100	1.5	1.6	
	0.1101-0.1200	1.6	1.7	
	0.1201-0.1400	1.7	1.8	
	0.1401-0.1500	1.8	1.9	
	0.1501-0.1800	1.9	2.0	
	0.1801-0.2100	2.0	2.1	
	0.2101-0.2600	2.2	2.3	
5005-H19	0.0601-0.0700	1.3	...	53.5
	0.0701-0.0800	1.4	...	
	0.0801-0.0900	1.5	...	
	0.0901-0.1000	1.5	...	
	0.1001-0.1100	1.5	...	
	0.1101-0.1200	1.6	...	
	0.1201-0.1400	1.7	...	
	0.1401-0.1500	1.8	...	
	0.1501-0.1600	1.9	...	
	0.1601-0.2100	2.0	...	
	0.2101-0.2600	2.2	...	
6201-T81	0.0612-0.1327	3.0	...	52.5
	0.1328-0.1878	3.0	...	

G. Aluminum Wire – Property Limits – Resistivity at 20°C (68°F)

Volume Conductivity Percent 1ACS at 20°C (68°F)	Volume Ohm – Circ. Mil/Ft	Ohm – mm^2/Metre	Microhm – In.	Microhm cm
52.5	19.754	0.03284	1.2929	3.284
53.5	19.385	0.032226	1.2688	3.2226
61.0	17.002	0.028264	1.1128	2.8264

H. Properties of Conductors

Size AWG, MCM	Area Cir. Mils	Concentric Lay Stranded Conductors		Bare Conductors		Dc. Resistance Ohms/M Ft. At 25°C, 77°F.		
						Copper		Aluminum
		No. Wires	Diam. Each Wire Inches	Diam. Inches	Area Sq. Inches	Bare Cond.	Tin'd. Cond.	
18	1620	Solid	.0403	.0403	.0013	6.51	6.79	10.7
16	2580	Solid	.0508	.0508	.0020	4.10	4.26	6.72
14	4110	Solid	.0641	.0641	.0032	2.57	2.68	4.22
12	6530	Solid	.0808	.0808	.0051	1.62	1.68	2.66
10	10380	Solid	.1019	.1019	.0081	1.018	1.06	1.67
8	16510	Solid	.1285	.1285	.0130	.6404	.659	1.05
6	26240	7	.0612	.184	.027	.410	.427	.674
4	41740	7	.0772	.232	.042	.259	.269	.424
3	52620	7	.0867	.260	.053	.205	.213	.336
2	66360	7	.0974	.292	.067	.162	.169	.266
1	83690	19	.0664	.332	.087	.129	.134	.211
0	105600	19	.0745	.372	.109	.102	.106	.168
00	133100	19	.0837	.418	.137	.0811	.0843	.133
000	167800	19	.0940	.470	.173	.0642	.0668	.105
0000	211600	19	.1055	.528	.219	.0509	.0525	.0836
250	250000	37	.0822	.575	.260	.0431	.0449	.0708
300	300000	37	.0900	.630	.312	.0360	.0374	.0590
350	350000	37	.0973	.681	.364	.0308	.0320	.0505
400	400000	37	.1040	.728	.416	.0270	.0278	.0442
500	500000	37	.1162	.813	.519	.0216	.0222	.0354
600	600000	61	.0992	.893	.626	.0180	.0187	.0295
700	700000	61	.1071	.964	.730	.0154	.0159	.0253
750	750000	61	.1109	.998	.782	.0144	.0148	.0236
800	800000	61	.1145	1.030	.833	.0135	.0139	.0221
900	900000	61	.1215	1.090	.933	.0120	.0123	.0197
1000	1000000	61	.1280	1.150	1.039	.0108	.0111	.0177
1250	1250000	91	.1172	1.289	1.305	.00863	.00888	.0142
1500	1500000	91	.1284	1.410	1.561	.00719	.00740	.0118
1750	1750000	127	.1174	1.526	1.829	.00616	.00634	.0101
2000	2000000	127	.1255	1.630	2.087	.00539	.00555	.00885

1.5 Full Load Line Amperes for Three-Phase① Transformers or Loads

kVA	Volts 208	240	480	600	2400	4160	13200
1.5	4.16	3.61	1.80	1.44	.....	.....	.....
3	8.33	7.22	3.61	2.89	0.72	0.42	0.13
5	13.88	12.03	6.01	4.81	1.20	0.69	0.22
7.5	20.82	18.04	9.02	7.22	1.80	1.04	0.33
10	27.76	24.06	12.03	9.62	2.41	1.39	0.44
15	41.63	36.08	18.04	14.43	3.61	2.08	0.66
25	69.39	60.14	30.07	24.05	6.01	3.47	1.09
37.5	104.09	90.21	45.10	36.08	9.02	5.20	1.64
50	138.78	120.28	60.14	48.11	12.03	6.94	2.19
75	208.17	180.42	90.21	72.16	18.04	10.41	3.28
100	277.56	240.56	120.28	96.22	24.06	13.88	4.37
150	416.34	360.84	180.42	144.33	36.08	20.82	6.56
200	555.12	481.12	240.56	192.44	48.11	27.76	8.75
300	832.68	721.67	360.83	288.66	72.17	41.63	13.12
400	1110.25	962.23	481.11	384.87	96.22	55.51	17.49
500	1387.81	1202.79	601.39	481.09	120.28	69.39	21.87
750	2081.71	1804.19	902.09	721.64	180.42	104.09	32.80
1000	2775.62	2405.58	1202.79	962.19	240.56	138.78	43.74

① For single-phase transformers or loads, multiply the above three-phase values by 1.73. Example: A 5 kVA single-phase transformer has a line current of 12.03 x 1.73 = 20.8 amperes at 240v when operating at full load.

1.6 Voltage Regulation – Quick Estimating Data

Three phase power in terms of KW x Distance is shown for 5% regulation and 80% P.F.

Use correction factor for other power factors

Approximate Voltage Regulation Correction Factor 70% P-f	90% P-f	100% P-f	Copper Conductor Wire Size	kW x Hundreds of Feet (8" Spacing) 208v 3θ	240v 3θ	460v 3θ	550v 3θ	kW x Miles (36" Spacing) 4160v 3θ	4800v 3θ	12,470v 3θ	13,200v 3θ	% Loss 5% Reg. 80% P-f 8" Sp	36"
0.93	1.07	1.25	#6	40	52	193	278	286	381	2,571	2,880	6.5	6.2
0.92	1.10	1.30	#4	58	76	282	406	407	543	3,667	4,107	6.1	5.6
0.89	1.13	1.51	#2	82	108	399	574	560	745	5,036	5,640	5.4	4.9
0.86	1.18	1.75	1/0	112	149	548	789	741	987	6,668	7,468	4.7	4.1
0.85	1.21	1.91	2/0	130	172	633	912	839	1,117	7,547	8,454	4.3	3.7
0.82	1.25	2.28	4/0	168	222	819	1,179	1,038	1,383	9,341	10,463	3.5	2.9
0.82	1.27	2.41	250,000	186	245	905	1,303	1,125	1,498	10,123	11,338	3.3	2.6
0.81	1.31	2.72	350,000	215	283	1,046	1,506	1,260	1,678	11,338	12,699	2.7	2.1
0.80	1.34	3.13	500,000	247	327	1,205	1,735	1,402	1,867	12,617	14,132	2.2	1.7

Example: How much power can be transmitted 2.5 miles at 4,800 volts 3θ over No. 2 wire at 90% P-f and 7% regulation?
(1) From Table 745 ÷ 2.5 = 298 kW at 5% reg. 80% P-f
(2) 90% P-f correction factor = 1.13: 1.13 × 298 = 337 kW at 90% P-f
(3) 337 × 7/5 = approx. 472 kW at 7% reg., 90% P-f
Note: For single phase power based on line-to-neutral voltage, divide above values by 6.
e.g. 40 at 208v, 3θ gives 40/6 = 6.67 at 120v, 1θ.
For single-phase power based on line-to-line voltage, divide above values by 2.
e.g. 52 at 240v. 3θ gives 52/2 = 26 at 240v. 1θ.

Volume 4
Chapter 2

Connection and Terminal Markings

Warning: Follow the safety instructions given in Volume 1 Chapter 5, and throughout the book. Failure to do so can result in severe personal injury or death, and substantial damage to property.

Connection and Terminal Markings

The markings on the external leads of an induction motor are sometimes removed or defaced. Proper identification must be made before the motor can be connected to the line. This identification requires only a lighting or ringing circuit, a voltmeter with a range covering the motor operating voltage, and a means of measuring approximate resistance.

Warning: Take care to prevent short-circuits between leads of the same group, as these leads are all live. Failure to heed this warning can cause severe personal injury or death, and damage to property.

Three-phase, three-lead and two-phase, four-lead motors are no particular problem.

A three-phase motor with three leads brought out should be connected to the line in any convenient way and then if it rotates in the wrong direction, any two leads should be interchanged. A two-phase motor with four leads may be lighted out to determine which leads belong to one phase. These two leads are then connected to one phase of the line and the other two leads to the other phase. If the motor rotates in the wrong direction, the two leads of either phase should be interchanged. The real problem comes with double-voltage and consequent-pole motors, which have more leads and circuits.

2.1 Double-Voltage Motors

A. Three-Phase Star Connection—This type of motor will have nine leads and four separate circuits, as shown in Figure 1. Three circuits have two leads each, and the fourth has three leads. The circuits should be tested out with a lamp or buzzer, and the three leads on a common circuit forming the internal star should be permanently tagged T-7, T-8 and T-9 in any order. The other leads should be temporarily tagged T-1, T-4 for one circuit; T-2, T-5 on the second circuit; and T-3, T-6 on the third circuit. It will be assumed here that in all cases of double voltage the motor is wound to operate on 220-440 volts, as this is the most common voltage range. For any other voltages all the following test voltages should be changed in proportion to the motor rating.

The motor may be started on 220 volts, with leads T-7, T-8 and T-9 connected to the source of power and all other leads disconnected. If the motor is too large to be started by connecting it directly to the line, the

starting voltage should be reduced as in the regular operation of the motor. With the motor running light, the voltage across each of the three open circuits should be measured. This voltage should be slightly under 127 volts and should be the same on all three circuits. With the motor still running, connect T-7 to T-4 and measure the voltage across leads T-1 and T-8, also across leads T-1 and T-9. If these voltages are both of the same value and equal about 335 volts, tags T-1 and T-4 should be marked permanently. If the two voltages are of the same value and equal about 127 volts, interchange T-1 and T-4. If the voltage between T-1, T-8 and T-1, T-9 are unequal, then disconnect T-4 from T-7 and connect T-4 to T-8, measuring the voltages between T-1, T-7 and T-1, T-9. Changes and measurements should be made in this way until a position is found at which both voltages are equal and of a value of about 335 volts. With the motor still running light, and with leads T-7, T-8, T-9 used as terminals, leads T-4, T-5, T-6 may be connected together and the voltage read between leads T-1, T-2, T-3. The voltage thus read should equal approximately 220 volts. For a further check, the motor should be shut down and reconnected, using leads T-1, T-2, T-3 as terminals, with T-4, T-5 and T-6 connected together and leads T-7, T-8 and T-9 disconnected. Care should be taken to connect the line that was on T-7 to T-1, the one that was on T-8 to T-2, and the one that was on T-9 to T-3. The direction of rotation should be the same as with the previous connection. The motor is now ready to operate on 220 volts by connecting T-4, T-5 and T-6 together and using T-1, T-7 as one lead; T-2, T-8 as another; and T-3, T-9 as a third. By connecting T-4 to T-7, T-5 to T-8, and T-6 to T-9 and using T-1, T-2, T-3 as leads, the motor should operate on 440 volts.

The connection plate mounted on the motor may disagree with the lead markings as determined herein and shown on Figure 1, indicating that markings T-4 and T-7 are interchanged, as well as T-5 and T-8, and T-6 and T-9. Lead markings as shown on Figure 1 is the present NEMA standard, whereas, Figure 1a illustrates the lead marking as formerly used on some dual-voltage star connected motors. When re-marking motor leads it is recommended that the present standard marking be adhered to in every case, and where necessary the connection plate be revised or replaced.

B. Three-Phase Delta Connection—This motor will also have nine leads but only three separate circuits; three leads are connected to each circuit. In this case it is also necessary to have an instrument for measuring resistance in addition to other equipment. Only comparative values, not actual values, are required. Such values can be obtained with a Wheatstone bridge; or comparative results can be obtained by taking the voltage drop over the various parts of the circuit with a millivolt meter. There should be a constant value of direct current in the windings which should not exceed the current rating of the motor.

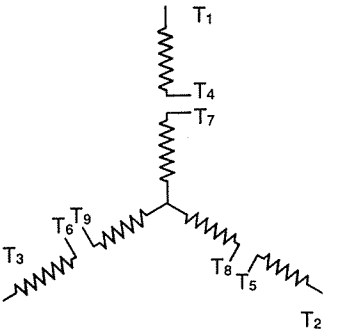


Fig. 1 – Dual-Voltage Three-Phase Star Connection

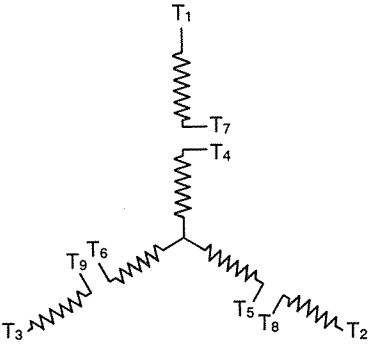


Fig. 1a – Dual-Voltage Star Connection (obsolete)

It is necessary to find leads T-1, T-2 and T-3, Figure 2. They can be found by an approximate measurement of resistance, since the resistance from T-4 to T-9 is twice that from T-4 to T-1. T-2 and T-3 are similarly located by corresponding measurements in the other circuits. These leads should then be permanently marked. The remaining leads in the circuit containing T-1 should be temporarily marked T-4 and T-9; those in the same circuit with T-2 should be marked T-5 and T-7; and those in the same circuit with T-3 should be marked T-8 and T-6 in any order.

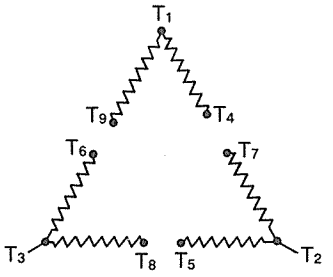


Fig. 2 – Dual-Voltage Three-Phase Delta Connection

After leads T-1, T-2 and T-3 have been located, the motor should be started and run on 220 volts, using T-1, T-4 and T-9 as leads and leaving all other terminals disconnected. T-4, T-7 should then be connected together and the voltage read between T-1 and T-2. If this voltage equals approximately 440 volts, the marking is correct. If this voltage is approximately 380 volts, interchange T-5 and T-7 or T-4 and T-9 and

measure the voltage again. If it is approximately 220 volts, interchange both T-5, T-7 and T-4, T-9. When this voltage equals approximately 440 volts, mark T-4, T-9, T-7 and T-5 permanently, taking care that leads are marked T-4 and T-7 which when connected together gives 440 volts between T-1 and T-2. A similar procedure should then be followed, connecting T-6 to T-9 and measuring the voltage between T-1 and T-3. When the markings are all correct, the voltages between T-1, T-2, and T-3 should equal approximately 440 volts.

As a check the motor should be shut down and reconnected using T-2, T-5 and T-7 as leads. Care should be taken that T-7 is attached to the line previously connected to T-9, T-2 attached to the line previously connected to T-1, and T-5 to the line previously connected to T-4. When the motor is again started, the direction of rotation should be in the same direction as with the previous connection. If the direction of rotation is correct, the motor should again be reconnected using T-3, T-6, T-8 as leads and connecting the line from T-5 to T-6, the line from T-2 to T-3 and the line from T-7 to T-8. When the motor is again started, the direction of rotation should be in the same direction as with the previous connections. When the above tests have been completed, the motor is ready to be connected permanently. If it is desired to run the motor on 220 volts, connect T-6, T-1, and T-7 together and use them as one lead; T-4, T-2, and T-8 as a second lead; and T-3, T-9, and T-5 as a third lead. If it is desired to run the motor on 440 volts, connect T-4 to T-7, T-5 to T-8 and T-6 to T-9 using T-1, T-2 and T-3 as leads. Permanent markings should be made on all leads.

The two-phase double-voltage motor can always be distinguished by its eight leads. There are four separate circuits with two leads to a circuit. Trace out the circuits by a lamp or buzzer as in the previous case. Temporarily tag the leads on the first circuit T-1, T-5; those on the second circuit T-2, T-6; those on the third circuit T-3, T-7; and those on the fourth circuit T-4, T-8. Start the motor and run it single phase on 220 volts, using any pair of leads from a single circuit. In order to do so it will be necessary to bring the motor up to speed by externally applied power. This is preferably done by belting it to another motor. However, any available means of giving the motor a slight start is satisfactory, as it will come up to speed single phase if given a sufficient start. Connect T-7 to T-5 and measure the voltage from T-1 to T-3. If the voltage equals 440 volts, mark T-1, T-5, T-3, and T-7 permanently. If this voltage is zero, interchange either pair of leads. If the voltage measured equals approximately 310, disconnect T-7 and try leads from another circuit until one is found that will give 440 volts from T-1 to the lead on the other end of the circuit. When such a circuit is found, mark the leads permanently T-1, T-5 and T-7, T-3, being careful that leads marked T-6 and T-7 are those which when connected give 440 volts

between T-1 and T-8. This procedure should then be followed with the other four leads making final markings as shown in Figure 3. When all the leads have been permanently marked, the motor may be connected for 440-volt operation by connecting T-5 to T-7, T-6 to T-8 and using T-1, T-3 as leads for one phase and T-2, T-4 as leads for the second phase. For operation on 220 volts, connect T-1 to T-7, T-2 to T-8, T-3 to T-5, and T-4 to T-6. Use T-2, T-8 and T-4, T-6 as leads on one phase and T-1, T-7 and T-3, T-5 as leads on the second phase.

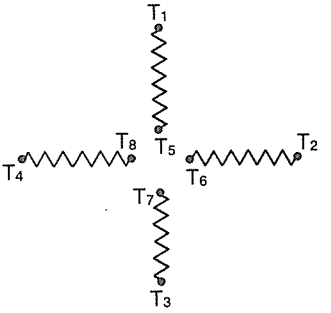


Fig. 3 – Two-Phase Double-Voltage Motor Connection

2.2 Two-Speed, Consequent-Pole Motors

An induction motor using the consequent-pole principle to obtain two speeds with a single winding requires that six leads be brought out. In this case all leads are interconnected, so that it is not necessary to test for separate circuits. In the following discussion it will be assumed that the motor is wound to run on 220 volts. If it is wound for any other voltage, the test voltages given should be changed in proportion to the change in rating.

The star-connected motor (shown in Figure 4) is used for variable torque ratings having a high-speed horsepower rating four times the low-speed horsepower rating. If this fact is not apparent from the name-plate reading, the motor can be identified as star-connected by measuring the resistance between the various leads. Referring to the left portion of Figure 4, it can be seen that regardless of between which two leads the resistance is measured, a relative value of either 1, 2, 3, or 4 must be obtained. For example, if the resistance between T-1 and T-4 is 1, then between T-4 and T-6 the resistance will be 2, between T-1 and T-6 it will be 3, and between T-1 and T-2 it will be 4. Hence the three leads having the highest resistance (relative value of 4) between them should be located and permanently marked T-1, T-2, and T-3. Then the

resistance between T-1 and each of the remaining three unmarked leads should be measured, and the lead that gives lowest resistance (relative value of 1) should be marked T-4. Similarly, the resistance between lead T-2 and each of the two remaining unmarked leads should be measured, and the lead that gives a relative resistance of 1 should be marked T-6. The final remaining lead should be marked T-5.

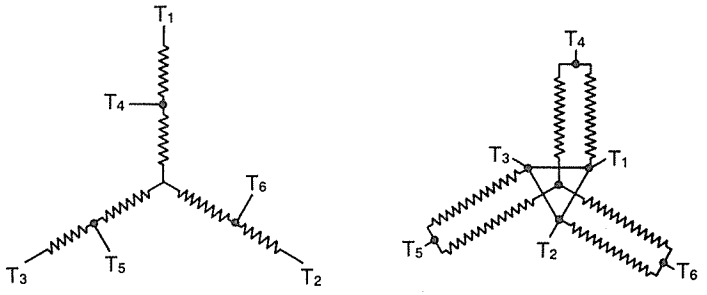


Fig. 4 – Two-Speed Variable-Torque Star Connected Motor

The lead marking thus determined should then be checked by running the motor at normal voltage with T-1, T-2, and T-3 connected to the line and leads T-4, T-5, and T-6 left open. The motor should run at its normal slow speed, this being the series-star connection shown in left half of Figure 4. The direction of rotation should be noted.

Finally, leads T-1, T-2, and T-3 should be connected together and leads T-4, T-5, and T-6 connected to the line, with T-4 to the same line lead previously used for T-1, T-5 to line lead previously used for T-2, and T-6 to the lead used for T-3. The motor should run at its normal high speed and have the same direction of rotation as before, this being the parallel-star connection shown in the right half of Figure 4.

The delta-connected motor (Figure 5) for constant torque ratings has a high-speed horsepower rating twice the low-speed horsepower rating. It can be distinguished from the star-connected motor by measuring the resistances. Referring to the left portion of Figure 5, it can be seen that regardless of between which two leads the resistance is measured, a relative value of either 1, 1.6, or 1.8 must be obtained. For example, if the resistance between T-1 and T-6 is 1, then between T-1 and T-2 or between T-5 and T-6 the resistance must be 1.6, and between T-1 and T-5 it must be 1.8. The lowest value of resistance obtainable (relative value of 1) between any two leads should be found, and if the motor is delta-connected it will be possible to go through all the leads measuring the lowest value of resistance from lead to lead and ending up at the lead at which the start was made. Starting with the first pair of leads

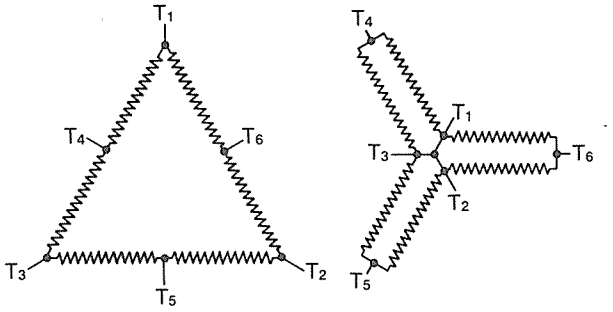


Fig. 5 – Two-Speed Constant-Torque Delta Connected Motor

that give the lowest resistance (relative value of 1) between terminals, mark them temporarily T-1 and T-6. The lead should then be found which will give a resistance to T-6 equal that between T-6 and T-1. When this lead is found, it should be marked T-2. The lead should then be found which will give the same resistance to T-2 as that between T-2 and T-6, and this lead should be marked T-5. This procedure should be followed until all the leads have been used. They should be marked from the beginning and in the order in which they are found T-1, T-6, T-2, T-5, T-3, and T-4. When all leads have been marked as described, the motor should be started and run single phase applying 110 volts across T-1 and T-6. The voltage should then be measured between T-1 and T-2, between T-2 and T-3 and between T-3 and T-1. If each of these readings is 220 volts, then the leads are correctly marked and the markings should be permanently affixed. If these readings are 110 volts, then permanently remark all leads changing T-6 to T-1, T-2 to T-6, T-5 to T-2, T-3 to T-5, T-4 to T-3, and T-1 to T-4. Start up again and with 110 volts single phase impressed on T-1 and T-6, check the voltage from T-1 to T-2, from T-2 to T-3, and from T-3 to T-1, each of which should equal 220 volts.

To operate the motor at slow speed, use T-1, T-2, and T-3 as line leads with leads T-4, T-5, and T-6 disconnected, giving a series-delta connection as shown at the left in Figure 5. Note the direction of rotation.

To operate at high speed connect leads T-1, T-2, and T-3 together and connect T-4, T-5, and T-6 to the line, using the same line lead for T-4 as previously used for T-1, similarly for T-5 and T-2 and for T-6 and T-3. This should give the same direction of rotation as on previous slow-speed operation and is the parallel-star connection shown at the right in Figure 5.

The delta-connected motor for constant horsepower has the same relative resistances between leads as its constant-torque counterpart, hence it can be distinguished from the latter only by observing the nameplate rating. The determination of proper lead marking for the two types of connections is essentially the same.

Referring to Figure 6, first locate any pair of leads that give the lowest resistance between terminals and mark them temporarily T-4 and T-1. The lead should then be found which gives a resistance to T-1 equal to that between T-4 and T-1, and this lead should be marked T-6. The lead should then be found which gives a resistance to T-6 equal to that between T-6 and T-1, this lead being marked T-2. This procedure should be followed until all the leads are used, and they should be temporarily marked from the beginning and in the order in which they are found as T-4, T-1, T-6, T-2, T-5, and T-3. When all leads have been marked as described, the motor should be started and run single phase with 110 volts impressed across T-4 and T-1. The voltage should then be measured between T-4 and T-6, between T-6 and T-5 and between T-5 and T-4. If each of these readings is 220 volts, then the leads are correctly marked and the markers should be permanently affixed. If these readings are 110 volts, then permanently re-mark all leads changing T-1 to T-4, T-6 to T-1, T-2 to T-6, T-5 to T-2, T-3 to T-5 and T-4 to T-3. Start up again and with 110 volts single-phase applied across leads T-4 and T-1, check the voltage between T-4 and T-6, between T-6 and T-5, and between T-5 and T-4. Each reading should now be 220 volts.

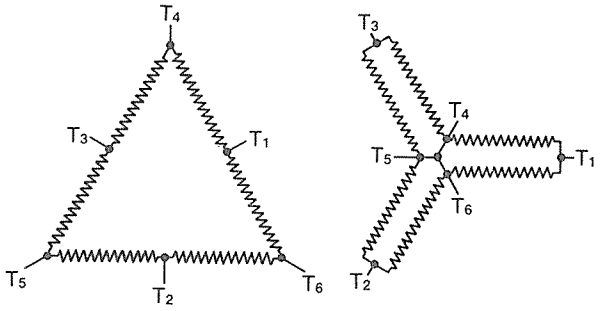


Fig. 6 – Delta Connected Motor for Constant-Horsepower

To operate the motor at high speed, connect leads T-4, T-5, and T-6 to the line with leads T-1, T-2, and T-3 disconnected giving the series-delta connection shown at the left in Figure 6. Note the direction of rotation.

To operate the motor at slow speed connect leads T-4, T-5 and T-6 together and T-1, T-2 and T-3 to the line, using same line lead for T-1 as previously used to T-4, and similarly for T-2 and T-5 and for T-3 and T-6. This should give the same direction of rotation as obtained in previous high-speed operation and is the parallel-star connection shown at the right in Figure 6.

The open-delta connection is frequently used for consequent-pole motors, particularly for four-speed, two-winding motors to avoid the possibility of harmful circulating currents being induced in the idle winding while the other is energized. The connections are identical to the previously discussed closed-delta connections, except that one corner of the delta is opened and an extra lead T-7 is provided.

Figure 7 shows the lead markings for the open-delta constant torque connection. There are obviously six relative values of resistance between leads, these being 1, 2, 3, 4, 5, or 6 depending upon which pair of leads are used. First locate the pair of leads that give the highest resistance (relative value of 6) and mark these leads T-3 and T-7. Then the lead should be located that gives the lowest resistance (relative value of 1) to T-3, and this lead marked T-4. Then the unmarked lead should be located that gives the lowest resistance (relative value of 1) to T-4, and this lead marked T-1. This procedure should be followed until all leads are used, and they should be marked from the beginning and in the order in which they are found as T-3, T-4, T-1, T-6, T-2, T-5 and ending with T-7. The connections for a two-speed motor are shown in Figure 7.

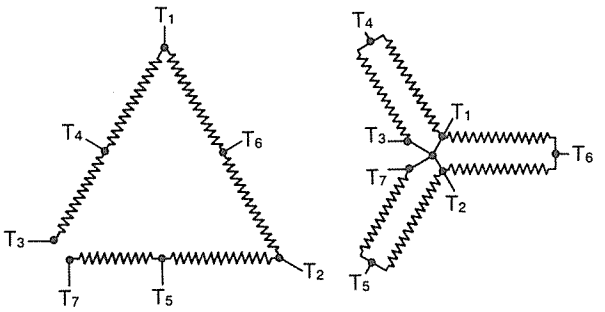


Fig. 7 – Open-Delta Constant-Torque Connection (similar to Fig. 4 but used for Two-winding Multi-speed Motors)

For a four-speed motor, the second winding is marked identically to the first, except that ten is added to each lead number, that is T-1 will be T-11, T-2 will be T-12, etc. After first determining which leads belong to a common winding by ringing or lighting out the two separate circuits, lead identification can proceed as outlined above. The winding

containing leads T-1, through T-7 will give the lowest and next to highest speeds; the winding containing leads T-11 through T-17 will give the highest and next to lowest speeds.

Figure 8 shows the lead markings for the open-delta constant horsepower connection. Relative resistances, procedure for lead identification, marking of the second winding in a four-speed two-winding motor, and the relative speeds provided by the two windings are all identical to the constant-torque motor except that the sequence around the open-delta is T-5, T-3, T-4, T-1, T-6, T-2 and T-7 with low and high-speed connections as shown in Figure 8.

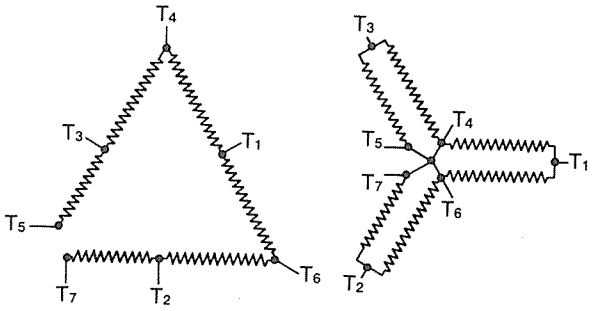


Fig. 8 – Open-Delta Constant-Horsepower Connection

2.3 D-C Machines

D-C machines may be divided basically into three types: shunt, series, and compound wound. All three types may have the same armature and frame, differing one from another only in the arrangement of the field coils and the wiring around the frame. Each type may or may not have commutating poles and compensating windings, although most machines today are of the non-compensated commutating pole type.

The purpose of applying markings to the terminals of electrical power apparatus according to a standard is to aid in making connections to other parts of the electric power system and to avoid improper connections which may result in unsatisfactory operation or damage.

Terminal markings are used to tag only those terminals to which connections must be made from outside circuits or from auxiliary devices which must be disconnected for shipment. The subscript numerals indicate the direction of current flow in the windings. That is, with a standard direction of shaft rotation and polarity, the current in all windings will be flowing from 1 to 2 or from a lower to a higher subscript numeral. In d-c machines A-1 and A-2 always indicate the armature leads, S-1 and S-2 the series-field leads, and F-1 and F-2 the shunt-field leads.

A. Direct-Current Motors—General

The standard direction of shaft rotation for d-c motors is clockwise facing the drive end. To obtain standard direction of shaft rotation, the motor must be connected to the line in such a way that the current will flow through the first winding from 1 to 2, then to 1 of the next winding in the proper sequence, 1 of the first winding being connected to one side of the line and 2 of the last winding being connected on the other side of the line. Figure 9 illustrates this flow.

1. Shunt-Wound Motors

When leads F-1 and A-1 of Figure 9 are connected to the plus side of the line, the current flow will be from 1 to 2. The direction of rotation will be standard or counterclockwise. To obtain a clockwise direction of shaft rotation it is necessary to reverse either the shunt-field leads F-1 and F-2 or the armature leads A-1 and A-2, as shown in Figure 10, but not both.

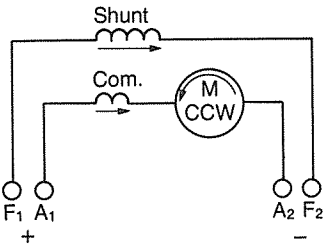


Fig. 9 – D-C Motor Connection for Standard Counterclockwise Rotation

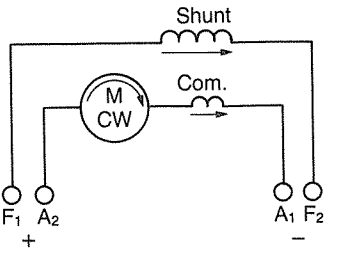


Fig. 10 – D-C Shunt-Wound Motor Connection for Clockwise Rotation

2. Series-Wound Motors

When lead A-1 is connected to the plus side of the line and lead A-2 connected to lead S-1, the current will flow from a lower number to a higher number in succeeding windings. Thus a standard counterclockwise direction of shaft rotation will be obtained as shown in Figure 11. To obtain a clockwise direction of shaft rotation, it is necessary to reverse either the series-field leads S-1 and S-2 or the armature leads A-1 and A-2, as shown in Figure 12, but not both.

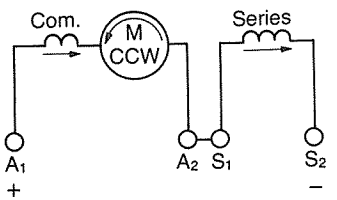


Fig. 11 – D-C Series-Wound Motor Connection for Standard Counterclockwise Rotation

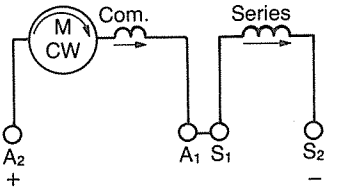


Fig. 12 – D-C Series-Wound Motor Connection for Clockwise Rotation

3. Compound-Wound Motors

In compound machines, the series field is always tagged such that when current flows from 1 to 2, a cumulative field is produced. Hence when leads F-1 and A-1 are connected to the plus side of the line and lead A-2 connected to S-1, the direction of current flow will be from a lower number to a higher number in each winding. Thus a standard counterclockwise direction of rotation will be obtained, as shown by Figure 13. To obtain a clockwise direction of shaft rotation it is necessary to reverse either the armature leads A-1, A-2 as shown by Figure 14, or both the shunt and series-field leads F-1, F-2 and S-1, S-2. It is necessary to reverse both shunt and series fields in a compound machine. If this is not done, the resulting connection will be opposite the former connection. For example, if the connection had been cumulative compound it would now become differential compound and vice versa.

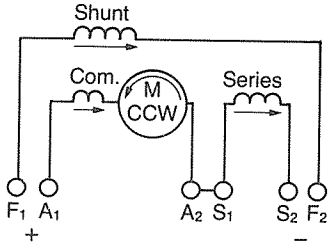


Fig. 13 – D-C Compound-Wound Motor Connection for Standard Counterclockwise Rotation

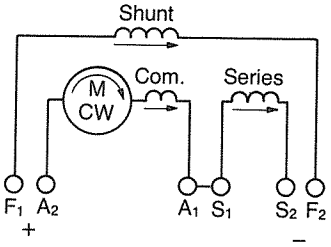


Fig. 14 – D-C Compound-Wound Motor Connection for Clockwise Rotation

B. Generators—General

The standard direction of shaft rotation for d-c generators is clockwise facing the commutator end or end opposite the drive. With standard clockwise direction of shaft rotation, the direction of current flow through the windings is from a lower numeral to a higher numeral. Thus the terminal marked A-2 will be the plus terminal and correspondingly A-1 the negative terminal. The fields whether series or shunt or both must be connected accordingly.

1. Shunt Generators

The shunt generator (shown in Figure 15) will have the polarity as shown when driven in a standard or clockwise direction of rotation. The current flow will be from a lower to a higher numeral as previously stated for standard rotation. If the generator is driven in a counterclockwise direction, the polarity will be reversed and the connections must be made as shown in Figure 16.

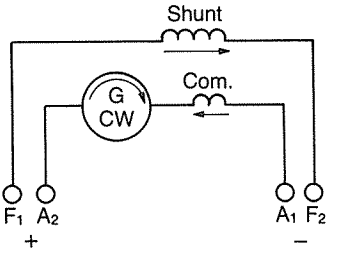


Fig. 15 – Shunt Generator Connection for Standard Clockwise Rotation

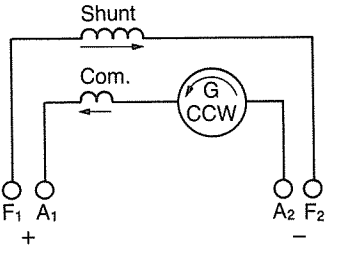


Fig. 16 – Shunt Generator Connection for Counterclockwise Rotation

2. Series Generators

The series generator shown in Figure 17 will have the polarity shown when driven in a standard clockwise direction of rotation. The current flow will be from a lower to a higher number in both series and armature circuits. If the generator is driven counterclockwise, the polarity will be reversed and the connection must be made as shown in Figure 18.

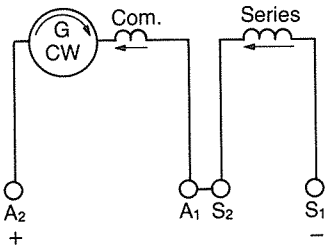


Fig. 17 – Series Generator Connection for Standard Clockwise Rotation

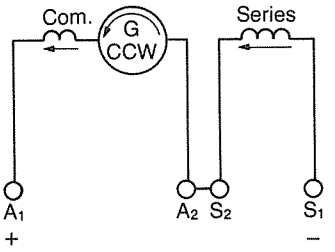


Fig. 18 – Series Generator Connection for Counterclockwise Rotation

3. Compound Generators

The compound generator (shown in Figure 19) will have the polarity shown when driven in a standard clockwise direction. The current flow will be from a lower to a higher numeral in the three circuits. If the generator is driven in a counter-clockwise direction the polarity will be reversed and the connections must be made as shown in Figure 20.

D-c machines, especially generators, often have other shunt fields beside the regular shunt field. These fields may be marked F-3 and F-4, F-5 and F-6 and so on. However, it is important to remember that the fields are always tagged such that a cumulative field will be produced with respect to the main or regular field, when the current flow is from a lower numeral to a higher numeral. If the machine is to have a differential field, this field must be so connected when the machine is applied.

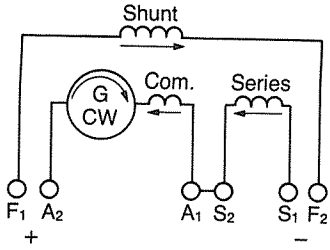


Fig. 19 – Compound Generator Connection for Standard Clockwise Rotation (also short shunt where A1, S2, S1, and F2 connect together and S1 is (–))

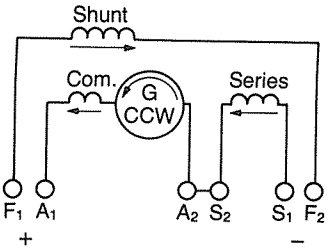


Fig. 20 – Compound Generator Connection for Counterclockwise Rotation (also short shunt, see Fig. 19)

2.4 A-C Machines

The markings of the terminals of a machine serve the best purpose if they indicate the electrical relations between the several circuits within the machine. The windings of a machine are seldom accessible and the arrangement of the terminal numbers on the terminal board varies with the combinations of connections which are required. However, if a definite system of numbering is used, the markings of the terminal may be made to tell the exact relations of the windings within the machine. To achieve this, a system is used that employes as one of its fundamental points a clockwise rotation in the sequence of terminal numbering. This applies to all three-phase a-c generators, three-phase synchronous motors, and three-phase induction motors having only one synchronous speed.

Terminals marked T-1, T-2, T-3, etc., indicate the various stator terminals; F-1, F-2, the d-c field windings; M-1, M-2, M-3, etc., the brush on the collector ring, except the d-c field.

For example, consider the terminal markings of a three-phase, two-circuit, star winding shown in Figure 21. If the winding in Figure 21 is to be connected with two circuits in multiple per phase (parallel connection for low voltage operation), the connections are as shown in Figure 22. If the winding in Figure 21 is to be connected with the two circuits in series per phase (series connection for high voltage operation), the connections are as shown in Figure 23.

Figures 21, 22, and 23 cover the general case, depicting the standardized terminal markings and connections when leads are brought out from all the internal circuits. In most cases, however, leads are not brought out from the neutral points of the individual circuits, and leads T_{10}, T_{11} & T_{12} of Figure 21 are permanently connected together inside the machine. In such cases, as depicted in Figure 24, only nine leads are brought out for external connection as follows:

	Connect to:			Connect Together
	L_1	L_2	L_3	
Parallel (low voltage)	T_1-T_7	T_2-T_8	T_3-T_9	T_4-T_5-T_6
Series (high voltage)	T_1	T_2	T_3	T_4-T_7, T_5-T_8, T_6-T_9

If a lead is brought out from the internal star point (not usually done), it will be marked T_0.

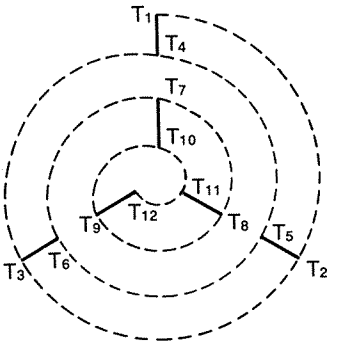


Fig. 21 – Terminal Markings of a Three-Phase Two-Circuit Star Winding 12 Leads Brought Out

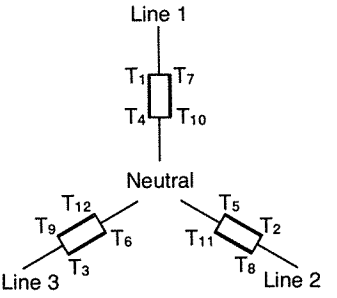


Fig. 22 – Typical Terminal Markings when All Terminal Circuit Leads are Brought Out

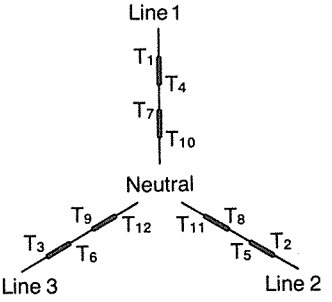


Fig. 23 – Typical Terminal Markings when All Circuit Leads are Brought Out

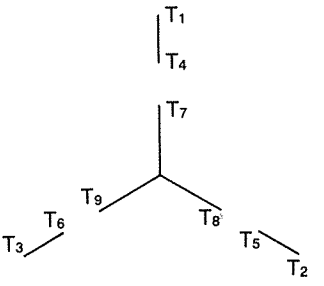


Fig. 24 – Terminal Markings when Nine Leads are Brought Out for Connection

The standardized lead markings for dual voltage, delta-connected windings are shown in Figure 25, with external connections as follows:

	Connect to:			Connect Together
	L_1	L_2	L_3	
Parallel (low voltage)	T_1-T_6-T_7	T_2-T_4-T_8	T_3-T_5-T_9	—
Series (high voltage)	T_1	T_2	T_3	T_4-T_7, T_5-T_8, T_6-T_9

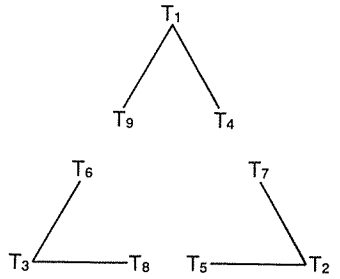


Fig. 25 – Standardized Lead Markings for Dual-Voltage Delta-Connected Windings

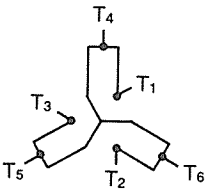
The standard direction of shaft rotation for a-c generators is clockwise when facing the end opposite the drive or the connection end of the coil windings. With this standard clockwise shaft rotation, the subscript numerals 1, 2, 3, etc., on the terminals indicate the order in which voltages at the terminals reach their maximum positive values (phase sequence). Therefore with a counterclockwise shaft rotation (not standard) when facing the same end, the phase sequence will be 1, 3, 2. However, it should be noted that the order of numerals on terminal leads does not necessarily indicate the phase sequence, but the phase sequence is determined by the direction of shaft rotation relative to the connection end of the coil windings.

The standard direction of shaft rotation for synchronous motors is counter-clockwise facing the end opposite the drive or the connection end of the coil windings. Synchronous condensers and synchronous motors may be operated with counterclockwise shaft rotation viewed from the connection end of the coil windings by connecting them to leads in which the phase sequence is 1, 2, 3, in the following manner; power leads 1, 2, 3; machine terminals 1, 3, 2.

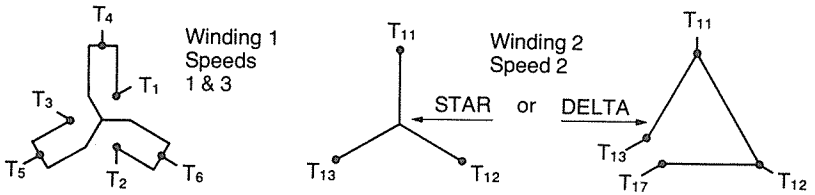
Induction motors do not have any standard direction of rotation. Most applications on which they are used are of such a nature that either or both directions of shaft rotation may be required. Also the phase sequence of power lines is rarely known. As a result an induction motor purchased from a supplier must be connected to the power source to ascertain which direction it will rotate with which connection.

Fig. 26 – Drawings Giving Connections for Variable Torque, Constant Torque, and Constant Horsepower

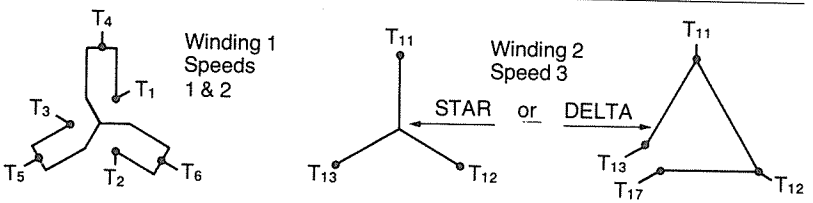
Speed	Connect Lines L1 L2 L3 to Motor Terminals			Connect Together	
TWO SPEED, SINGLE WINDING					
1	T1	T2	T3	———	Typical Speeds
2	T6	T4	T5	T1, T2, T3	600, 1200



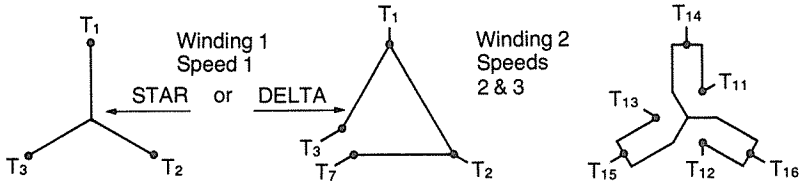
THREE SPEED, TWO WINDING					
1	T1	T2	T3	———	Alternate (1-2-1)
2	T11	T12	T13, T17	———	Arrangement.
3	T6	T4	T5	T1, T2, T3	Typical Speeds 600, 900, 1200



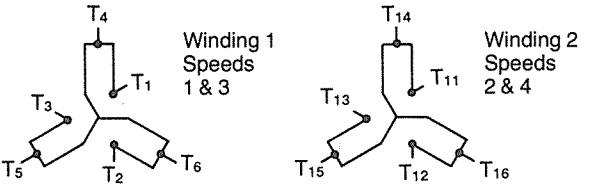
THREE SPEED, TWO WINDING					
1	T1	T2	T3	———	Tandem (1-1-2)
2	T6	T4	T5	———	Arrangement.
3	T11	T12	T13, T17	———	Typical Speeds 600, 1200, 1800



Speed	Connect Lines L1	L2	L3 to Motor Terminals	Connect Together	
THREE SPEED, TWO WINDING					
1	T1	T2	T3, T7	———	Tandem (1-2-2)
2	T11	T12	T13	———	Arrangement.
3	T16	T14	T15	T11, T12, T13	Typical Speeds 600, 900, 1800



Speed	Connect Lines L1	L2	L3 to Motor Terminals	Connect Together	
FOUR SPEED, TWO WINDING					
1	T1	T2	T3	———	Alternate (1-2-1-2)
2	T11	T12	T13	———	Arrangement.
3	T6	T4	T5	T1, T2, T3	Typical Speeds
4	T16	T14	T15	T11, T12, T13	600, 900, 1200, 1800



Speed	Connect Lines L1	L2	L3 to Motor Terminals	Connect Together	
FOUR SPEED, TWO WINDING					
1	T1	T2	T3	———	Tandem (1-1-2-2)
2	T6	T4	T5	T1, T2, T3	Arrangement.
3	T11	T12	T13	———	Typical Speeds
4	T16	T14	T15	T11, T12, T13	600, 1200, 1800, 3600

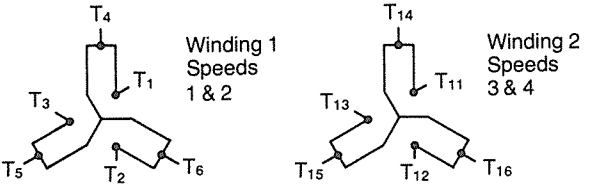
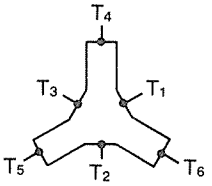
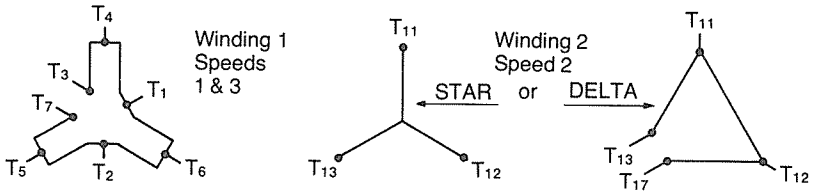


Fig. 27 – Connections for Variable Torque, Constant Torque, and Constant Horsepower

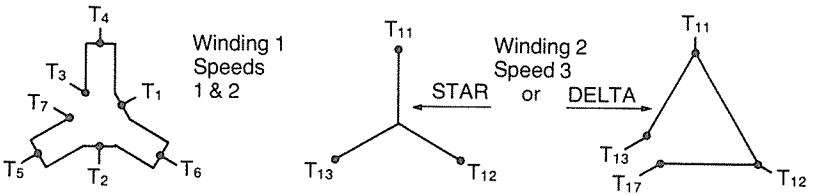
Speed	Connect Lines L1	L2	L3 to Motor Terminals	Connect Together	
TWO SPEED, SINGLE WINDING					
1	T1	T2	T3	———	Typical Speeds
2	T6	T4	T5	T1, T2, T3	600, 1200



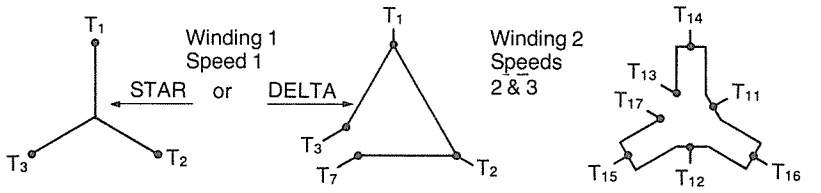
THREE SPEED, TWO WINDING					
1	T1	T2	T3, T7	———	Alternate (1-2-1)
2	T11	T12	T13, T17	———	Arrangement.
3	T6	T4	T5	T1, T2, T3, T7	Typical Speeds 600, 900, 1200



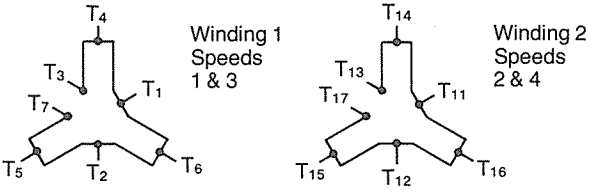
THREE SPEED, TWO WINDING					
1	T1	T2	T3, T7	———	Tandem (1-1-2)
2	T6	T4	T5	T1, T2, T3, T7	Arrangement.
3	T11	T12	T13, T17	———	Typical Speeds 600, 1200, 1800



Speed	Connect Lines L1 L2 L3 to Motor Terminals			Connect Together	
THREE SPEED, TWO WINDING					
1	T1	T2	T3, T7	———	Tandem (1-2-2)
2	T11	T12	T13, T17	———	Arrangement.
3	T16	T14	T15	T11, T12, T13, T17	Typical Speeds 600, 900, 1800



FOUR SPEED, TWO WINDING					
1	T1	T2	T3, T7	———	Alternate (1-2-1-2)
2	T11	T12	T13, T17	———	Arrangement.
3	T6	T4	T5	T1, T2, T3, T7	Typical Speeds
4	T16	T14	T15	T11, T12, T13, T17	600, 900, 1200, 1800



FOUR SPEED, TWO WINDING					
1	T1	T2	T3, T7	———	Tandem (1-1-2-2)
2	T6	T4	T5	T1, T2, T3, T7	Arrangement.
3	T11	T12	T13, T17	———	Typical Speeds
4	T16	T14	T15	T11, T12, T13, T17	600, 1200, 1800, 3600

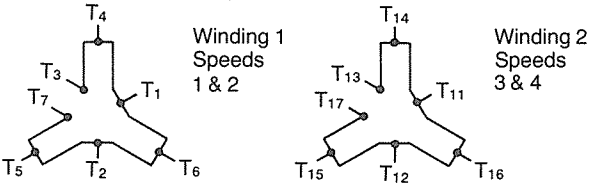
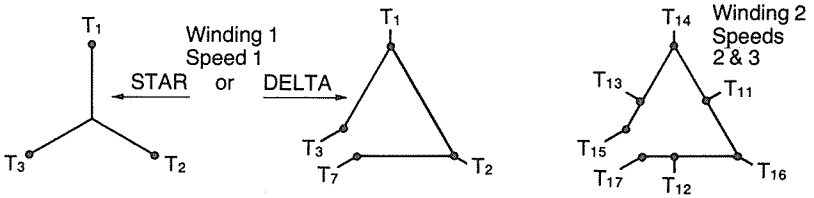
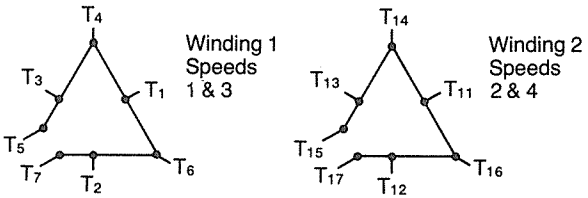


Fig. 28 – Connections for Variable Torque, Constant Torque, and Constant Horsepower

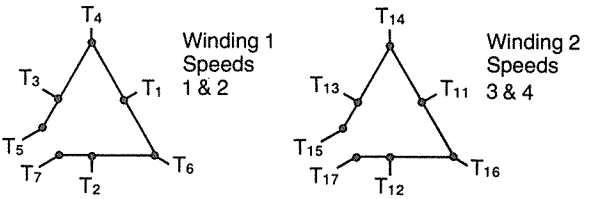
Speed	Connect Lines L1	L2	L3 to Motor Terminals	Connect Together	
THREE SPEED, TWO WINDING					
1	T1	T2	T3, T7	———	Tandem (1-2-2)
2	T11	T12	T13	T14, T15, T16, T17	Arrangement.
3	T16	T14	T15, T17	———	Typical Speeds 600, 900, 1800



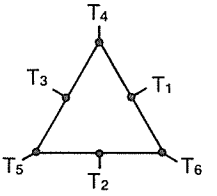
FOUR SPEED, TWO WINDING					
1	T1	T2	T3	T4, T5, T6, T7	Alternate (1-2-1-2)
2	T11	T12	T13	T14, T15, T16, T17	Arrangement.
3	T6	T4	T5, T7	———	Typical Speeds
4	T16	T14	T15, T17	———	600, 900, 1200, 1800



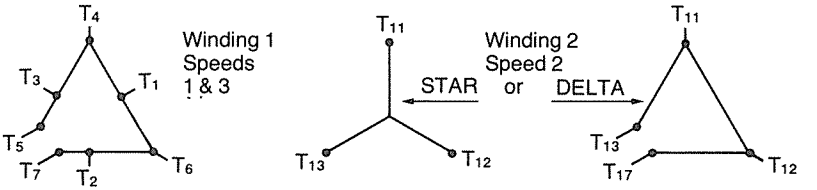
FOUR SPEED, TWO WINDING					
1	T1	T2	T3	T4, T5, T6, T7	Tandem (1-1-2-2)
2	T6	T4	T5, T7	———	Arrangement.
3	T11	T12	T13	T14, T15, T16, T17	Typical Speeds
4	T16	T14	T15, T17	———	600, 1200, 1800, 3600



Speed	Connect Lines L1 to Motor Terminals	L2	L3	Connect Together	
TWO SPEED, SINGLE WINDING					
1	T1	T2	T3	T6, T4, T5	Typical Speeds
2	T6	T4	T5	———	600, 1200



THREE SPEED, TWO WINDING					
1	T1	T2	T3	T4, T5, T6, T7	Alternate (1-2-1)
2	T11	T12	T13, T17	———	Arrangement.
3	T6	T4	T5, T7	———	Typical Speeds 600, 900, 1200



THREE SPEED, TWO WINDING					
1	T1	T2	T3	T4, T5, T6, T7	Tandem (1-1-2)
2	T6	T4	T5, T7	———	Arrangement.
3	T11	T12	T13, T17	———	Typical Speeds 600, 1200, 1800

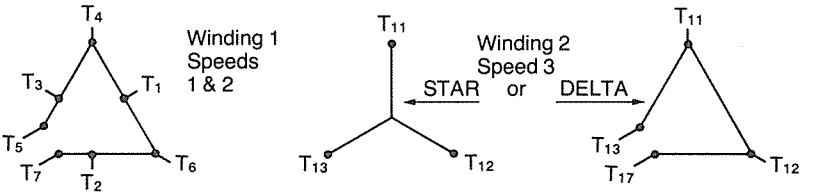
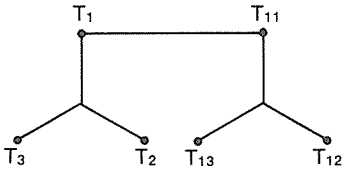
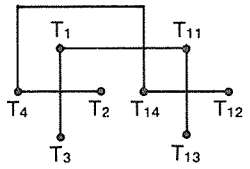


Fig. 28 continued on next page.

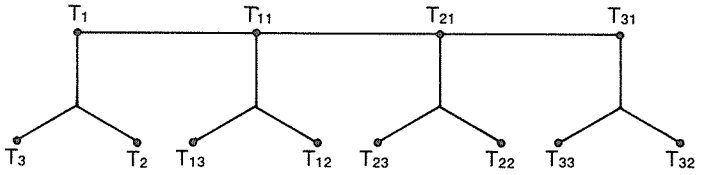
Speed	Connect Lines L1 to Motor Terminals	L2	L3	L4
TWO SPEED, TWO WINDING, THREE PHASE				
1	T1	T2	T3	
2	T11	T12	T13	



TWO SPEED TWO WINDING, TWO PHASE, FOUR WIRE				
1	T1	T2	T3	T4
2	T11	T12	T13	T14



FOUR SPEED, FOUR WINDING, THREE PHASE			
1	T1	T2	T3
2	T11	T12	T13
3	T21	T22	T23
4	T31	T32	T33



Volume 4
Chapter 3

Maintenance Records and Inspections

Warning: Follow the safety instructions given in Volume 1 Chapter 5, and throughout the book. Failure to do so can result in severe personal injury or death, and substantial damage to property.

Chapter 3

Maintenance Records and Inspections

Essential to the operation of a successful maintenance program is an orderly system of record keeping that provides practical information needed to maintain the equipment, reach selection and buying decisions at the time of replacement or expansion, and evaluate suitability of application.

Notice: All inspections should be conducted by knowledgeable personnel and in strict compliance with proper safety procedures.

3.1 Maintenance department records should include:

Diagrams of all electrical systems showing all equipment on each system.

Equipment records giving complete information on all apparatus for which the maintenance department has any responsibility. This record should show the manufacturer, manufacturer's identification (name, catalog or style number, serial number, or order number), user's identification, size, rating, original settings and subsequent resettings, location on system, date of acquisition, supplier, and all manufacturer's drawings, diagrams, instruction literature, parts lists, modifications, and field changes issued by the manufacturer.

Repair cost records giving a history of repair and associated costs of maintenance for each piece of equipment. This is an essential diagnostic tool for avoiding future difficulties. The record may show that the equipment is of poor quality or is mis-applied.

Daily maintenance schedule that provides for a complete listing of the day-to-day duties of the maintenance inspectors and the equipment to be maintained. This record should be reviewed daily as it is compiled and potential trouble situations investigated and corrected as soon as possible.

Inspection check lists provide an assurance that vital inspections will not be overlooked, and should also indicate the dates or the time frequencies of inspections.

3.2 Thermographic Inspection

Infrared photography was originated for research purposes and found some practical application as early as World War II, but it was in the 1960's when the technique was first applied to the detection of potential maintenance problems in mechanical and electrical systems.

Thermography is the process of converting infrared radiant heat into visual form. All objects radiate infrared heat in proportion to the temperature of the object.

Since many incipient mechanical and most potential electrical problems are first evidenced by rising temperatures, the ability to see and photograph radiant heat offers obvious advantages to those responsible for equipment and system maintenance.

Thermographic inspection strikes directly at detection of the most reliable symptom of trouble—heat. Heat is evidence of lost energy but more importantly heat is a warning of even greater losses due to failure and forced system shutdown.

A hotspot is a heat loss. If there is no current there is heat, but the more current the more likely the problem will be severe. A 10 C temperature rise doubles the oxidation rate, oxidation makes resistance rise which makes temperature rise even more in a vicious circle that leads to equipment failure. The failure ratio increases in direct proportion to temperature rise in some components.

The economic statistics on thermographic surveys are impressive. They have been economically beneficial in about 70 percent of the cases. These economic benefits can, however, be very dramatic. In one instance a $2 million replacement cost was avoided by taking only 17 pictures in a main switch house.

Thermography will reveal the hot spots, the interpretation of these symptoms is what solves the problem:

High voltage line connections heat when they are loose. Thermographic scanning reveals the rising temperature so preventive action can be taken.

Switch contacts and internal operating spring mechanisms, if not tight, will cause a heat build-up. Scanning spots these potential problems.

Improper contacts in oil circuit breakers can actually heat the insulating oil.

Connection problems not readily discernable, such as corroded or worn contacts and loose connections, are revealed by thermographic inspection.

If only one check can be made, check the back of the switchgear. A large portion of the system's electrical problems will show up there. Thermographic inspection and comparison of the front and back of the switchgear will help to determine the source of the problems.

Bus bar heating due to loose connections can lead to voltage drop and, as has happened, voltage can drop to zero so all motors on the line stopped. Without thermographic inspection this would be a real mystery.

It is necessary to recognize that thermographic technique registers relative heat and does not discriminate. When equipment such as contactors and control centers (contactor coils are normally hot), are scanned, they must be viewed from at least two different angles. Attention should be given to contactor and starter heaters, they could be burned open, the wrong size, or jumpered out.

Because the thermographic survey is ultimately only as good as the interpretation of the findings, it is generally better to have the survey made by one of the companies equipped to offer the service. They will provide expert interpretation or refer to specialists who can interpret the survey. Care should be taken in selecting a survey service to assure that they have experience in industrial thermographic survey work and experience with the kind of equipment to be surveyed.

Thermographic surveys are made with portable equipment capable of scanning considerable areas rapidly and capable of taking stop-action photographs (thermograms) to provide records and identification. The equipment will usually consist of a hand-held camera (scanner) and a video display.

Power line and large roof surveys can be made from helicopters.

The best time to make a thermographic survey is when a regularly scheduled shutdown is being planned. Using the survey to make the diagnosis of maintenance problems will enormously increase the effectiveness of the maintenance program. Planning for the shutdown program can be much more accurate, preparation can be more complete, and the maintenance work much less exploratory.

Thermographic inspection has a ready application in process industries where losses of energy can easily stem from unknown design faults and undetected component failures.

There are three fundamental causes for energy loss: design, workmanship, and component failure.

Designs of systems and structures that were adequately energy efficient at yesterday's energy costs may not be acceptable today or tomorrow.

A good design poorly executed or maintained may become energy wasteful.

Component failure is always a potential energy waster, deteriorated insulation, a faulty steam valve, a failed port seal, or a malfunctioning heat exchanger is always a possibility.

Any one of these three factors is sufficient reason for thermographic inspection and often more than one can be checked at a time. For efficient application the factor being checked at a given inspection should be identified and given primary attention. Design efficiency would probably be examined only when making fundamental decisions about alteration. Workmanship would normally be checked immediately upon completion, and component failure should be searched for on a regularly scheduled maintenance inspection.

Thermographic inspection as an energy conservation tool can be applied not only to electrical and mechanical equipment but to buildings to measure heat loss.

There are two types of building infrared surveys, the qualitative analysis and the quantitative analysis.

A qualitative analysis will locate and identify a construction defect, poor workmanship, or component failure such as an insulation failure.

A quantitative analysis will locate, identify, and measure the energy loss. The primary variable between the quantitative and qualitative analysis is engineering time.

As a diagnostic tool the infrared survey has proved to be of great help and its future in the area of energy conservation is one of great growth.

3.3 Some typical inspection check lists are:

A. Switchgear Inspection Check List

Annunciator alarm or target; test

Automatic transfer relay operation; test

Bolted bus; torque test

Breaker and cell contacts; inspect

Breakers; inspect and test

Bus insulators; clean, resistance test for ground

Bus and support insulators; inspect

Bus, support and spacing; check

Cables, bus, potheads; dielectric test

Control knobs and switches; check freedom of movement, condition of contacts

Controls; operate, close and trip breakers electrically

Cubicle interiors; clean, vacuum

Doors, handles, locking bars, mechanisms; check for damage, free operation

Door interlocks; check positive action

Grounding, all equipment; verify

Instruments; inspect and test

Interlocks and auxiliary contact assemblies; check

Panel lights; check operation, missing or burned out lamps

Power cable or bus to switchgear; inspect and resistance test

Rails, drawout breakers, guides, shutter mechanisms; check, lubricate

Relays; check for positive tripping

Transformers, control and metering; inspect

Transformers; ratio test

B. Air Circuit Breaker Inspection Check List

Mechanical Checks

Arc boxes; remove, inspect, clean, re-assemble

Arc splitter grids and ceramics; inspect

Auxiliary devices, shock absorbers, bumpers, position indicators, latch checking switches, key lock-out, etc.; check mechanical condition and operation

Auxiliary switches, operating linkage; check sequence and contact alignment

Blow-out coils; inspect if used

Breaker; inspect for arc damage, deteriorated insulation.

Breaker; remove, blow off, clean, re-assemble

Bushings, primary, porcelains and finger clusters; check for cracks or damage

Contacts; inspect, replace damaged units

Contacts; check alignment, overtravel, pressure, adjust as necessary

Contact springs; check, replace damaged or weakened springs

Current carrying parts, all; inspect for signs of overheating

Electrical clearances; check for adequacy

Frame and castings; check for cracks

Lift rods, latch mechanisms, and details; check for damage and operation

Lubrication; as required, remove hardened lubricants

Manual operation, close latch and trip; test

Shunts and brazed and soldered connections; check and verify

Terminal blocks and connections; check, tighten, verify

Trip-free operation; test

Trip mechanism, test

Wiring, connections, check condition, inspect insulation, verify connections

Electrical Checks

Breakers; operate electrically, conduct high voltage test

Capacitor trip; check if used

Closing coil; check connections, resistance test

Measure and record voltage and current, rated and minimum

Close, latch, and trip operation, electrical; test

Control wiring, resistance test

Current limiting fuses, check

Dash pots, oil filled; dismantle, clean, fill, re-install

Overload settings; record as found, make calibration check of instantaneous trip, short time delay, long time delay, make necessary adjustments

Reverse current trip; check if used

Shunt trip, check operation at rated voltage and minimum voltage

C. Dry-Type Transformers

Mechanical Checks

Accessories; inspect

Base or support insulators; inspect

Bolted connections, all; tighten

Coils; inspect for damaged winding or loose iron

Connections, primary, secondary, ground; examine and verify

Core and coils; inspect for loose mounting and supports

Electrical clearances; confirm adequacy

Fuse; confirm rating (if fused)

Insulation; examine for signs of overheating

Porcelain insulators; clean, check for damage

Porcelain spacers and pancake insulators; clean, check for damage

Resistance; test high to low to ground

Tap connections, tap changer; inspect, confirm

Transformer; clean, remove dust with vacuum or blower

Electrical Checks

Overpotential; insulation test

Polarity; confirm

Ratio; check

Sound level; measure, record

D. Liquid Immersed Distribution Transformer Inspection Check List

Mechanical Checks

Breaker, low voltage; inspect, test

Bushings; clean, inspect

Connections, primary, secondary, ground; clean, tighten

Core and coil; inspect for loose coils, coil blocks, core laminations, deteriorating insulation, broken ties, banding

Electrical clearances; verify adequacy

External protection, fuses, cutouts, etc.; inspect, test

Gaskets, cover and handhole; check seal

Indicator lamp; test

Insulating fluid; check for siphoning through terminal lead insulation, sample and test for contamination

Internal arcing, overheating, carbon, sludge; inspect for evidences

Internal protection, fuses, protective links; inspect test

Load break disconnect; inspect, test

Liquid level gauge; check

Tank; examine for leaks, broken mounting brackets

Tap changer; inspect, check tightness of internal tap and bushing lead connections

Temperature gauge; check

Terminal connections; check for broken wire strands, tightness

Electrical Checks

Ratio; turn to turn test

Impedance; check

Polarity; check

Protective devices; overload test

Overpotential insulation test

E. Liquid Immersed Power Transformer Inspection Check List

Mechanical Checks

Bushings; clean, inspect bushings, clamps, gaskets

Connections, primary, secondary, ground; examine, tighten

Fuses, cutouts, etc.; inspect, verify seal

Gaskets, cover, handhole; inspect, verify seal

Insulating liquid; sample, test, check level

Lightning arresters; inspect

Seals, tap changer compartment; inspect

Radiators; inspect for damage, oil leaks

Sudden pressure relay; inspect, test

Switch and terminal chambers; inspect

Tap changer and position indicator; inspect condition, confirm operation

Temperature gauge; check, test

Internal Inspection, atmospheric pressure types only

Arcing, overheating, contamination, moisture; examine for evidences

Auxiliary transformers; inspect, tighten leads

Connections; tighten, check for broken wire strands

Core and coils; inspect for loose laminations blocking, deterioration of insulation

Electrical clearances; verify adequacy

Tap changer and contacts; inspect, operate

Electrical Tests

Alarm systems and relays; test operation

Balanced load conditions; test

Combustible gas; check for presence

Dielectric test, high voltage

Fans and pumps; test operation

Fuses, arresters, disconnects; check, verify ratings

Ground connection resistance; measure

Resistance test, phase to phase, high to low to ground

Power factor test bushings

Ratio test, turn to turn, and auxiliary transformers

Tap changer, motorized; test operation, cam and limit switches

Maintenance records should be available at all times to other departments such as manufacturing, purchasing, plant management.

F. Integral HP A-C Motors

Mechanical Checks

Air gap; check for uniform gap, center rotor, replace bearings if necessary

Alignment; check alignment between shafts, correct and secure mounting bolts

Balance; check balance weights, rebalance if necessary

Bearings; if hot, check alignment, belt tension, end play, lubrication. Replace bearing if damaged.

Belted drives; check alignment of motor and load sheaves

Belt tension; check tension and wear

Cleaning; remove dirt and dust with dry compressed air, dry cloths, or by brushing

End play; if too much, check and replace bearings if necessary, check alignment of belt drives

Lubrication; follow manufacturer's instructions. Either too little or too much lubrication is detrimental to the motor

Noise; check for source, windage (air movement), mechanical, or electrical

Rotation; check direction of rotation. If opposite rotation is wanted on a 3-phase motor, reverse leads

Ventilation; check to be sure all air passages are open

Vibration; check alignment, foundation, driven apparatus, and hold down bolts. Check for electrical unbalance and motor unbalance.

Electrical Checks

Frequency; a variation of 5% is allowed, if greater variation is detected, correct at source

Leads; inspect lead wires and terminals, replace as necessary

Moisture; check for dampness at end turns, if wet, dry and reinsulate

Overload protection; if motor is shut down by overload protection, check current unbalance, voltage unbalance, and assure motor is free to rotate

Single phase; if polyphase motor single phases, check motor connections, fuses, control contacts, and thermal overload elements

Speed; check with tachometer

Temperature; if motor overheats, shut down immediately, investigate cause, voltage, load, cooling systems, etc.

Voltage; a variation of 10% is allowable, if greater variation is detected correct at the source. All phases must be balanced.

G. Panelboards—Inspection Check List

Mechanical Checks

Connections, incoming, outgoing cables, phase, neutral and ground—examine, tighten.

Fuses, tightness of fuse clips.

Mechanical operation of all circuit breaker or switch operating mechanisms.

Interior firmly bolted in cabinet and aligned.

Broken or missing parts from breakers or switch devices.

Missing hardware from the internal assembly, cabinet or outer trim.

Outer trim accurately aligned and securely fastened

Inspection Checks

Discoloration at fuse clips and device terminals.

Charring of molded insulating parts, including molded breaker cases, fuse holders, wire insulation.

Evidence of moisture, contamination, dust, hardware, debris, etc.

Cracking, peeling, brittleness of cable, wire insulation.

Clearances to grounded metal and between phases of installed devices and cable/wire.

Abrasion of cable and wire insulation.

Nicking of wire or cable strands at terminals.

Overcrowding in wiring gutters.

Adequate sealing of conduits and cabinet openings.

Electrical Checks

Fuses, check, verify type, voltage, current and interrupting ratings.

Resistance test, phase to phase to ground, insulation.

On service entrance type, neutral-to-ground bonding conductor in place and securely connected.

Equipment grounding terminal bar securely connected to cabinet or panelboard frame.

Proper connection of ground fault devices, pushbutton test of ground fault breakers.

H. Switchboards—Inspection Check List

Mechanical Checks

Bus joints, incoming and outgoing cable connections, phase, neutral and ground for proper tightness, also bolted structural members.

Fuse clip tightness.

Mechanical operation of all device operating mechanisms.

Missing hardware from terminals, bus connectors internal steel brackets and enclosures.

Broken or missing parts from breakers, switches, instruments, meters, terminal blocks, relays, other devices in assembly.

Anti-turn integrity of all terminal lugs.

Hinged covers for free swing without damage to hinge wiring.

Free movement of mechanical interlocks.

Proper action of plug-in or drawout removable circuit breakers.

Inspection Checks

Discoloration at fuse clips, breaker and switch terminals.

Charring of molded insulating parts, e.g. breaker parts, bus supports, terminal boards, fuse holders.

Evidence of insulation tracking, cracked or contaminated insulation and safety barriers.

Evidence of moisture on insulating or conducting parts.

Loose hardware, wire scraps and other debris inside cabinet.

Physical abrasion of cable insulation or control wire bundles. Loose wire ties.

Evidence of cable insulation cracking, peeling or heat brittleness.

Nicking of cable strands at terminal lugs.

Clogged or partially clogged ventilated openings and dust filters.

Clearances to grounded metal and phase to phase of installed buswork and all uninsulated live parts.

Contacts of control switches, relays, circuit breakers and instrument switches.

Electrical Checks

Resistance checks, phase to phase to ground, using "megger" test methods.

Trip settings of adjustable type overcurrent devices.

On service entrance type, neutral to ground bonding connector in place, of adequate size and securely connected.

Neutral disconnect link securely in place on 4 wire services using 3 pole main disconnect.

Station grounding connector (lug) securely in place on neutral conductor ahead of neutral disconnect link in 4 wire services.

Proper connection of ground fault equipment per drawings.

Fuses, check, verify type, voltage, current and interrupting ratings.

I. Fuse Cutouts—Inspection Checklist

Visual inspection for apparent damage.

Assure that all parts work freely.

Insert fuse link.

Check for positive latching.

J. Molded Case Circuit Breakers

Arc quenchers and ceramics; examine (serviceable designs only).

Breaker; examine for signs of overheating, dielectrically test.

Bi-metal trip operation; simulate, observe.

Blown fuse operation; simulate, observe (fused designs only).

Connection hardware; inspect, tighten.

Contacts; examine, test for resistance, clean

Cover and case; clean, examine for defects.

Fuse; confirm rating and continuity (fused designs only).

Heater; check, confirm rating.

Interlocking; mechanical or electrical lock-out; test.

Latch mechanism; inspect, test.

Mechanism, breaker; inspect (serviceable designs only).

Motor operated mechanism; check, test.

Operation; operate manually, check action.

Phase barrier insulation; inspect (serviceable designs only).

Positive close latch and trip operation; test.

Safety trip when cover is removed; test.

Terminals; check condition, tighten hardware.

K. Protective Relays

The following are sample relay test and inspection report forms designed to assure that important items are not overlooked, and to provide records for individual devices:

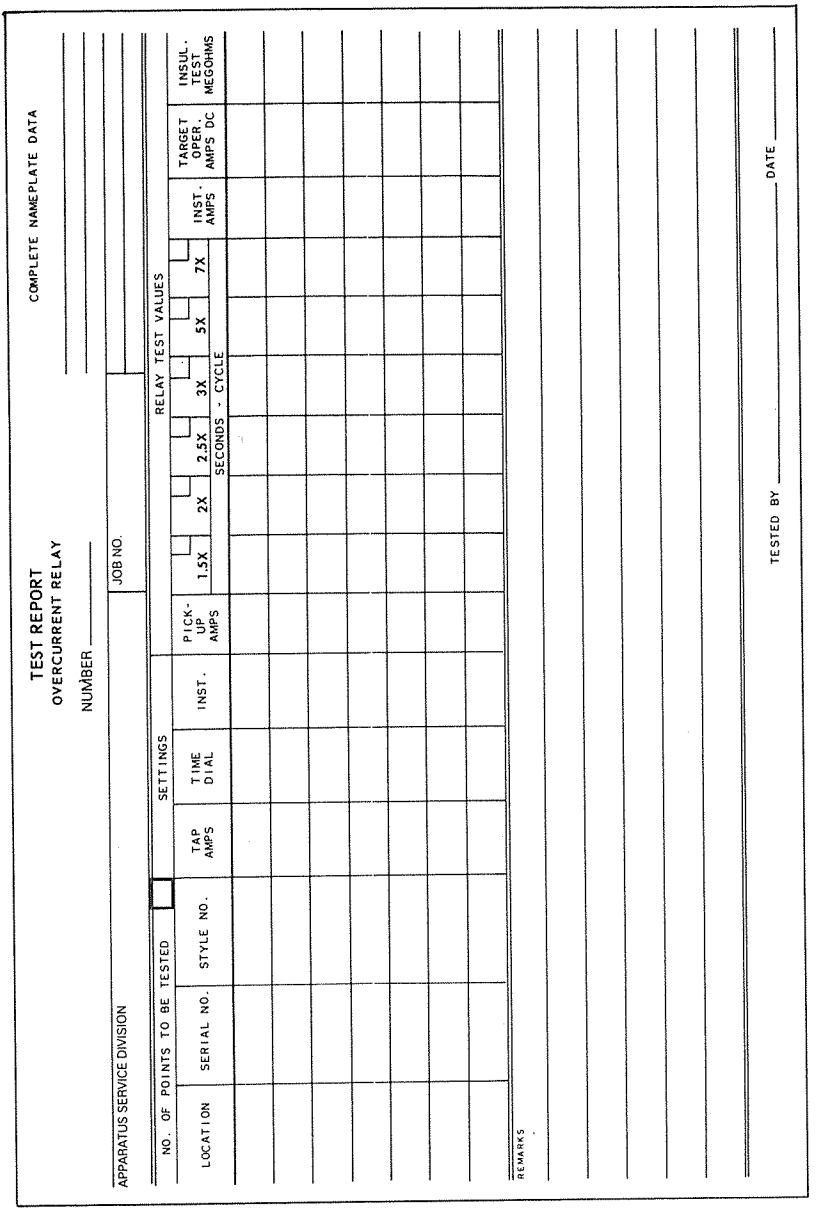
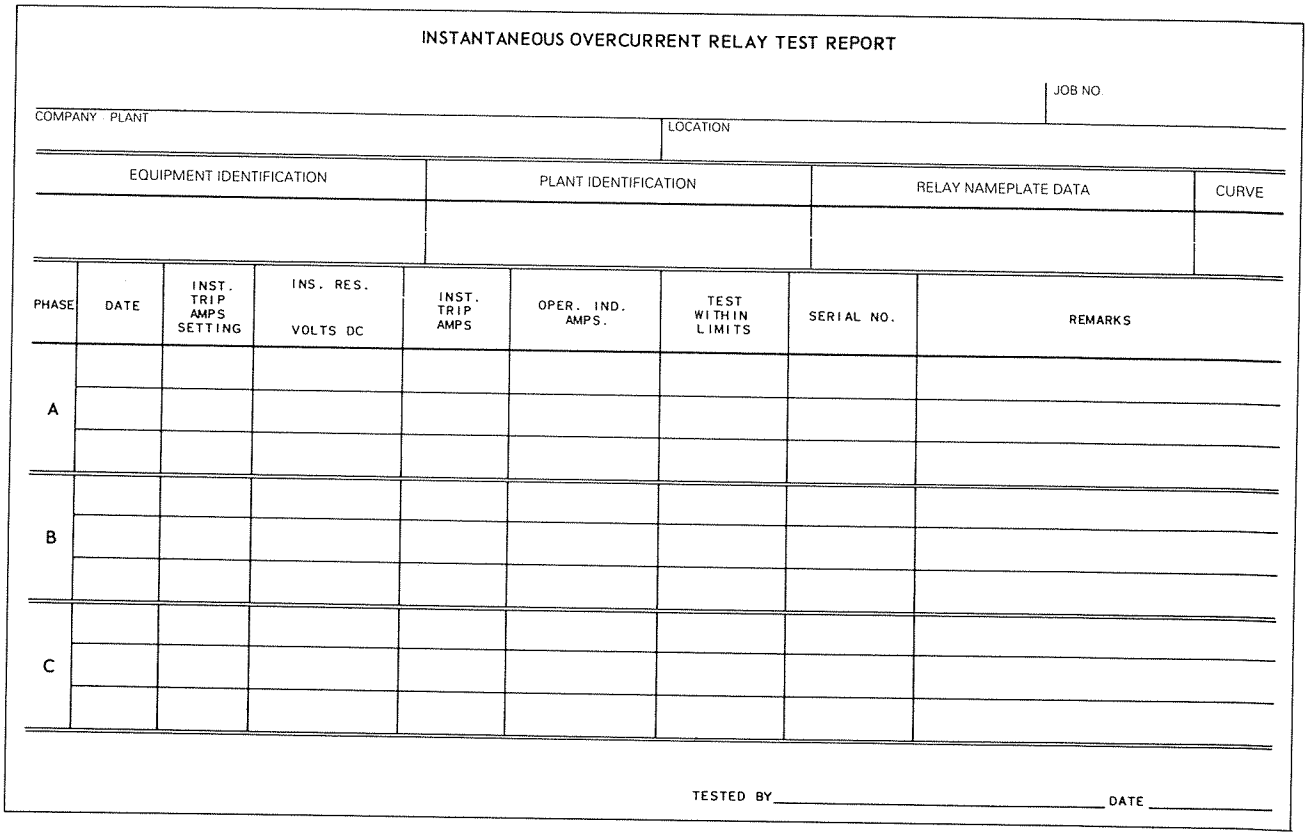


Fig. 1 – Overcurrent Relay



INSTANTANEOUS OVERCURRENT RELAY TEST REPORT

JOB NO.

COMPANY PLANT

LOCATION

EQUIPMENT IDENTIFICATION	PLANT IDENTIFICATION	RELAY NAMEPLATE DATA	CURVE

PHASE	DATE	INST. TRIP AMPS SETTING	INS. RES. VOLTS DC	INST. TRIP AMPS	OPER. IND. AMPS.	TEST WITHIN LIMITS	SERIAL NO.	REMARKS
A								
B								
C								

TESTED BY _____ DATE _____

Fig. 2 – Instantaneous Overcurrent Relay

DIRECTIONAL OVERCURRENT RELAY TEST RECORD

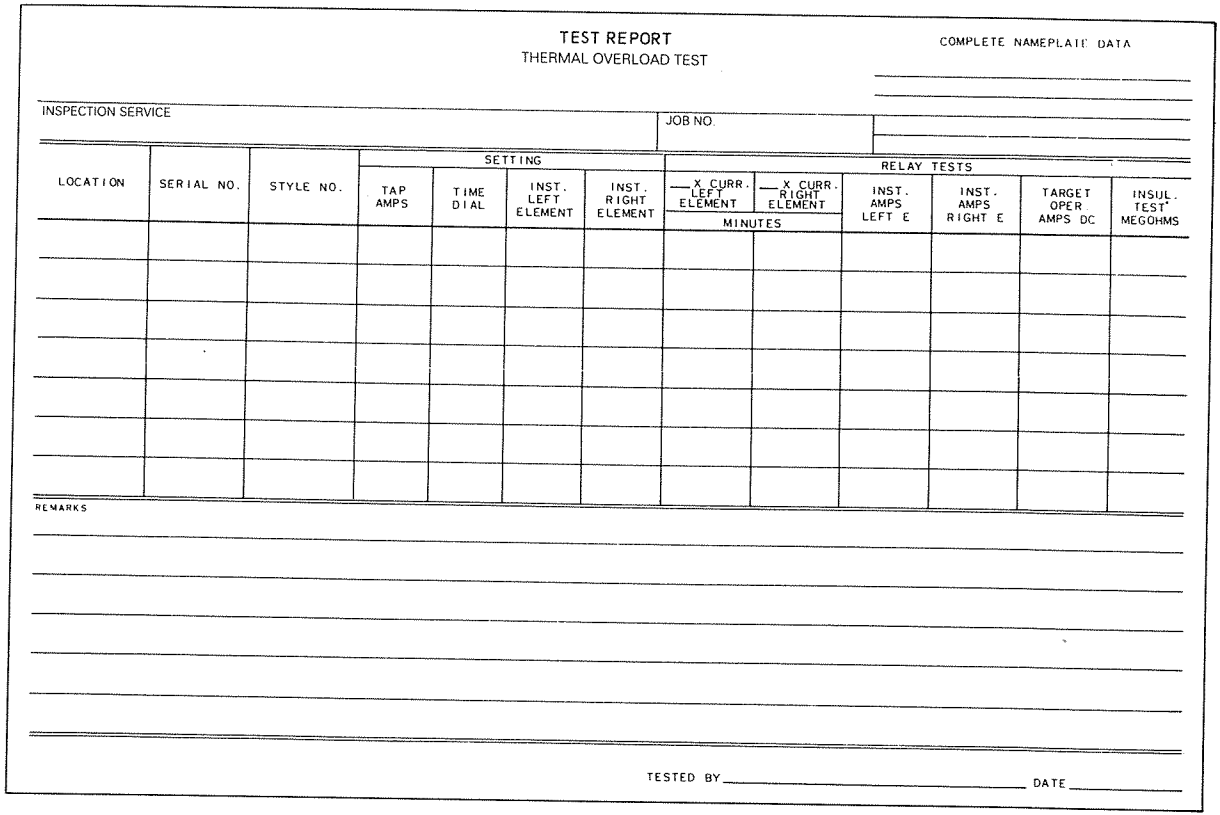
INSPECTION SERVICE	JOB NO.
COMPANY – PLANT	LOCATION

EQUIPMENT IDENTIFICATION	PLANT IDENTIFICATION	RELAY NAMEPLATE DATA	CURVE

DATE	INS. RES. VOLTS DC	SPEC. RELAY SETTING AMPS. TAP	TIME DIAL NO.	ZERO ADJ.	PICK UP AMPS	TIMING POINTS % AMPS	TIMING POINTS TIME CYCLES	OPER. IND. AMPS	TEST WITHIN LIMITS	SERIAL NO.	REMARKS

TESTED BY _____ DATE _____

Fig. 3 – Directional Overcurrent Relay



TEST REPORT
THERMAL OVERLOAD TEST

COMPLETE NAMEPLATE DATA

INSPECTION SERVICE

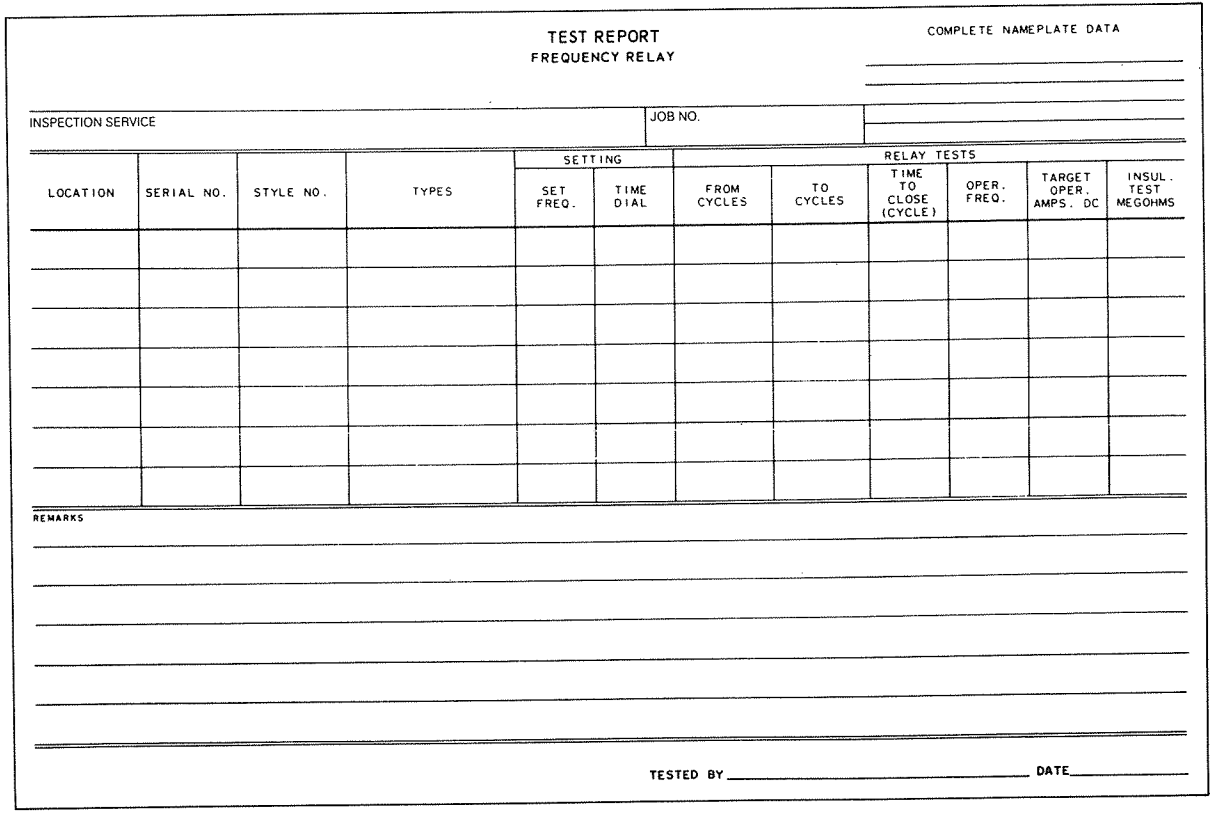
JOB NO.

LOCATION	SERIAL NO.	STYLE NO.	SETTING				RELAY TESTS					
			TAP AMPS	TIME DIAL	INST. LEFT ELEMENT	INST. RIGHT ELEMENT	X CURR. LEFT ELEMENT (MINUTES)	X CURR. RIGHT ELEMENT (MINUTES)	INST. AMPS LEFT E	INST. AMPS RIGHT E	TARGET OPER AMPS DC	INSUL. TEST MEGOHMS

REMARKS

TESTED BY _____ DATE _____

Fig. 4 – Thermal Overload Relay



TEST REPORT
FREQUENCY RELAY

COMPLETE NAMEPLATE DATA

INSPECTION SERVICE

JOB NO.

LOCATION	SERIAL NO.	STYLE NO.	TYPES	SETTING		RELAY TESTS					
				SET FREQ.	TIME DIAL	FROM CYCLES	TO CYCLES	TIME TO CLOSE (CYCLE)	OPER. FREQ.	TARGET OPER. AMPS. DC	INSUL. TEST MEGOHMS

REMARKS

TESTED BY _____ DATE _____

Fig. 5 – Frequency Relay

TEST REPORT
DIFFERENTIAL RELAY

COMPLETE NAMEPLATE DATA

INSPECTION SERVICE

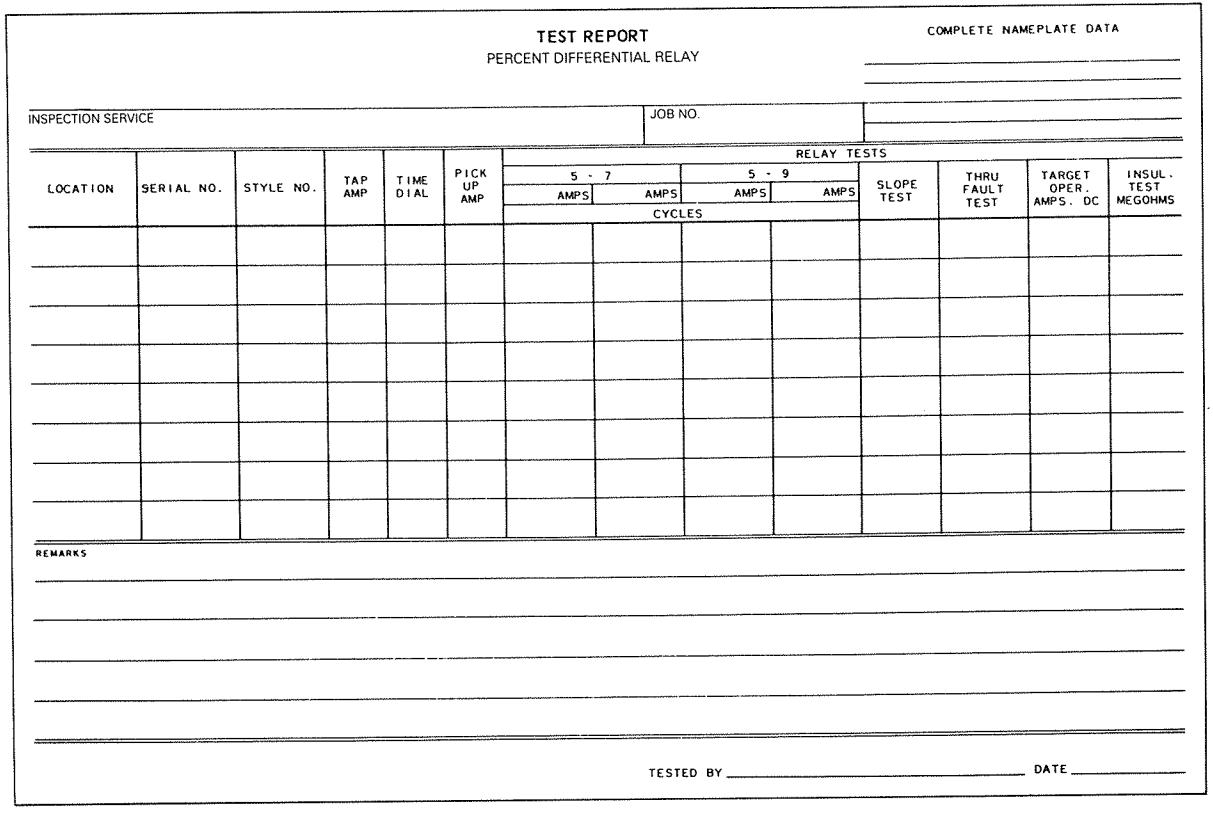
JOB NO.

LOCATION	SERIAL NO.	STYLE NO.	TAP SETTINGS				MIN. TRIP CURRENT	RELAY TESTS				
			1 TAP AMPS	2 TAP AMPS	3 TAP AMPS	4 TAP AMPS		DIFFERENTIAL CHARACTERISTICS		HARMONIC RESTRAINT CHARACTER	TARGET OPER. AMPS DC	INSUL. TEST MEGOHMS
								A	B			

REMARKS

TESTED BY _____ DATE _____

Fig. 6 – Differential Relay



TEST REPORT
PERCENT DIFFERENTIAL RELAY

COMPLETE NAMEPLATE DATA

INSPECTION SERVICE

JOB NO.

LOCATION	SERIAL NO.	STYLE NO.	TAP AMP	TIME DIAL	PICK UP AMP	RELAY TESTS 5 - 7 AMPS	5 - 7 AMPS	5 - 9 AMPS	5 - 9 AMPS	SLOPE TEST	THRU FAULT TEST	TARGET OPER. AMPS. DC	INSUL. TEST MEGOHMS
						CYCLES							

REMARKS

TESTED BY _____ DATE _____

Fig. 7 – Percent Differential Relay

POWER FACTOR RELAY TEST RECORD

INSPECTION SERVICE | JOB NO.

COMPANY – PLANT | LOCATION | TYPE

EQUIPMENT IDENTIFICATION	PLANT IDENTIFICATION	RELAY NAMEPLATE DATA	CURVE

SPECIFIED RELAY SETTINGS | TAP SETTING | OTHER

DATE	ZERO ADJ.	TEST AMPS	INS. RES. VOLTS AC	POWER FACTOR TO CLOSE CONTACTS		SERIAL NO.	REMARKS
				AS FOUND	AS LEFT		

TESTED BY _____ DATE _____

Fig. 8 – Power Factor Relay

Common Abbreviations and Technical Terminology

The following is a list of common abbreviations and technical terminology, given in the most accepted form.

Å	angstrom
- - -	abcoulomb (10 coulombs) electrical charge
- - -	abfarad (10^9 farads) capacitance
- - -	abhenry (10^9 henrys) inductance
- - -	abohm (10^9 ohms) resistance
abamp	abampere, (10 amperes) current also absolute ampere
abs	absolute
ABT	automatic bus transfer
- - -	abvolt (10^8 volts) potential
ac	alternating current (noun)
a-c	alternating-current (adj.)
ADf	automatic direction finder
Af	audio frequency
AFC	automatic frequency control
AGC	automatic gain control
AGMA	American Gear Manufacturer's Association
AISE	Association of Iron and Steel Engineers
amorph	amorphous
amp	ampere
amp-hr	ampere-hour
AMPL (dwgs. only)	amplifier
AM	amplitude modulation
a.m.	ante meridian
amu	atomic mass unit
anh	anhydrous
ANSI	American National Standards Institute
antilog	antilogarithm
API	American Petroleum Institute
a/o	atomic percent
α-particle	alpha particle
aq	aqueous
α-radiation	alpha radiation
α-ray	alpha ray
- - -	arc weld (noun)
- - -	arc-weld (verb)
- - -	as-compound words (as-annealed, as-quenched, etc.)

As	standard atmosphere
asym	asymetrical
atm	atmosphere
at	atomic
at. no.	atomic number
at. wt.	atomic weight
auto.	automatic
aux	auxiliary
AVC	automatic volume control
AWG	American Wire Gauge
awu	atomic weight unit
avg	average
back EMF	back electromotive force
- - -	backflow
- - -	backleakage
- - -	back pressure
- - -	backscatter
- - -	backup (noun, adj.)
- - -	back up (verb)
- - -	ball-bearing (adj.)
- - -	ball bearing (noun)
°B	Baume, degree
°Be	degree Baume
- - -	barye (dy/cm^2)
- - -	bar
- - -	barn
BIL	basic impulse level
β-particle	beta particle
β	beta radiation
β-ray	beta ray
bhd	bulkhead
BHP	brake horsepower
- - -	bicompound words (bimetallic, bipolar, etc.)
Bev	billion electron volts
bkr	breaker
- - -	blowdown (noun, adj.)
- - -	blow down (verb)
bp	boiling point
BH	Brinell hardness
BHN	Brinell hardness number
BSI	British Standards Institute
Btu	British thermal unit
Btu/hr-ft-°f	British thermal units per hour per hour per foot per degree fahrenheit
Btu/hr-ft^2	British thermal units per hour per square foot
- - -	buildup (noun)
- - -	build up (verb)
- - -	built-up (adj.)
- - -	burned-out (adj.)
- - -	burnout (noun)
- - -	burn out (verb)

BWG	Birmingham Wire Gage
- - -	bypass (noun, verb, adj.)
C	Celsius or Centigrade
°C	degree Celsius
C	heat capacity
Cal	Calorie
cal/g	Calories per gram
cal/g – °C	calories per gram per degree Celsius
cal/sec-cm-°C	calories per second per centimeter per degree Celsius
cap.	capacity
- - -	cap screw
- - -	carry-over (noun)
- - -	carry over (verb)
- - -	case harden (verb)
- - -	case-hardened (adj.)
- - -	cast-iron (adj.)
- - -	cast iron (noun)
- - -	cathode-ray (adj.)
- - -	cathode ray (noun)
CB	center of buoyancy
ccw	counterclockwise
CEMF	counter electromotive force
- - -	cent (unit of reactivity)
- - -	center-of-mass (adj.)
- - -	center of mass (noun)
CFE	Contractor-furnished equipment
cfm	cubic feet per minute
cfp	Contractor-furnished property
CFS	cubic feet per second
cgm	centimeter-gram-second
cgsu	centimeter-gram-second unit
CL or $\mathbb{C}_L$	Center line
cg	centigram
- - -	chain reaction (noun)
- - -	chain-react (verb)
circum	circumference
cl	centiliter
cm	centimeter
Cm	heat capacity per mole
cm^2	square centimeter
cm^3	cubic centimeter
- - -	coastdown (noun)
- - -	coast down (verb)
- - -	cocompound words (cooperate, coordinate, etc.)
coef	coefficient
- - -	cooldown (adj. noun)
- - -	cool down (verb)
cosh	hyperbolic cosine

coth	hyperbolic cotangent
csch	hyperbolic cosecant
cse	cosecant
CSI	Canadian Standards Institute
cos	cosine
cot	cotangent
counts/min	counts per minute
counts/sec	counts per second
cp	candle power
CPD	contact potential difference
cpm	cycles per minute
cps (Hz)	cycles per second
- - -	cutoff (adj. noun)
- - -	cut off (verb)
CW	continuous wave
cw	clockwise
db	decibel
dbm	decibel referred to one milliwatt
dc	direct current (noun)
d-c	direct-current (adj.)
deg or ° (dwg. only)	degree
Δ	differential (Delta)
ΔT	differential temperature (Delta)
δk	reactivity (delta)
dg	decigram
diam	diameter
dis/sec	disintegrations per second
dl	deciliter
dm	decimeter
dm^2	square decimeter
dn	delta amplitude
DNB	departure from nucleate boiling
DNBPR	departure from nucleate boiling power ratio
- - -	dollar (units of reactivity)
D_2O	heavy water
d/p or Δp	differential pressure (Delta p)
DPDT	double pole, double throw
DPM	decades per minute
DPR	design power ratio
DPST	double pole, single throw
dy/cm^2	dyne per square centimeter
EHF	extremely high frequency
EHV	extremely high voltage
ELF	extremely low frequency
EMF	electromotive force
emu	electromagnetic unit
Ep	potential energy
Eq.	equation
esu	electrostatic unit
ev	electron volts
F	Fahrenheit

°F	degree Fahrenheit
fissions/cm^3	fissions per cubic centimeter
- - -	fission-product (adj.)
- - -	fission product (noun)
fissions/sec	fissions per second
FM	frequency modulation
fnp	fusion point
F.O.B.	free on board
fpm	feet per minute
fps	feet per second
fps	foot-pound-second
ft	foot
ft.^{3}	cubic foot
ft-lb	foot-pound
g	gravity
gal	gallon
g-atom	gram atom
g-cal	gram calorie
g/cm^3	grams per cubic centimeter
- - -	gauss (singular and plural)
gc	gigacycle
GFE	Government furnished equipment
GFP	Government furnished property
gph	gallons per hour
gpm	gallons per minute
gps	gallons per second
H	enthalpy
hav	haversine
HF	high frequency
hp	horsepower
hr	hour
Hz	hertz (cps)
HYD (dwg. only)	hydraulic
IÅ	international angstrom
ICT	international critical tables
ID	inside diameter
IEC	International Electromechanical Commission
IF	intermediate frequency
in.	inch
in.^{3}	cubic inch
in. H_2O	inches of water (pressure)
in.-lb.	inch-pound
in./min.	inches per minute
K	Kelvin
°K	degree Kelvin
kcal	kilocalories
kcal/mole	kilocalories
kev	kiloelectron volts
kg	kilogram

kgauss	kilogauss
kg-m	kilogram-meter
kHz	kilohertz
kip	thousand pounds
kj	kilojoule
kl	kiloliter
km	kilometer
km^2	square kilometer
kohm	kilohm
k-ohm	ohms, thousand
ksi	thousand pounds per square inch
kt	thousand tons
kV	kilovolt
kVA	kilovolt-ampere
kvar	reactive kilovolt-ampere
kVP	kilovolt peak
kW	kilowatt
kW (e)-hr	kilowatt-hour (electrical)
kWhr	kilowatt-hour
lb	pound
lb-ft (or oz-in.)	moments of torque
ln	natural logarithm
log	logarithm
LF	low frequency
m	meter
m^2	square meter
m^3	cubic meter
mÅ	milliangstrom
ma	milliampere
mb	millibar
mHz	megahertz
mc	millicurie
megohm	ohms, million
mep	mean effective pressure
Mev	million electron volts
MF	medium frequency
mf	millifarad
M-G (dwg. only)	motor-generator
mg	milligram
mh	millihenry
MI	mineral insulated
min	minute (time)
mL	millilambert
ml	milliliter
mmu	milli-mass-units
m/o	mole percent
mph	miles per hour
mr	milliroentgen
mrep	milliroentgens equivalent physical
mr/hr	milliroentgens per hour
msec	millisecond

Mt	megaton
mm^3	cubic millimeter
mμ	millimicron
μ	micron
μÅ	microangstrom
μa	microampere
μc	microcurie
μf	microfarad
μl	microliter
μohm	microohm
μsec	microsecond
μv	microvolt
μw	microwatt
MV	megavolt
mV	millivolt
MVA	megavolt-ampere
MW	megawatt
mW	milliwatt
MWD/adjacent ton	megawatt-days per adjacent ton
MWD/central ton	megawatt-days per central ton
MWD/T	megawatt-days per ton
MWd	megawatt-day
MWe	megawatt (electrical)
MW/sec	megawatt second
MWt	megawatt (thermal)
MW/year	megawatt year
N	normal (concentration, with a number)
NC	normally closed
NEC	National Electric Code
NEMA	National Electrical Manufacturer's Association
NO	normally open
no., nos.	number, numbers
NPR	nominal power ratio
NPSH	net positive suction head
NPT	normal pressure and temperature
nsec	nanosecond
OD	outside diameter
oersted-cm	oersted-centimeter
ohm-cm	ohm-centimeter (resistivity)
$(ohm\text{-}cm)^{-1}$	$(ohm\text{-}centimeter)^{-1}$ (conductivity)
OSHA	Occupational Safety and Health Administration
oz	ounce
oz-in	ounce-inch
pcu	pound centigrade unit
pf	picofarad
pf	power factor
p or δk	coefficient of reactivity (rho) (delta k)
PH	precipitation handling

pH	hydrogen ion concentration reciprocal
ϕ	phase (phi)
p.m.	post meridian
PM	phase modulation
PPIP	primary plant instrument panels
precip	precipitate
press.	pressure
PE	probable error
psi	pounds per square inch
psia	pounds per square inch, absolute
psig	pounds per square inch, gage
pot.	potentiometer
PP	peak to peak
ppb	parts per billion
ppm	parts per million
pps	pulses per second
PVC	polyvinyl chloride
PVT	pressure-volume-temperature
°R	degree Rankine
°Re	degree Reaumur
RC	reactor compartment
redox	oxidation-reduction
RF	radio frequency
RFI	radio frequency interference
ρ	reactivity (rho)
r	roentgen
rem	roentgen equivalent, man
rep	roentgen equivalent, physical
r/hr	roentgens per hour
rms	root mean square
RPCP	reactor plant control panel
rpm	revolutions per minute
rps	revolutions per second
scf	standard cubic feet
scfh	standard cubic feet per hour
scfm	standard cubic feet per minute
sec	secant
sec	second (angular)
sec	second (time)
sech	hyperbolic secant
Σ	summation operator (sigma)
sinh	hyberbolic sine
S/N	signal to noise ratio
sin	sine
/	per (tables only)
sol.	soluble
soln	solution
SOP	standard operating procedure
SPDT	single pole, double throw
sp gr	specific gravity

sp ht	specific heat
SPST	single pole, single throw
sq ft	square foot
sq in	square inch
SRB	styrene-butadiene rubber
STBY	standby (adj., noun)
std	standard
STP	standard temperature and pressure
sym	symmetrical
SWR	standing wave ratio
T or H^3	Tritium
TACH	tachometer (dwgs. only)
tan	tangent
tanh	hyperbolic tangent
tavg	temperature, average
T_c	cold leg temperature
temp	temperature
T_h	hot leg temperature
toor	millimeters of mercury (pressure)
ts	tensile strength
tsi	tons per square inch
TTR	transformer turn ratio
TV	television
UHF	ultra high frequency
USASI	USA Standards Institute
V	volt
VA	volt-ampere
VAR	reactive volt-ampere
VDE	German Standards Institute
VHF	very high frequency
VLF	very low frequency
VSWR	voltage standing wave ratio
v/o	volume percent
watt/cm-sec	watts per centimeter per second
watt-hr	watt-hour
w/o	weight percent
yd	yard
yd^3	cubic yard
Xtal	crystal

Table of Elements (Symbols)

Element	Symbol
Actinium	Ac
Aluminum	Al
Americium	Am
Antimony (stibium)	Sb
Argon	Ar
Arsenic	As
Astatine	At
Barium	Ba
Berkelium	Bk
Beryllium (glucinum)	Be
Bismuth	Bi
Boron	B
Bromine	Br
Cadmium	Cd
Calcium	Ca
Californium	Cf
Carbon	C
Cerium	Ce
Cesium	Cs
Chlorine	Cl
Chromium	Cr
Cobalt	Co
Copper	Cu
Curium	Cm
Dysprosium	Dy
Einsteinum	Es
Erbium	Er
Europium	Eu
Fermium	Fm
Fluorine	F
Francium	Fr
Gadolinium	Gd
Gallium	Ga
Germanium	Ge
Gold (aurum)	Au
Hafnium	Hf
Helium	He
Holmium	Ho
Hydrogen	H
Indium	In
Iodine	I
Iridium	Ir
Iron (Ferrum)	Fe
Krypton	Kr
Lanthanum	La
Lawrencium	Lw
Lead (plumbum)	Pb
Lithium	Li
Lutetium	Lu
Magnesium	Mg
Manganese	Mn
Masurium	Ma
Mendelevium	Md
Mercury (hydrargyrum)	Hg
Molybdenum	Mo
Neodymium	Nd
Neon	Ne
Neptunium	Np
Nickel	Ni
Niobium (columbium)	Nb
Nitrogen	N
Nobelium	No
Osmium	Os
Oxygen	O
Palladium	Pd
Phosphorus	P
Platinum	Pt
Plutonium	Pu
Polonium	Po
Potassium (kalium)	K
Praseodymium	Pr
Promethium	Pm
Protactinium	Pa
Radium	Ra
Radon (niton)	Rn
Rhenium	Re
Rhodium	Rh
Rubidium	Rb
Ruthenium	Ru

Element	Symbol
Samarium	Sm
Scandium	Sc
Selenium	Se
Silicon	Si
Silver (argentum)	Ag
Sodium (natrium)	Na
Strontium	Sr
Sulfur	S
Tantalum	Ta
Technetium	Tc
Tellurium	Te
Terbium	Tb
Thallium	Tl
Thorium	Th
Thulium	Tm
Tin (stannum)	Sn
Titanium	Ti
Tungsten (wolfranium)	W
Uranium	U
Vanadium	V
Wolfram (see Tungsten)	W
Xenon	Xe
Ytterbium	Yb
Yttrium	Yt
Zinc	Zn
Zirconium	Zr

Volume 4
Chapter 5

Graphic Symbols for Electrical Diagrams

Graphic Symbols for Electrical Diagrams

These symbols have been selected from Westinghouse Corporate Standard 32.62 of April 1976.

IEC (International Electrotechnical Commission) Identification
Symbols and build-ups that have been recommended by the international Electrotechnical Commission are indicated by IEC.

When alternate symbols are shown, the relative position does not imply preference. Alternate symbols identified as IEC are recommended.

F Indicates item names from The Federal Item Guide, Cataloging.

This chapter is not only a guide for those making electrical diagrams, it should also prove helpful for those reading electrical diagrams.

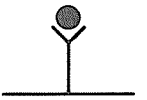
Graphic Symbols for Electrical Diagrams

5.1 Qualifying Symbols

5.1 **A. Test-Point Recognition Symbol**
Use if necessary to emphasize test points.

5.1 A. **1.** *General*

5.1 A. **2.** *Application*
Test-point recognition for a test jack.



5.1 B. Polarity Markings

5.1 B. 1. *Positive*

IEC +

5.1 B. 2. *Negative*

IEC −

5.1 B. 3. *Instantaneous Polarity Markings*

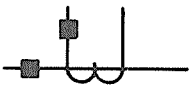
Use only when necessary to show relative polarity of windings.

Instantaneous polarity of voltage across windings corresponds at points indicated by polarity marks. Instantaneous direction of current into or out of one polarity mark corresponds to current out of or into the other polarity mark. If instantaneous currents enter the windings at the marked points, they will produce aiding fluxes.

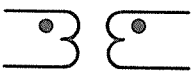
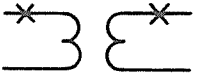
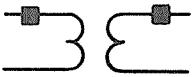
IEC ● OR × OR ■

5.1 B. 3. **a.** Application with Current Transformer

The dots are shown near one end of each coil or winding symbol. The exact location is not critical if the location is at one end or the other. Use only one polarity mark per winding even if the winding is tapped.

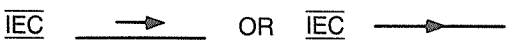
IEC  OR  OR 

5.1 B. 3. **b.** Application with Potential Transformer

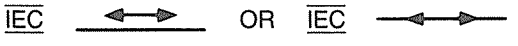
IEC  OR  OR 

5.1 **C. Direction of Flow of Power, Signal, or Information**
Avoid conflict with Relay Protective function symbols.

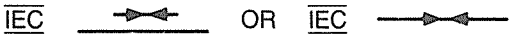
5.1 C. **1.** *One-Way*



5.1 C. **2.** *Either Way (But not simultaneously)*

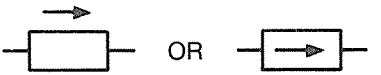


5.1 C. **3.** *Both Ways Simultaneously*



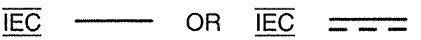
5.1 C. **4.** *Application, One-Way, General*
The n is not part of the symbol. Substitute a wave form or frequency range for n.

5.1 C. **5.** *Application, One-Way, Circuit Element, General*
Always indicate the type of apparatus by letters or words in the rectangle.

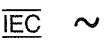


5.1 **D. Kind of Current**
Use only if necessary for clarity.

5.1 D. **1.** *Direct Current*
To be used only when first symbol is not suitable

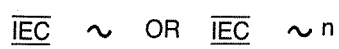


5.1 D. **2.** *Alternating Current*



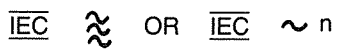
5.1 D. 2. **a.** Frequency Ranges
Use alternating current frequency ranges only when necessary to distinguish among different frequency bands.

5.1 D. 2. **b.** Power Frequencies

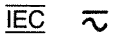


5.1 D. 2. **c.** Audio Frequencies

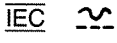
5.1 D. 2. **d.** Superaudio, Carriers, and Radio Frequencies



5.1 D. **3.** *Universal Current, Direct or Alternating*

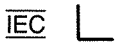


5.1 D. **4.** *Undulating or Rectified Current*

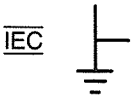


5.1 **E. Connection Symbols**
For use adjacent to the Symbols

5.1 E. **1.** *2-Phase 3-Wire*
5.1 E. 1. **a.** Ungrounded

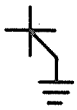


5.1 E. 1. **b.** Grounded



5.1 E. **2.** *2-Phase 4-Wire*

5.1 E. **3.** *2-Phase 5-Wire, Grounded*



5.1 E. **4.** *3-Phase 3-Wire Delta*
5.1 E. 4. **a.** Ungrounded

IEC 

5.1 E. 4. **b.** Grounded

IEC 

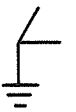
5.1 E. **5.** *3-Phase 4-Wire, Delta*
5.1 E. 5. **a.** Ungrounded

5.1 E. 5. **b.** Grounded

5.1 E. **6.** *3-Phase, Open, Delta*
5.1 E. 6. **a.** Ungrounded

IEC 

5.1 E. 6. **b.** Grounded at a Common Point

IEC 

5.1 E. 6. **c.** Grounded at Middle Point at One Winding

5.1 E. **7.** *Phase, Broken Delta*

IEC 

5.1 E. **8.** *3-Phase Wye or Star*
5.1 E. 8. **a.** Ungrounded

IEC 

5.1 E. 8. **b.** Grounded Neutral

IEC 

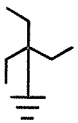
5.1 E. **9.** *3-Phase 4-Wire, Ungrounded*

IEC 

5.1 E. **10.** *3-Phase, Zigzag*
5.1 E. 10. **a.** Ungrounded

IEC 

5.1 E. 10. **b.** Grounded

IEC 

5.1 E. **11.** *3-Phase Scott or T*

IEC 

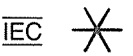
5.1 E. **12.** *6-Phase*
5.1 E. 12. **a.** Double Delta

IEC 

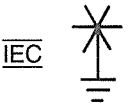
5.1 E. 12. **b.** Hexagonal or Chordal

IEC 

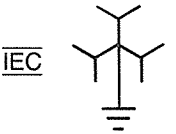
5.1 E. 12. **c.** Star or Diametrical



5.1 E. 12. **d.** Star with Grounded Neutral

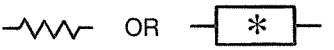


5.1 E. 12. **e.** Double Zigzag with Neutral Brought Out and Grounded

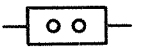


5.2 Fundamental Items

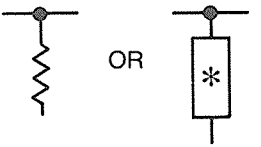
5.2 **A. Heating Resistor**
The asterisk is not part of the symbol, replace it with identification within or adjacent to the rectangle.



5.2 **B. Instrument or Relay Shunt**
Connect instrument or relay to terminals in the rectangle.



5.2 **C. Shunt Resistor**
The asterisk to be replaced by identification in or adjacent to the rectangle.

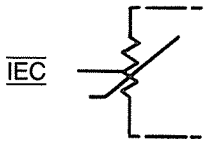


5.2 **D. Resistive Termination**
Commonly used in coaxial and wave guide diagrams.

5.2 D. **1.** *Application, Series Resistor and Path Open*

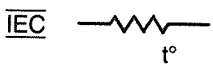
5.2 D. **2.** *Application, Series Resistor and Path Short-Circuited*

5.2 D. **3.** *Bolometer Element*
Broken lines indicate direct-current connections and are not part of the symbol.

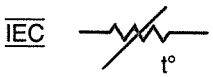


5.2 **E. Thermistor, Thermal Resistor, Temperature-Sensing Element**
Use only if essential to indicate special property.

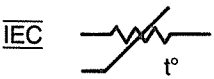
5.2 E. **1.** *General*



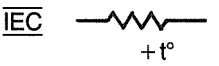
5.2 E. **2.** *Linear*



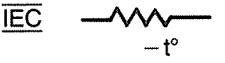
5.2 E. **3.** *Nonlinear*



5.2 E. **4.** *Positive Temperature Coefficient*

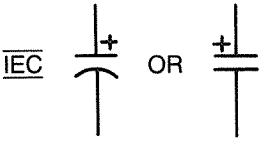


5.2 E. **5.** *Negative Temperature Coefficient*

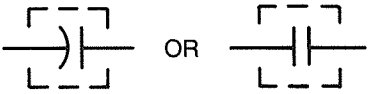


5.2 F. Capacitors

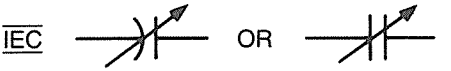
5.2 F. **1.** *Polarized*



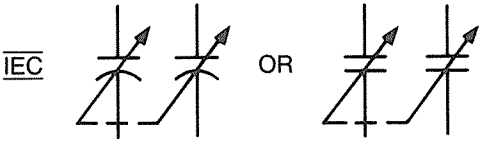
5.2 F. **2.** *Shielded*



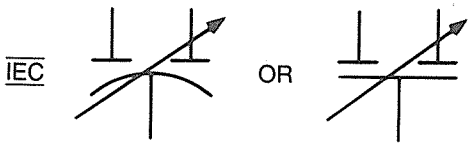
5.2 F. **3.** *Adjustable or Variable*



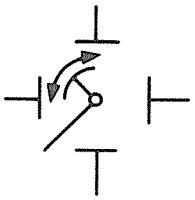
5.2 F. **4.** *Application*
Adjustable or variable capacitors with mechanical linkage of units.



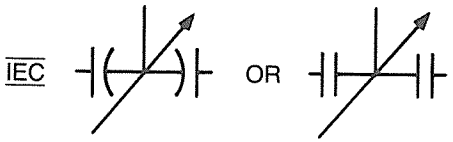
5.2 F. **5.** *Continuously Adjustable or Variable Differential Capacitor*
The capacitance of one part increases as the capacitance of the other part decreases.



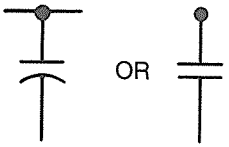
5.2 F. **6.** *Phase-Shifter Capacitor*



5.2 F. **7.** *Split-Stator Capacitor*

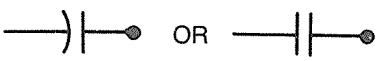


5.2 F. **8.** *Shunt Capacitor*

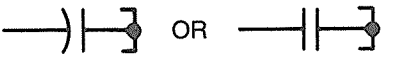


5.2 F. **9.** *Capacitative Termination*
Commonly used in on coaxial and wave guide diagrams

5.2 F. **10.** *Application*
5.2 F. 10. **a.** Series capacitor and path open



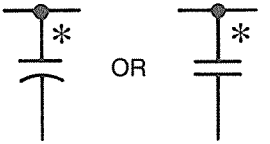
5.2 F. 10. **b.** Series capacitor and path short circuited



5.2 F. **11.** *Coupling Capacitor for Power Line Carrier*

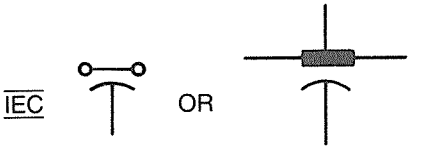
The asterisk is not part of the symbol. If identification is required replace with one of the following:

COM	carrier communications
LC	carrier load control
REL	carrier relaying
SUP	carrier supervisory
TLM	carrier telemetering
TT	carrier transferred trip



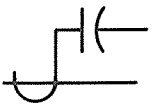
5.2 F. **12.** *Feed-Through Capacitor*

Terminals are shown on feed-through element for clarity. Commonly used for by-passing high-frequency currents to chassis.

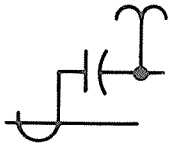


Application: feed-through capacitor between two inductors with third lead connected to chassis.

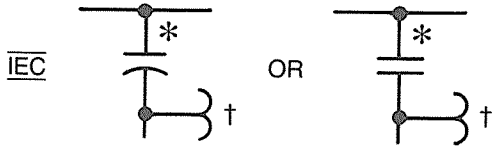
5.2 F. **13.** *Capacitor Bushing for Circuit Breaker or Transformer Application*



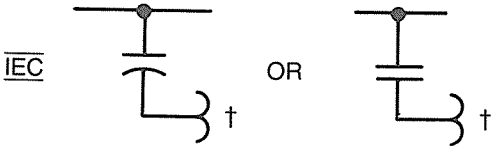
5.2 F. 13. **a.** Capacitor-Bushing Potential Device



5.2 F. 13. **b.** Carrier-Coupling Capacitor Potential Device
Used to provide a power-system-frequency voltage and as coupling for carrier signals.

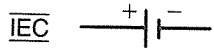


5.2 F. 13. **c.** Coupling Capacitor Potential Device
Used only to provide a power-system-frequency voltage.

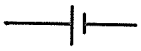


The dagger is not part of the symbol. For identification replace dagger with letter combination from Meters (5.10 A.). Replace the asterisk with letter combination from Coupling Capacitor (5.2 F. 11. above).

5.2 **G. Battery**
The long line is always positive but polarity may also be indicated.

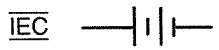


5.2 G. **1.** *Generalized Direct-Current Source*



5.2 G. **2.** *One Cell*

5.2 G. **3.** *Multicell*

IEC 

5.2 G. **4.** *Multicell Battery wtih Adjustable Tap*

IEC 

5.2 **H. Thermocouple-Dissimilar-Metals Device Temperature-Measuring**

IEC 

5.3 Transmission Path - Conductor, Cable, Wiring

5.3 A. Guided Path

5.3 A. **1.** *General*

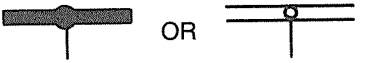
A single line represents the entire group of conductors or the transmission needed to guide the power or signal. For coaxial and waveguide work, the recognition symbol is used at the beginning and end of each transmission path and at intermediate points as needed for clarity. In waveguide work, mode may be indicated. IEC

When required, the length between two significant points may be indicated e.g. 2/4. IEC

When required, details of structure (e.g. elbow), type, impedance, rating, etc. may be shown adjacent to or within any symbol or in a note. IEC

IEC

5.3 A. **2.** *Bus Bar with Connections Shown*



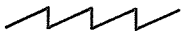
5.3 A. **3.** *Conductive Path or Conductor Wire*

5.3 A. 3. **a.** Two conductors or conductive paths

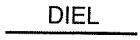
5.3 A. 3. **b.** Three conductors or conductive paths

5.3 A. 3. **c.** Multiconductors or conductive paths with the number indicated. The n in the symbol to be replaced with the number of conductors.

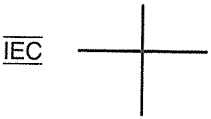
5.3 A. **4.** *Air or Space Path*



5.3 A. **5.** *Dielectric Path Other Than Air*



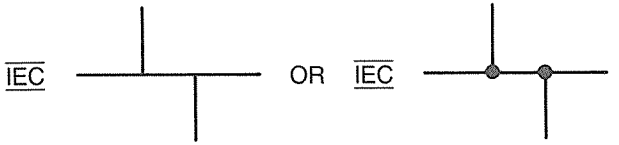
5.3 A. **6.** *Crossing of paths or conductors not connected.* Crossing can be at any angle.



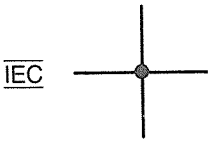
5.3 A. **7.** *Junction of Paths or Conductors*

5.3 A. 7. **a.** Junction of paths, conductors, or cables. If desired, path type or size may be indicated.

5.3 A. 7. **b.** Junction of connected paths, conductors, or wires

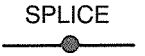


Only if required by layout considerations.

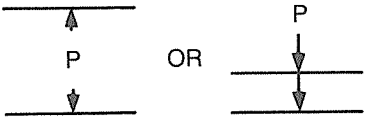


For microwave circuits, the type of coupling, power-division proportions, reflection coefficients, plane of junction, etc. may be indicated.

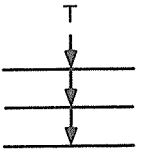
5.3 A. **8.** *Splice of Same Size Cables - Optional*
Junction of conductors of same or different sizes. Sizes of conductors may be indicated.



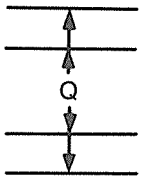
5.3 A. **9.** *Associated Conductors*
5.3 A. 9. **a.** Pair
Twisted unless otherwise specified.



5.3 A. 9. **b.** Triple
Twisted unless otherwise specified

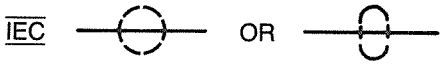


5.3 A. 9. **c.** Quad

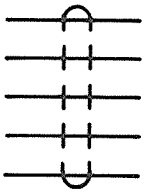


5.3 A. **10.** *Assembled Conductors, Cable*
Commonly used in communications diagrams.

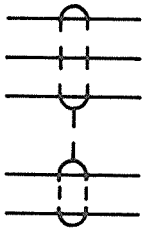
5.3 A. 10. **a.** Shielded Single Conductor



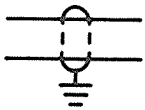
5.3 A. 10. **b.** Shielded 5-Conductor



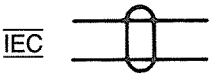
5.3 A. 10. **c.** Shielded 5-Conductor
Conductors separated on diagram for convenience.



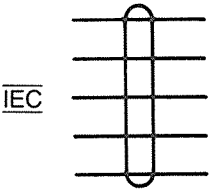
5.3 A. 10. **d.** Shielded 2-Conductor Cable
With Shield Grounded



5.3 A. 10. **e.** Two Conductor Cable



5.3 A. 10. **f.** 5-Conductor Cable



5.3 A. **11.** *Coaxial Cable*

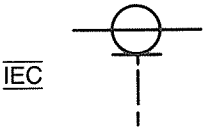
Recognition symbol: coaxial transmission path; radio-frequency cable F (coaxial)

If necessary for clarity an outer-conductor connection may be made to the symbol.

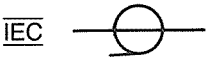
If the coaxial structure is not maintained, the tangential line may be drawn on the coaxial side.

The broken line indicates where the outer-conductor connection is made and is not part of the symbol.

5.3 A. 11. **a.** General



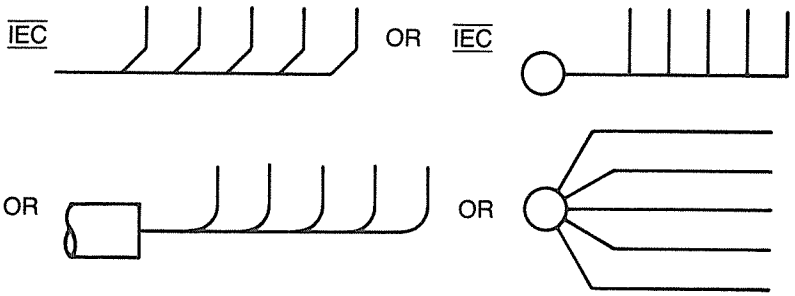
5.3 A. 11. **b.** Coaxial structure not maintained on the right.



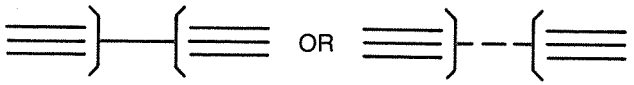
5.3 A. **12.** *Grouping of Leads*

5.3 A. 12. **a.** General

Bend of lines indicates direction in which the other end of the path will be found.



5.3 A. 12. **b.** Interrupted (on diagram), shown with individual paths at each side of a diagrammatic interruption.



5.3 A. 12. **c.** Interrupted Path

Used only when required for complex or special-purpose diagrams.

To ensure continuity, interrupted-path break points must be in alignment.

The asterisk to be replaced by identifying values, letters, numbers, or marks.

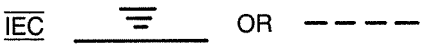
5.3 **B. Distribution Lines, Transmission Lines**

Commonly used on system diagrams, maps, and charts.

The following letters may be used to indicate type of transmission:

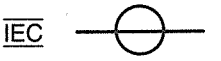
F Telephony IEC
S Sound (television) IEC
T Telegraphy IEC
Transmission of Data IEC
V Video (television) IEC

5.3 B. **1.** *Underground Cable or Line*

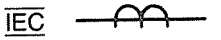


5.3 B. **2.** *Submarine, Underwater Line*

5.3 B. **3.** *Overhead Line*



5.3 B. **4.** *Loaded Line*



5.3 **C. Circuit Return**

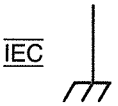
5.3 C. **1.** *Ground*

A direct conducting connection to the earth or a body of water that is connected to the earth.

A conducting connection to a structure that serves a function similar to that of an earth ground, i.e., a structure such as a frame of an air, space, or land vehicle that is not conductively connected to earth.

5.3 C. **2.** *Chassis or Frame Connection*
Equivalent chassis connection of Printed-Wiring Boards

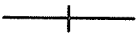
A conducting connection to a chassis or frame, or equivalent chassis connection of a printed-wiring board, may be at substantial potential with respect to the earth or structure in which the chassis, or frame, or printed-wiring board is mounted.



5.4 Contacts, Switches, Contactors, and Relays

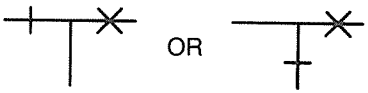
5.4 A. Switching Function

5.4 A. **1.** *Conducting, Closed Contact (break)*



5.4 A. **2.** *Nonconducting Open Contact (make)*

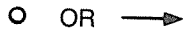
5.4 A. **3.** *Transfer*



5.4 B. Electrical Contact F]

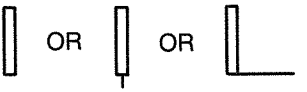
5.4 B. **1.** *Fixed Contact*
5.4 B. 1. **a.** For Jack, Key, Relay, etc.

5.4 B. 1. **b.** For Switch



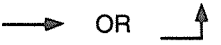
5.4 B. 1. **c.** For Momentary Switch

5.4 B. 1. **d.** Sleeve



5.4 B. **2.** *Moving Contact*

5.4 B. 2. **a.** Adjustable or Sliding Contact for Resistor, Inductor, etc.



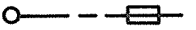
5.4 B. 2. **b.** Locking

5.4 B. 2. **c.** Nonlocking

5.4 B. 2. **d.** Segment; Bridging Contact

5.4 B. 2. **e.** Vibrator Reed

5.4 B. 2. **f.** Vibrator, Split Reed



5.4 B. 2. **g.** Rotating Contact (Slip Ring) and Brush

5.4 **C. Basic Contact Assemblies**

The standard method of showing a contact is by symbol indicating the circuit condition it produces when the actuating device is in the de-energized or nonoperated position. The actuating device may be of a mechanical, electrical, or other type and a clarifying note may be necessary with the symbol to explain the proper point at which the contact functions; for example the point where a contact closes or opens as a function of changing pressure, level, flow, voltage, current, etc.

Where it is desirable to show contacts in the energized or operated position and where confusion may result, a clarifying note should be added to the drawing.

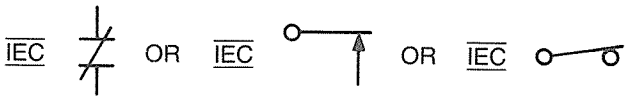
Auxiliary switches or contacts for circuit breakers, etc., may be designated as follows:

(a) Closed when device is energized or in operated position.
(b) Closed when device is de-energized or in nonoperated position.
(aa) Closed when operating mechanism is in energized or operated position.
(bb) Closed when operating mechanism of main device is in de-energized or nonoperated position.

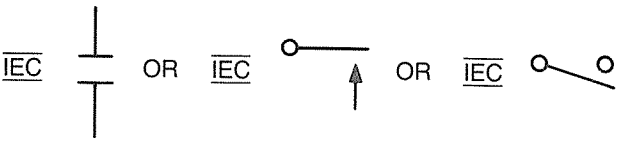
See *American National Standard Manual* and *Automatic Station Control, Supervisory, and Associated Telemetering Equipment, C37.2, 1970* for further details.

In the parallel-line contact symbols shown below, the length of the parallel lines should be approximately 1.75 times the width of the gap, except for symbol for time sequential closing, **5.c.** below.

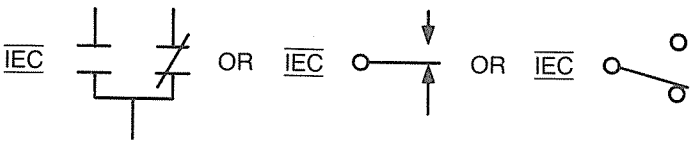
5.4 C. **1.** *Closed Contact (break)*



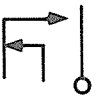
5.4 C. **2.** *Open Contact (make)*



5.4 C. **3.** *Transfer*

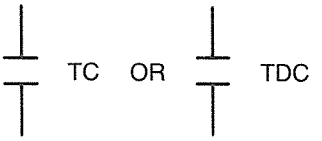


5.4 C. **4.** *Make-Before-Break*

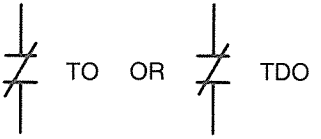


5.4 C. **5.** *Application*

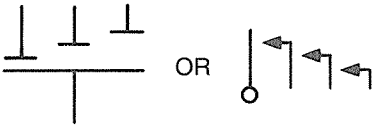
5.4 C. 5. **a.** Open Contact with Time Closing (TC) or Time-Delay Closing (TDC)



5.4 C. 5. **b.** Closed Contact with Time Opening (TO) or Time-Delay Closing

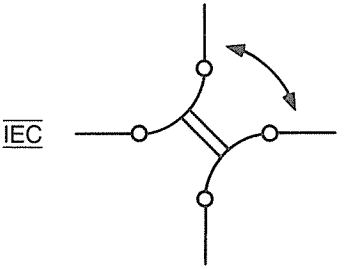


5.4 C. 5. **c.** Time Sequential Closing

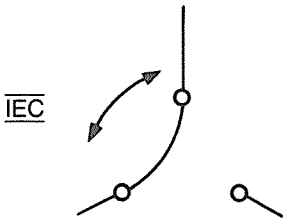


5.4 C. **6.** *Multiway Transfer Switch*

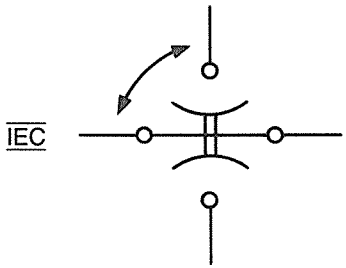
5.4 C. 6. **a.** Two-position switch (90 degree step)



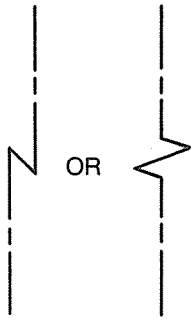
5.4 C. 6. **b.** Three-position switch (120 degree step)



5.4 C. 6. **c.** Four-position switch (45 degree step)



5.4 C. **7.** *Magnetic Blowout Coil F*



5.4 C. **8.** *Switch*

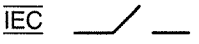
Fundamental symbols for contacts, mechanical connections, etc., may be used for switch symbols.

The standard method for showing switch symbols is in a position with no operating force applied. For switches that may be in any of two or more positions with no operating force applied, and for switches operated by some mechanical device

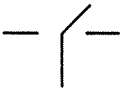
(air-pressure, liquid-level, rate-of-flow, etc.) a clarifying note may be necessary to explain the point at which the switch functions.

When basic switch symbols are shown in a closed position on a diagram, terminals must be added for clarity.

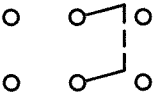
5.4 C. 8. **a.** Single-Throw, General



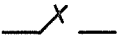
5.4 C. 8. **b.** Double-Throw, General



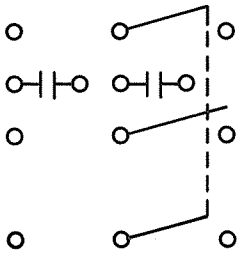
5.4 C. 8. b. **(1)** Two-Pole, Double-Throw Switch with Terminals Shown



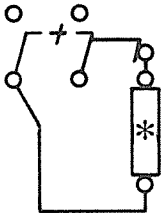
5.4 C. 8. **c.** Knife Switch F, General



5.4 C. 8. c. **(1)** 3-Pole, Double-Throw Knife Switch with Auxiliary Contacts and Terminals.

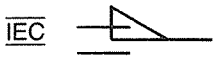


5.4 C. 8. c. **(2)** Two-Pole, Field Discharge Knife Switch with Terminals and Discharge Resistor
Replace asterisk with identification in or adjacent to the rectangle.



5.4 C. 8. **d.** Switch with Horn Gap

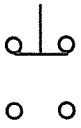
5.4 C. 8. **e.** Selector Switch F



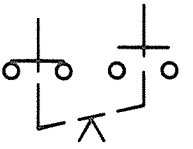
5.4 C. **9.** *Pushbutton F, Momentary or Spring-Return*
5.4 C. 9. **a.** Circuit Closing (make) Normally Open

5.4 C. 9. **b.** Circuit Opening (break) Normally Closed

5.4 C. 9. **c.** Two-Circuit



5.4 C. **10.** *Maintained, Not Spring-Return, Two-Circuit*

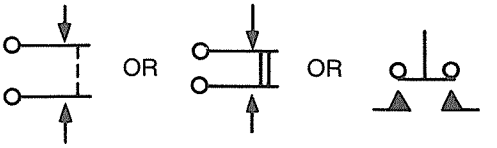


5.4 C. **11.** *Nonlocking Switch, Momentary or Spring-Return*
Symbols to the left are commonly used for spring buildups in key switches, relays, and jacks. Symbols to the right are commonly used for toggle switches.

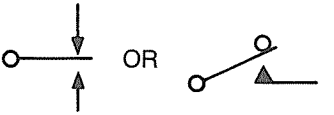
5.4 C. 11. **a.** Circuit Closing (make)

5.4 C. 11. **b.** Circuit Opening (break)

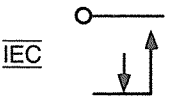
5.4 C. 11. **c.** Two-Circuit



5.4 C. 11. **d.** Transfer



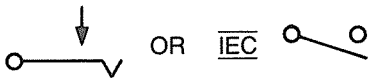
5.4 C. 11. **e.** Make-Before-Break



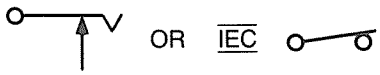
5.4 C. **12.** *Locking Switch*

Symbols to left are commonly used for spring buildups in key switches, relays, and jacks. Symbols to right are commonly used for toggle switches.

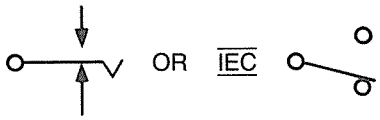
5.4 C. 12. **a.** Circuit Closing (make)



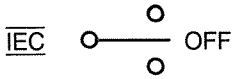
5.4 C. 12. **b.** Circuit Closing (break)



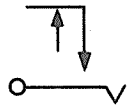
5.4 C. 12. **c.** Transfer, 2-Position



5.4 C. 12. **d.** Transfer, 3-Position

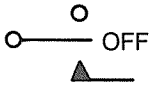


5.4 C. 12. **e.** Make-Before-Break

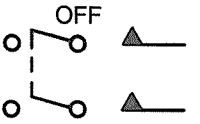


5.4 C. **13.** *Combination Locking and Nonlocking Switch commonly used for toggle switches*

5.4 C. 13. **a.** 3-Position, 1-Pole, Circuit Closing (make), Off, Momentary Circuit Closing (make).

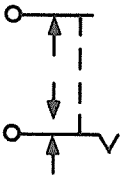


5.4 C. 13. **b.** 3-Position, 2-Pole, Circuit Closing (make), Off, Momentary Circuit Closing (make)

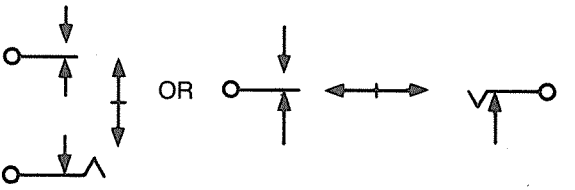


5.4 C. **14.** *Key-Type Switch, Lever Switch* F

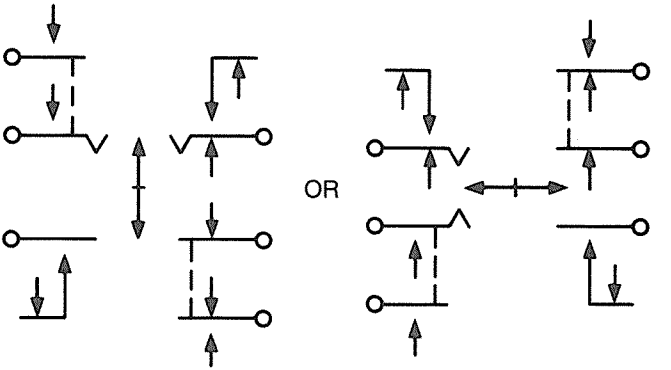
5.4 C. 14. **a.** 2-Position with Locking Transfer and Break Contacts



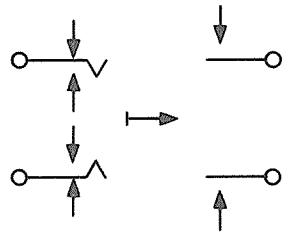
5.4 C. 14. **b.** 3-Position with Nonlocking Transfer and Locking Break Contacts



5.4 C. 14. **c.** 3-Position Multicontact Combination

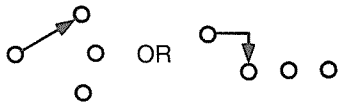


5.4 C. 14. **d.** 2-Position, Half of Key Switch Normally Operated, Multicontact Combination

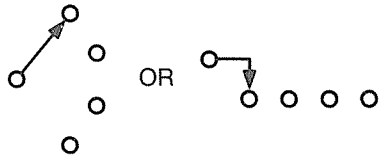


5.4 C. **15.** *Selector or Multiposition Switch*
The position in which the switch is shown may be indicated by a note or a designation.

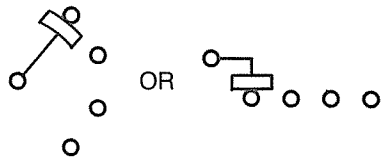
5.4 C. 15. **a.** General, for Power Control Diagrams any number of transmission paths may be shown.



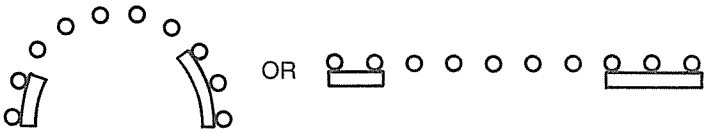
5.4 C. 15. **b.** Break-Before-Make, Nonshorting (nonbridging) During Contact Transfer.



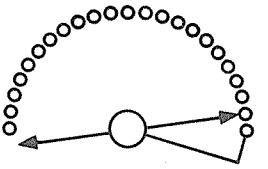
5.4 C. 15. **c.** Make-Before-Break, Shorting (bridging) During Contact Transfer.



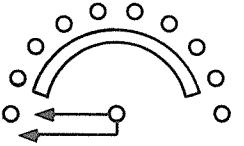
5.4 C. 15. **d.** Segmental Contact



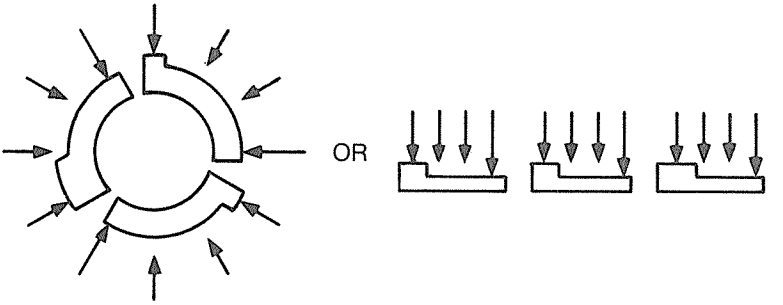
5.4 C. 15. **e.** 22-Point Selector Switch



5.4 C. 15. **f.** 10-Point Selector Switch with Fixed Segment



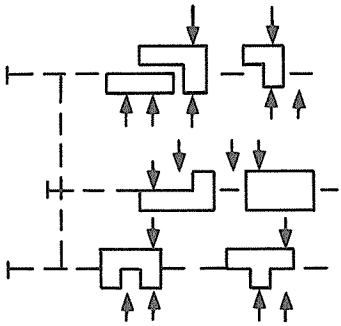
5.4 C. 15. **g.** Rotary Switch F
Section -, Deck -, or Water-Type
Viewed from end opposite control knob or actuator unless otherwise indicated. For more than one section, the first section is the one nearest the control knob or actuator. When contacts are on both sides, front contacts are nearest the control knob or actuator.



5.4 C. 15. **h.** Slide Switch F

Typical Ladder-Type Interlocks

In the example, one slide is shown operated. Slides are shown in the released position unless otherwise noted.



5.4 C. 15. **i.** Master or Control Switch

A table of contact operation must be shown on the diagram. Typical table shown here.

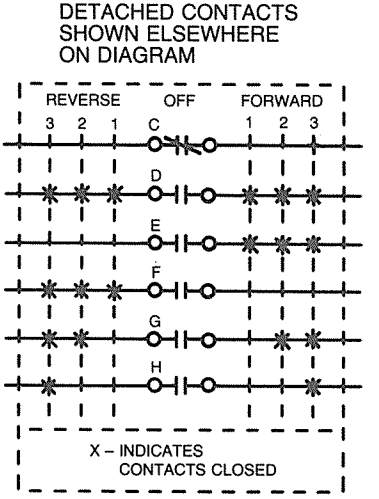
DETACHED CONTACTS SHOWN ELSEWHERE ON DIAGRAM

CONTACT	INDICATOR POSITION		
	A	B	C
1 – 2			X
3 – 4	X		
5 – 6			X
7 – 8	X		
X – INDICATES CONTACTS CLOSED			

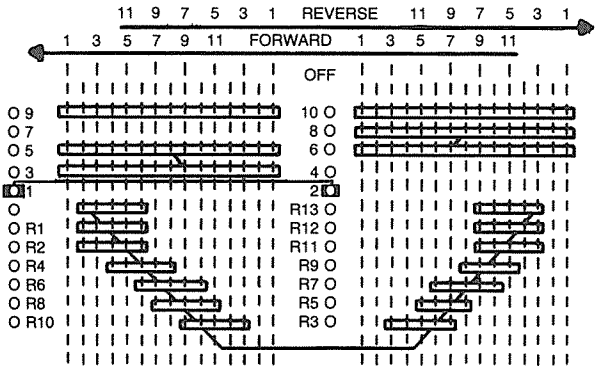
5.4 C. 15. **j.** Master or Control Switch, Cam Operated Contact Assembly

6-Circuit, 3-Point Reversing Switch

A table of contact operation must be shown on the diagram. A typical table shown here. Tabulate special features in a note.

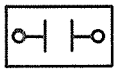


5.4 C. 15. **k.** Drum Switch, Sliding-Contact Type, Typical

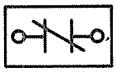


5.4 C. **16.** *Limit Switch, Sensitive Switch* F
Identify as limit switch by LS or other suitable note.

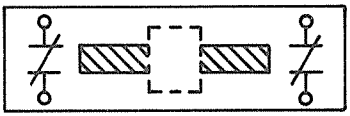
5.4 C. 16. **a.** Track-Type, Circuit-Closing Contact



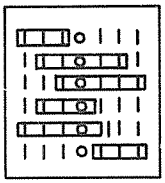
5.4 C. 16. **b.** Track-Type, Circuit-Opening Contact



5.4 C. 16. **c.** Lead-Screw-Type, Circuit-Opening Contacts



5.4 C. 16. **d.** Rotary-Type



5.4 C. 16. d. **(1)** Normally Open

5.4 C. 16. d. **(2)** Normally Open, Held Closed

5.4 C. 16. d. **(3)** Normally Closed

5.4 C. 16. d. **(4)** Normally Closed, Held Open

5.4 C. **17.** *Safety Interlock*

If specific type identification is not required, use applicable standard symbol. If specific type identification is required, see below:

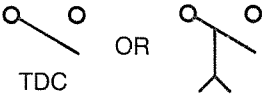
5.4 C. 17. **a.** Circuit Opening

5.4 C. 17. **b.** Circuit Closing

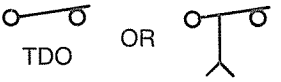
5.4 C. **18.** *Switches with Time Delay*

The point of the arrow indicates the direction of switch operation in which contact action is delayed.

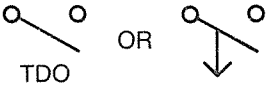
5.4 C. 18. **a.** Open Switch with Time-Delay Closing (TDC)



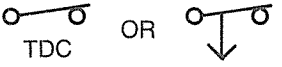
5.4 C. 18. **b.** Closed Switch with Time-Delay Opening (TDO)



5.4 C. 18. **c.** Open Switch with Time-Delay Opening (TDO)



5.4 C. 18. **d.** Closed Switch with Time-Delay Closing (TDC)



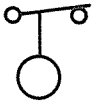
5.4 C. **19.** *Flow Actuated Switch*

5.4 C. 19. **a.** Closes on Increased Flow

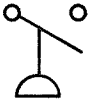
5.4 C. 19. **b.** Opens on Increased Flow

5.4 C. **20.** *Liquid-Level-Actuated Switch*
5.4 C. 20. **a.** Closes on Rising Level

5.4 C. 20. **b.** Opens on Rising Level

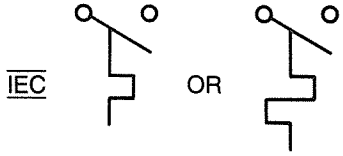


5.4 C. **21.** *Pressure or Vacuum-Actuated Switch*
5.4 C. 21. **a.** Closes on Rising Pressure

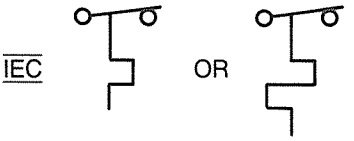


5.4 C. 21. **b.** Opens on Rising Pressure

5.4 C. **22.** *Temperature-Actuated Switch*
5.4 C. 22. **a.** Closes on Rising Temperature



5.4 C. 22. **b.** Opens on Rising Temperature

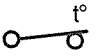


5.4 C. **23.** *Thermostat*

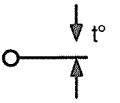
Add to t° the nominal or specific operation temperature. If clarification or direction of action of contact is needed a direction arrow may be added, the arrow to point in the direction of rising temperature operation. The arrow should always be shown for central-off (neutral) position devices.

5.4 C. 23. **a.** Closes on Rising Temperature With Contact-Movement Direction Arrow

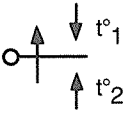
5.4 C. 23. **b.** Opens on Rising Temperature



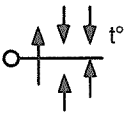
5.4 C. 23. **c.** Transfers on Rising Temperature



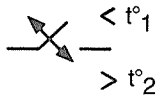
5.4 C. 23. **d.** Transfer, with Intended Central-Off (neutral)



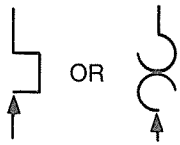
5.4 C. 23. **e.** Typical Multifunction



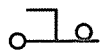
5.4 C. 23. **f.** With Operating Temperatures Indicated



5.4 C. **24.** *Flasher, Self-Interrupting Switch*

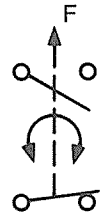


5.4 C. **25.** *Foot-Operated Switch, Foot Switch* F
5.4 C. 25. **a.** Opens by Foot Pressure

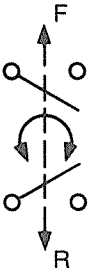


5.4 C. 25. **b.** Closes by Foot Pressure

5.4 C. **26.** *Switch Operated by Shaft Rotation and Responsive to Speed or Direction*
5.4 C. 26. **a.** Speed

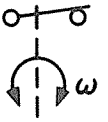


5.4 C. 26. **b.** Plugging
To stop drive after it has come practically to rest

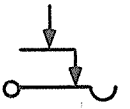


5.4 C. 26. **c.** Anti-Plugging
To prevent plugging of drive

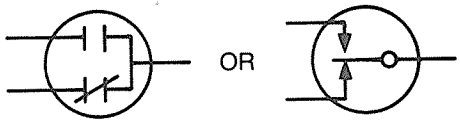
5.4 C. 26. **d.** Centrifugal Switch
Opening on increasing speed



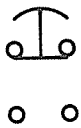
5.4 C. **27.** *Switches with Specific Features*
5.4 C. 27. **a.** Hook Switch F



5.4 C. 27. **b.** Switch in Evacuated Envelope
1-Pole, Double-Throw



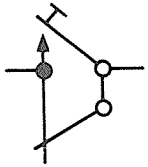
5.4 C. 27. **c.** Mushroom-Head Safety Feature
Applied to 2-Circuit Pushbutton



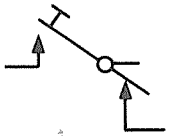
5.4 C. 27. **d.** Key-Operated Lock Switch
Use appropriate standard symbol and add key designation.

5.4 C. **28.** *Telegraph Key* F
5.4 C. 28. **a.** Simple

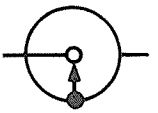
5.4 C. 28. **b.** Simple with Shorting Switch



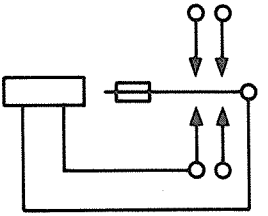
5.4 C. 28. **c.** Open Circuit or Pole-Changing



5.4 C. **29.** *Governor* F *Contact-Making Speed Regulator*
Contacts open or closed as required, shown here closed.



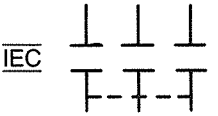
5.4 C. **30.** *Vibrator, Interrupter* F
Typical Shunt Drive, Terminals shown.
Show contacts as required.



5.4 C. **31.** *Contactor (See also Circuit Breaker)*
Fundamental symbols for contacts, coils, mechanical connections, etc., are the basis for contactor symbols and should be used to represent contactors on complete diagrams.

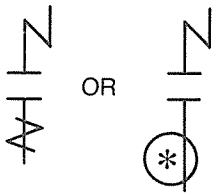
Complete diagrams of contactors consist of combinations of fundamental symbols for control coils, mechanical connections, etc., in such combinations as to represent the actual device. Mechanical interlocking should be indicated by notes.

5.4 C. 31. **a.** Manually Operated 3-Pole Contactor



5.4 C. 31. **b.** Electrically Operated 1-Pole Contactor with Series Blow-out Coil

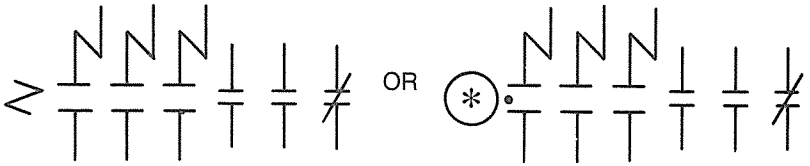
The asterisk is not part of the symbol. Replace with proper device designation.



5.4 C. 31. **c.** Electrically Operated 3-Pole Contactor with Series Blow-out Coils

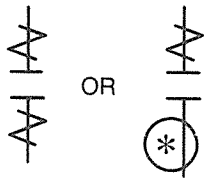
2-open and 1 closed auxiliary contacts shown smaller than main contacts.

Replace asterisk with proper device designation.



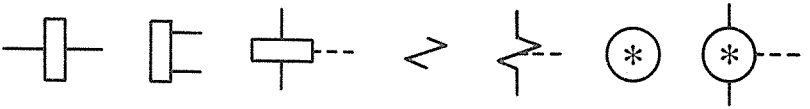
5.4 C. 31. **d.** Electrically Operated 1-Pole Contactor with Shunt Blow-out Coil

Replace asterisk with proper device



5.4 C. **32.** *Relays*

Fundamental symbols per contacts, mechanical connections, coils, etc., are the basis for relay symbols and should be used to represent relays on complete diagrams.

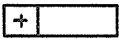


The following letter combinations or symbol elements may be used with relay symbols. Use the letter or symbol elements needed to show the special features of the relay.

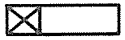
The terms slow and fast are relative, and the degree is not noted by a multiplicity of the same relay symbol. Relays that are direct-current operated are not so marked.

IEC 

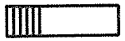
A-C	alternating current or ringing relay
D	differential
DB	double biased or biased in both directions
DP	dashpot
EP	electrically polarized
FO	fast-operate
FR	fast-release
L	latching
MG	marginal
ML	magnetic latching (remanent)
NB	no bias
NR	nonreactive



P	magnetically polarized using biasing spring or having magnet bias
SA	slow-operate and slow-release

IEC 

SO	slow-operate

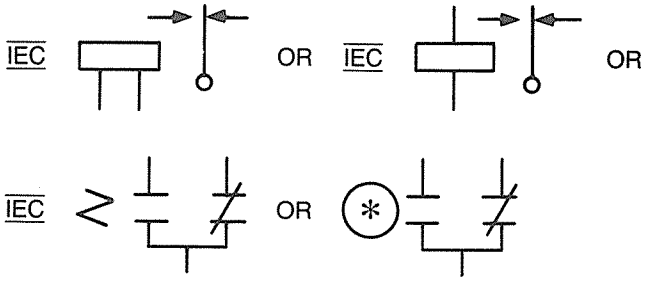


SR	slow-release
SW	sandwich-wound to improve balance to longitudinal currents.

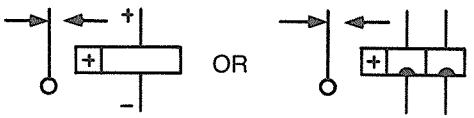
The proper poling for a polarized relay is shown by use of + or − designations applied to the winding leads. The interpretation of this is that a voltage applied with the indicated polarity will cause the armature to move toward the contact shown nearer the coil. If the relay is equipped with numbered terminals, they should be shown.

5.4 C. 32. **a.** Basic

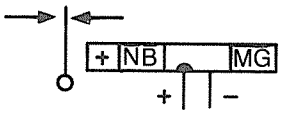
5.4 C. 32. **b.** Relay with Transfer Contacts
Replace asterisk with proper device number.



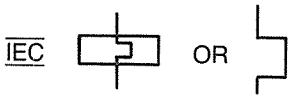
5.4 C. 32. **c.** Polarized Relay with Transfer Contacts



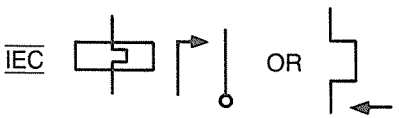
5.4 C. 32. **d.** Polarized, No Bias, Marginal Relay with Transfer Contacts



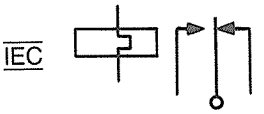
5.4 C. 32. **e.** Thermally Operated, Activating Device
Contacts may be shown separately from the operating device. Time of delay may be shown.



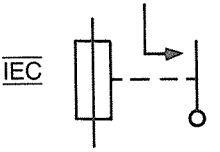
5.4 C. 32. e. **(1)** With Normally Open Contacts Shown



5.4 C. 32. e. **(2)** With Transfer Contacts Shown



5.4 C. 32. **f.** Thermal Relay, One-Time Type, Not Reusable Normally Open Contact Type Shown

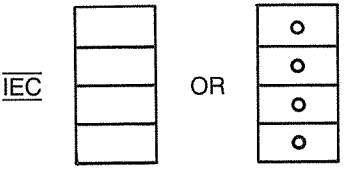


5.5 Terminals and Connectors

5.5 A. Terminals

5.5 A. **1.** *Circuit Terminal*

Terminal Board F or terminal strip 4 terminals shown, group of 4 terminals, number and arrangement as convenient. Internal lines and terminals may be omitted if terminal identifications are shown within the symbol.



5.5 A. **2.** *Terminals for Semiconductor Devices and Electron Tubes*
Used primarily in application data terminal diagrams for semiconductor devices, electron tubes, and other devices with similar terminations.

Explanatory words and arrows are not part of the symbol.

Where special attention is required, the following code letters may be used:

S Connection to an external shield integral with a device (including metal tube shell, base sleeve or shell, external conductive coating or casing). Not to be used if the external conductive coating serves as one side of a capacitor (as in cathode-ray tubes) and is not designed to function as an electrostatic shield.

IC Internal connection; not intended to be used for circuit connection.

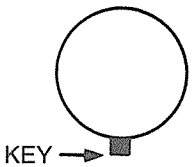
IS Internal shield not depicted in the terminal diagram.

5.5 A. 2. **a.** Base-Pin Terminals (Electron Tubes)
Pin Terminals (Semiconductor Devices)

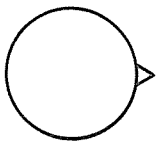
5.5 A. 2. **b.** Envelope Terminals
The rigid terminal symbol is used to indicate customary rigid terminals, caps, rods, rings, etc., as well as:
Any metallic envelope or external conductive coating that has a contact area (as in cathode-ray tubes, disc-seal tubes, pencil tubes, etc.).

Mounting flange or stud when it serves as a terminal.

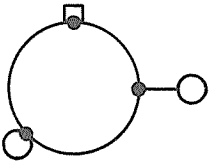
5.5 A. 2. **c.** Device with Base-Orientation Key



5.5 A. 2. **d.** Device with Reference Point
Such as a boss, colored dot, index pin, index tab or bayonet pin.



5.5 A. 2. **e.** Terminals Connected to Metallic Envelope or Enclosure



5.5 **B. Cable Termination**

Line on left of symbol indicates cable

5.5 **C. Connectors, Disconnecting Devices**

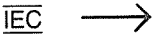
Jack F

Plug F

The contact symbol is not an arrow head. It is larger and the lines are drawn at a 90-degree angle.

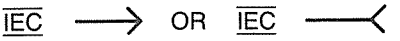
5.5 C. **1.** *Female Contact*

5.5 C. **2.** *Male Contact*

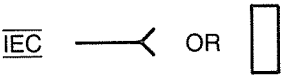


5.5 C. **3.** *Connector Assembly, Movable or Stationary Portion, Jack, Plug, or Receptacle.*

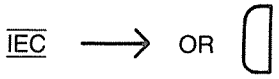
Use appropriate number of contact symbols.



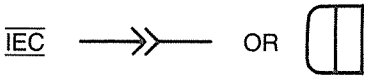
5.5 C. 3. **a.** Jack or receptacle



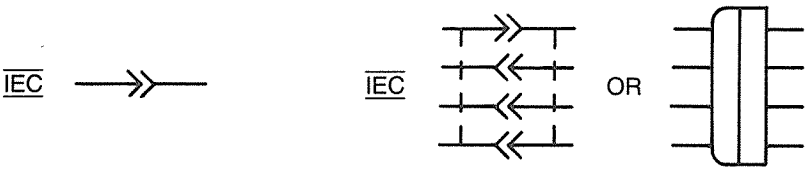
5.5 C. 3. **b.** Plug



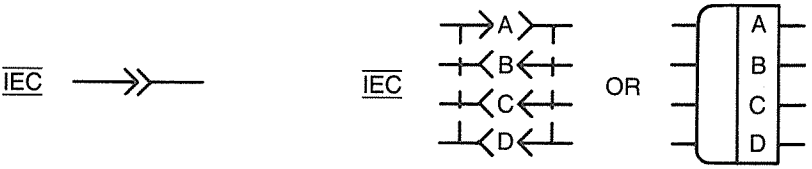
5.5 C. **4.** *Separable Connectors, Engaged*



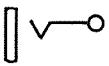
5.5 C. 4. **a.** 4-Conductor Connectors
The plug has 1 male and 3 female contacts. Shown engaged



5.5 C. 4. **b.** 4-Conductor Connectors
The plug has 1 male and 3 female contacts with individual contact designations shown in the complete-symbol column.

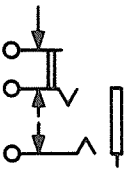


5.5 C. **5.** *Communication Switchboard-Type Connector*
5.5 C. 5. **a.** 2-Conductor Jack



5.5 C. 5. **b.** 2-Conductor Plug

5.5 C. 5. **c.** 3-Conductor Jack with 2 Break Contacts (normals) and 1 Auxiliary Make Contact

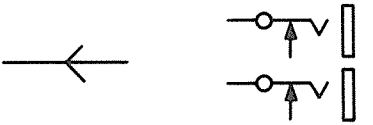


5.5 C. 5. **d.** 3-Conductor Plug

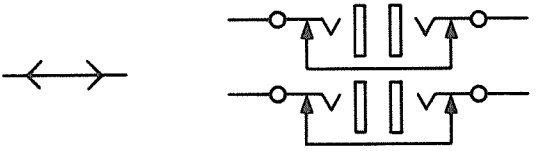
5.5 C. 5. **e.** Circuit Normalled Through

Normalled indicates that a through circuit may be interrupted by an inserted connector. As shown, the inserted connector opens the through circuit and connects to the circuit toward the left. 2-conductor jacks are shown here, the normal symbol is applicable to other types of connectors.

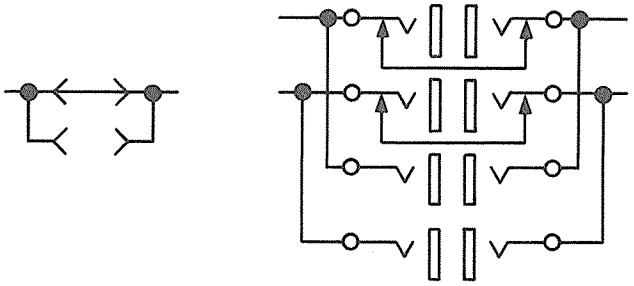
5.5 C. 5. e. **(1)** Jacks with Circuit Normalled Through One Way



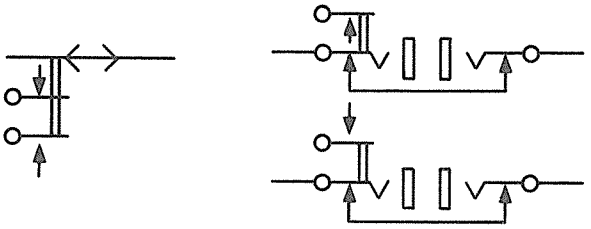
5.5 C. 5. e. **(2)** Jacks with Circuit Normalled Through Both Ways



5.5 C. 5. e. **(3)** Jacks in Multiple
One set with circuit normalled through both ways



5.5 C. 5. e. **(4)** Jacks with Auxiliary Contacts with Circuit Normalled Through Both Ways



5.5 C. **6.** *Power Supply Connectors*
Convenience Outlets and Mating Connectors

American National Standards Dimensions of caps, plugs, and receptacles, ANSI (73.10-1966 (R1972) through (73.68-1966 (R1972)

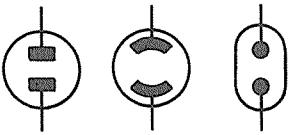
These symbols are primarily for applications where the type of connector must be indicated semi-pictorially.

Contacts and contact arrangements should be shown in simplified form as viewed from the mating face, approximately in proportion to the arrangement in the physical item. A simplified-shape outline should surround the contact symbols.

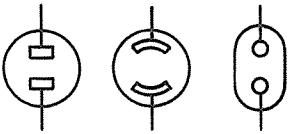
5.5 C. 6. **a.** Male Contact
Filled outline approximating contact end-view. Typical forms.

5.5 C. 6. **b.** Female Contact
Open outline approximating limiting shape of mating male contact.

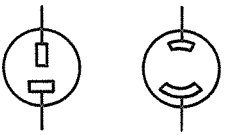
5.5 C. 6. **c.** 2-Conductor Non-Polarized Connectors
Typical male contacts shown.



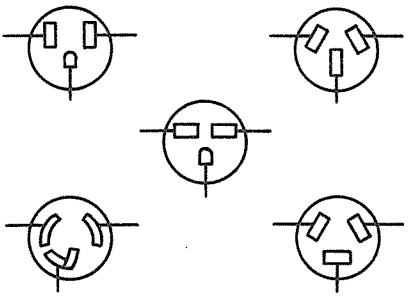
5.5 C. 6. **d.** 2-Conductor Non-Polarized Connectors
Typical female contacts shown.



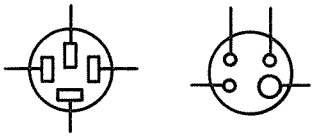
5.5 C. 6. **e.** 2-Conductor Polarized Connectors
Typical female contacts shown.



5.5 C. 6. **f.** 3-Conductor Polarized Connectors
Typical female contacts shown.



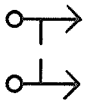
5.5 C. 6. **g.** 4-Conductor Polarized Connectors
Typical female contacts shown.



5.5 C. **7.** *Test Blocks*

5.5 C. 7. **a.** Female Portion with Short-Circuiting Bar Terminals Shown.

5.5 C. 7. **b.** Male Portion

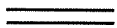


5.6 Transformers, Inductors, and Windings

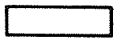
5.6 A. Core

5.6 A. **1.** *General or Air Core*
If it is necessary to identify an air core, a note should be shown adjacent to the symbol of the inductor or transformer. There is no symbol for an air core.

5.6 A. **2.** *Magnetic Core, Inductor or Transformer*
Not to be used unless it is necessary to identify a magnetic core.

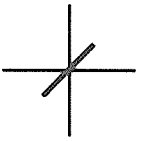


5.6 A. **3.** *Core of Magnet*
For use when representation of the core is necessary. See also *Permanent Magnet*.



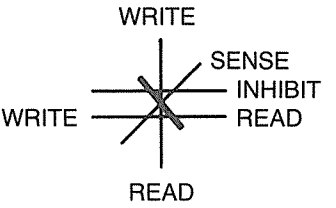
5.6 A. 4. *Magnetic Memory Core*

5.6 A. 4. **a.** Single-Aperture Type with Windings Shown



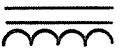
5.6 A. 4. **b.** Four Windings, Two *Write-Read*, One *Inhibit*, and One *Sense* Winding

Words are explanatory, not part of symbol.



5.6 B. Inductor, Winding (Machine or Transformer), Reactor, Radio Frequency Coil, Telephone Retardation Coil

5.6 B. 1. *Magnetic-Core Inductor Telephone Loading Coil*
Use if necessary to show a magnetic core.



5.6 B. 2. *Tapped*

IEC 

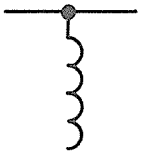
5.6 B. 3. *Adjustable Inductor*

IEC 

5.6 B. 4. *Continuously Adjustable Inductor*

IEC 

5.6 B. **5.** *Shunt Inductor*



5.6 B. **6.** *Inductive Termination*

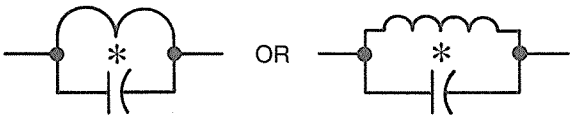
Commonly used in coaxial and waveguide diagrams.

5.6 B. 6. **a.** Series Inductor and Path Open

5.6 B. 6. **b.** Series Inductor and Path Short-Circuited

5.6 B. **7.** *Carrier Line Trap*

The symbol represents a general trap or single-frequency trap unless *2f* (two frequency) or *WB* (wide-band) is used to replace the asterisk.



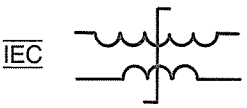
5.6 **C. Transductor, Saturable-Core Inductor, Saturable-Core Reactor**

If necessary for clarity, the magnetic core symbol may be added.

Power windings are drawn with 3 loops or scallops, control windings with five. The saturable properties indicator may also be used to indicate two or more windings.

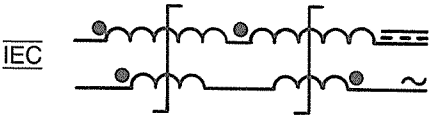
5.6 C. **1.** *Transducer Element, Assembled*

When windings are separated on a drawing, suitable indication should be provided to show that they are on the same core.

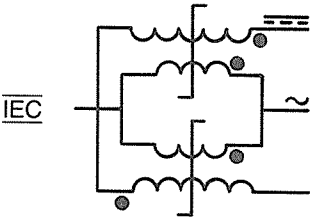


5.6 C. **2.** *Single-Phase Series Transductor with Winding Polarity and Kind-of-Current Marking*

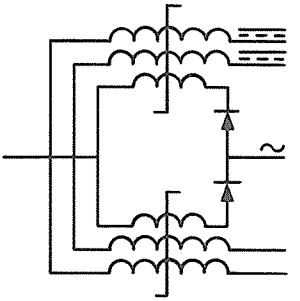
An increase of current entering the end of the control winding marked with a dot causes an increase in the power output.



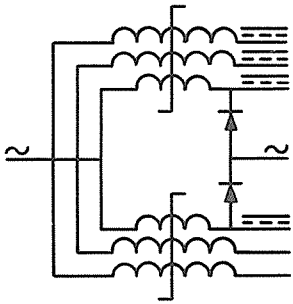
5.6 C. **3.** *Single-Phase Parallel Transductor with Winding Polarity and Kind-of-Current Markings*



5.6 C. **4.** *Self-Exciting Transductor with Two Control Circuits and Kind-of-Current Markings*



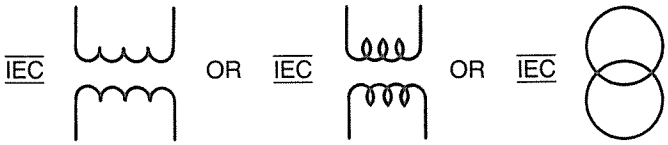
5.6 C. **5.** *Transductor with Direct-Current Output and Kind-of-Current Markings*



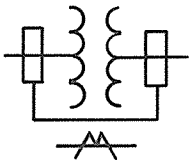
5.6 D. Transformer F, Telephone Induction Coil, Telephone Repeating Coil

5.6 D. **1.** *General*

In coaxial and waveguide circuits, this symbol represents a taper or stop transformer without mode change.



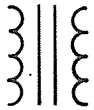
5.6 D. 1. **a.** Transformer with direct-current connections and mode suppression between two rectangular waveguides.



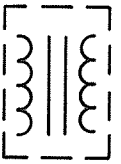
5.6 D. **2.** *Magnetic-Core Transformer*

Use when necessary to show a magnetic core.

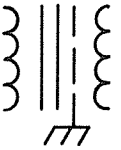
5.6 D. 2. **a.** Nonsaturating



5.6 D. 2. **b.** Shielded Transformer with Magnetic Core

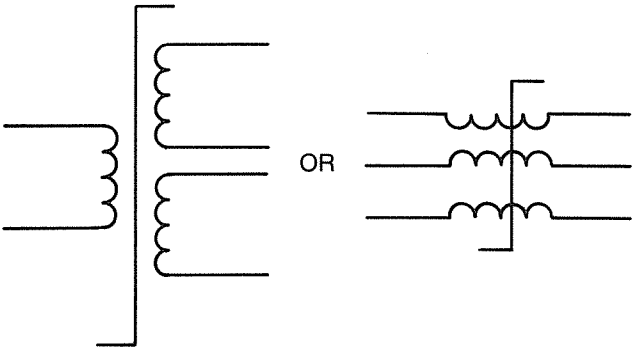


5.6 D. 2. **c.** Transformer with Magnetic Core
With magnetic shield between windings and connected to the frame.

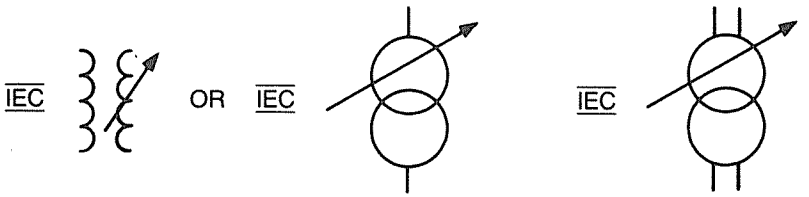


5.6 D. **3.** *Saturating Transformer*

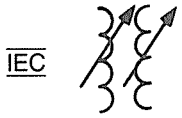
5.6 D. 3. **a.** Saturable Properties Indicator
May be drawn between or across two or more windings that are magnetically coupled by a saturable core.



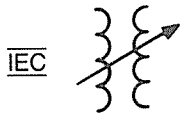
5.6 D. 3. **b.** One Winding with Adjustable Inductance



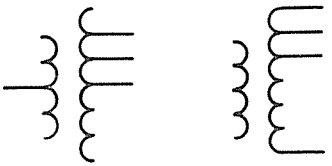
5.6 D. 3. **c.** Each Winding with Separately Adjustable Inductance



5.6 D. 3. **d.** Adjustable Mutual Inductor; Constant-Current Transformer

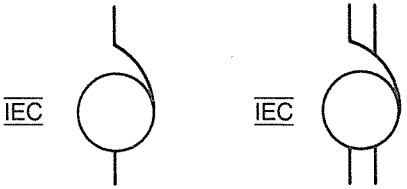


5.6 D. 3. **e.** With Taps, 1-Phase

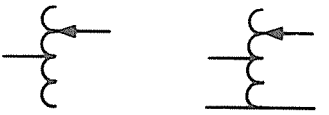


5.6 D. 3. **f.** Autotransformer, 1-Phase

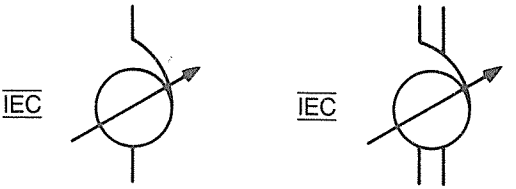
OR



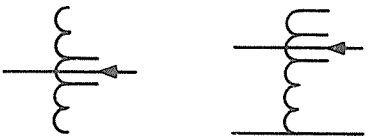
5.6 D. 3. **g.** Adjustable



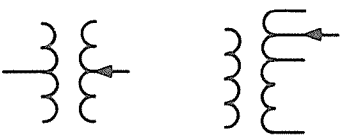
OR



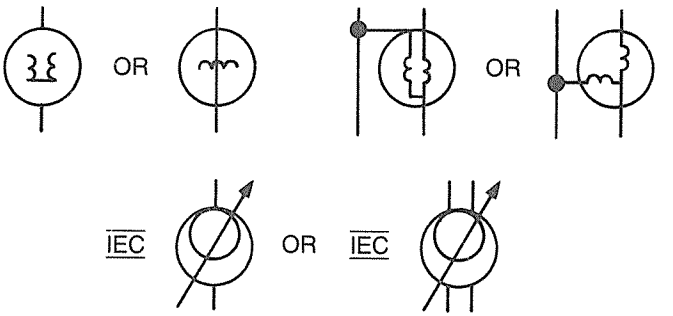
5.6 D. 3. **h.** Step-Voltage Regulator or Load-Ratio Control Autotransformer



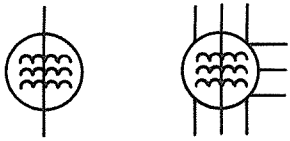
5.6 D. 3. **i.** Load-Ratio Control Transformer with Taps



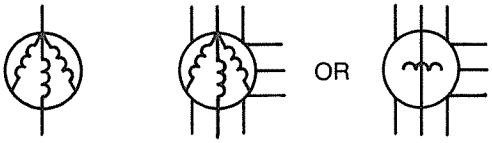
5.6 D. 3. **j.** Single-Phase Induction Voltage Regulator(s) Number of regulators may be shown adjacent to the symbol.



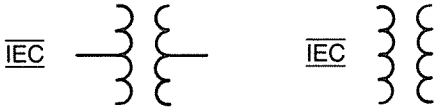
5.6 D. 3. **k.** Triplex Induction Voltage Regulator



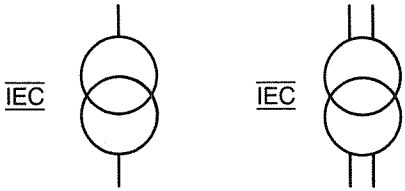
5.6 D. 3. **l.** 3-Phase Induction Voltage Regulator



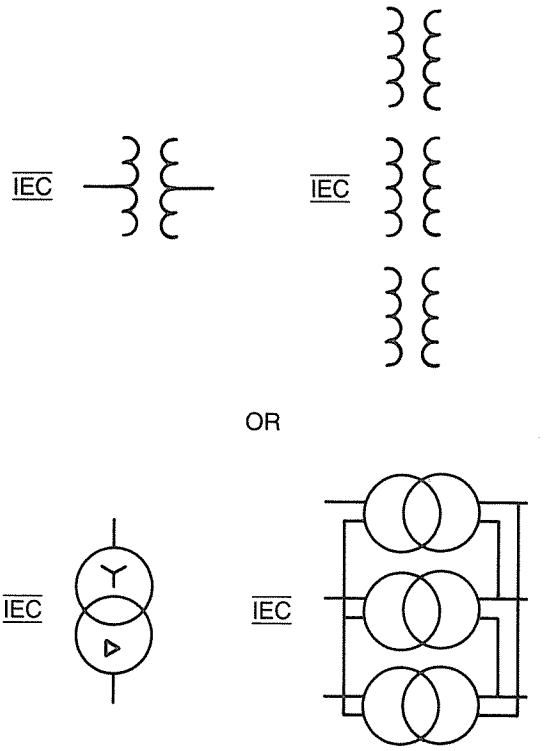
5.6 D. 3. **m.** Single-Phase, Two-Winding Transformer



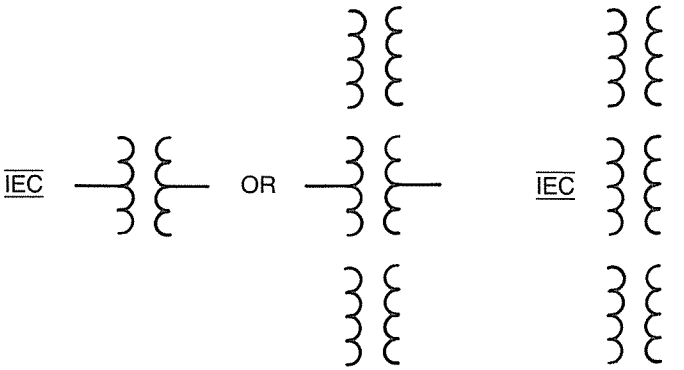
OR



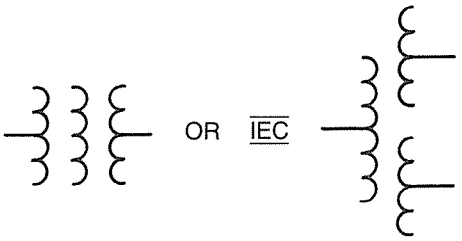
5.6 D. 3. **n.** 3-Phase Bank of Single-Phase, Two-Winding Transformers



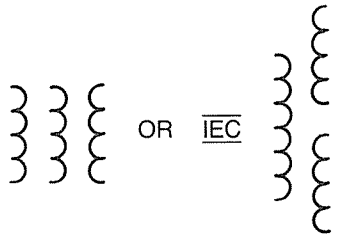
5.6 D. 3. **o.** Polyphase Transformer



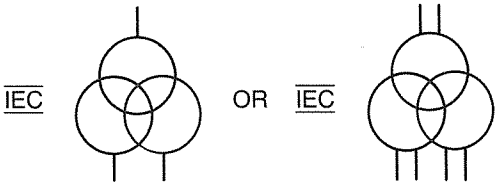
5.6 D. 3. **p.** Single-Phase, 3-Winding Transformer



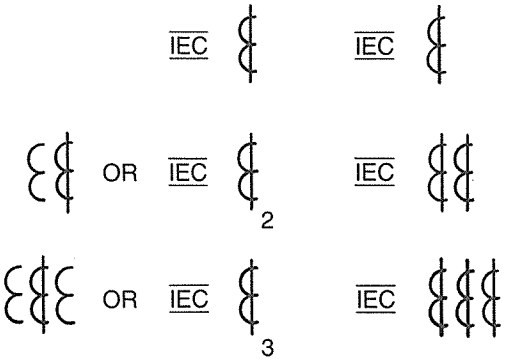
OR



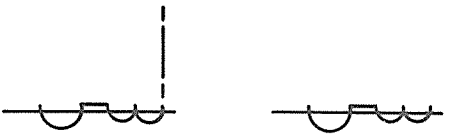
OR



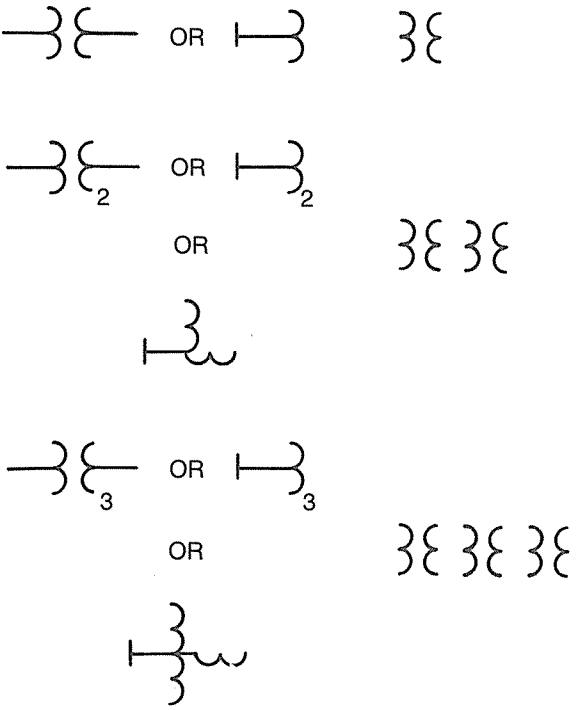
5.6 D. 3. **q.** Current Transformers



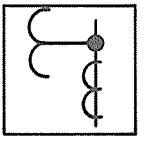
5.6 D. 3. **r.** Bushing-Type Current Transformer



5.6 D. 3. **s.** Potential Transformer

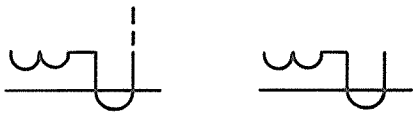


5.6 D. 3. **t.** Outdoor Metering Device
Show actual connection inside border.



5.6 **E. Linear Coupler**

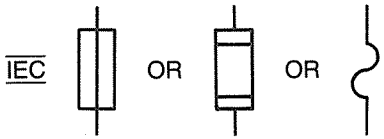
The broken line indicates where line connection is made to a symbol, it is not part of the symbol.



5.7 Circuit Protectors

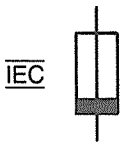
5.7 **A. Fuse**

One-Time Thermal Current-Overload Device



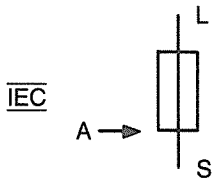
5.7 A. **1.** *General*

Fuse with supply side shown by thick line

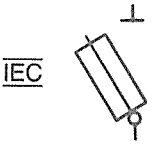


5.7 A. **2.** *Fuse with Alarm Contact*

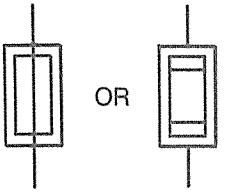
When fuse blows, alarm bus A is connected to power supply bus S. The letters S (supply), L (load), and A (alarm circuit) are here for explanation only, they are not part of the symbol.



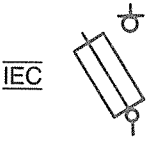
5.7 A. **3.** *Isolating Fuse-Switch*
High-voltage primary fuse cutout, dry



5.7 A. **4.** *High-Voltage Primary Fuse Cutout, Oil*



5.7 A. **5.** *Isolating Fuse-Switch for On-Load Switching*



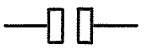
5.7 A. **6.** *Temperature-Sensitive Fuse*
Ambient temperature operated

5.7 **B. Current Limiter For Power Cable**
Use the appropriate number of single-line diagram symbols.

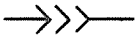
5.7 **C. Lightning Arrester** F
Arrester (electric surge, etc.)
Gap

5.7 C. **1.** *General*

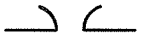
5.7 C. **2.** *Carbon Block*
Telephone Protector Block F
The sides of the rectangle are at an approximate ration of 1 to 2 and the space between rectangle is approximately equal to the width of a rectangle.



5.7 C. **3.** *Electrolytic or Aluminum Cell*
Symbol is not composed of arrow heads. Lines are at right angles.

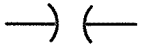


5.7 C. **4.** *Horn Gap*

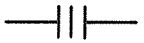


5.7 C. **5.** *Protective Gap*
Triangles are not filled.

5.7 C. **6.** *Sphere Gap*



5.7 C. **7.** *Valve or Film Element*



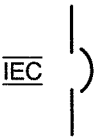
5.7 C. **8.** *Multigap, General*

5.7 C. **9.** *Gap plus Valve plus Ground, 2-Pole*

5.7 **D. Circuit Breaker** F

If it is desired to show the condition causing the breaker to trip, the relay protective-function symbols may be used alongside the breaker symbol.

5.7 D. **1.** *General*



5.7 D. **2.** *Air Circuit Breaker*

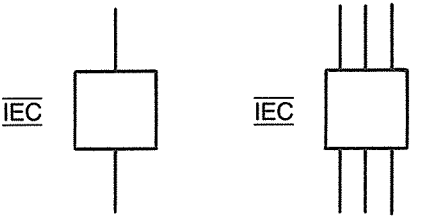
If distinction is needed for a-c breakers rated at 1500V or less and all d-c breakers.

5.7 D. **3.** *Network Protector*

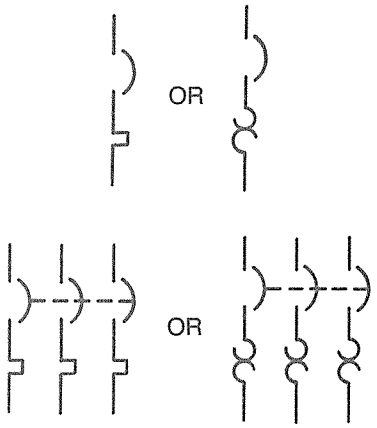
5.7 D. **4.** *Circuit Breaker*

Other than above.
Symbol on right is for a 3-pole breaker.

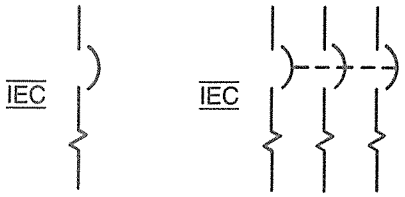
On a power diagram the symbol may be used without other identification. On a composite drawing where confusion with the general circuit element symbol may result, add identifying letters CB inside or adjacent to the square.



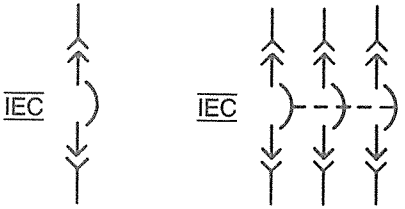
5.7 D. **5.** *3-Pole Circuit Breaker with Thermal Overload in All Three Poles*



5.7 D. **6.** *3-Pole Circuit, Breaker with Magnetic Overload in All Three Poles*



5.7 D. **7.** *3-Pole Circuit Breaker, Drawout Type*



5.7 **E. Protective Relay**

Fundamental symbols for contacts, coils, mechanical connections, etc., are the basis for relay symbols and should be used to represent relays on complete diagrams.

5.7 E. **1.** *Relay Protective Functions*

The following symbols may be used to indicate protective functions or device function numbers may be placed in the circle or adjacent to the basic symbol. Refer to ANSI (37.2-1970)

An operating quantity number must be added to general symbols 2 through 6 below in accordance with 9 below.

5.7 E. **2.** *Over, General*

5.7 E. **3.** *Under, General*

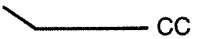
5.7 E. **4.** *Direction; General; Directional Over*

5.7 E. **5.** *Balance, General*

5.7 E. **6.** *Differential, General*

5.7 E. **7.** *Pilot Wire, General*

5.7 E. **8.** *Carrier Current*



5.7 E. **9.** *Operating Quantity*

The operating quantity is indicated by the following letters or symbols placed either on or immediately above the relay protective-function symbols shown in 2 through 6 above.

C	current (optional)
Z	distance
F	frequency
GP	gas pressure
Ø	phase
W	power
S	synchronism
T	temperature
V	voltage

5.7 E. **10.** *Ground Relays*

Relays operative on residual current only are designated by attaching the ground symbol —⫴ to the relay protective-function symbol. Note that the zero phase-sequence designation given below may be used instead when desirable.

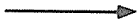
5.7 E. **11.** *Phase Sequence Quantities*

Operations on phase sequence quantities may be indicated by use of the conventional subscripts 0, 1, and 2 after the letter indicating the operating quantity.

5.7 E. **12.** *Applications*

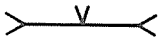
5.7 E. 12. **a.** Overcurrent

5.7 E. 12. **b.** Directional Overcurrent



5.7 E. 12. **c.** Directional Residual Overcurrent

5.7 E. 12. **d.** Overvoltage



5.7 E. 12. **e.** Power Directional

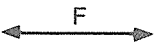
5.7 E. 12. **f.** Balanced Current

5.7 E. 12. **g.** Differential Current

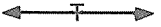
5.7 E. 12. **h.** Distance

5.7 E. 12. **i.** Directional Distance

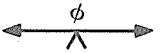
5.7 E. 12. **j.** Overfrequency



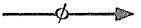
5.7 E. 12. **k.** Over Temperature



5.7 E. 12. **l.** Phase Balance

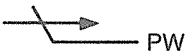


5.7 E. 12. **m.** Phase Sequence



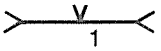
5.7 E. 12. **n.** Pilot Wire, Differential Current

5.7 E. 12. **o.** Pilot Wire, Directional-Comparison

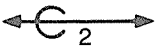


5.7 E. 12. **p.** Carrier Pilot

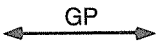
5.7 E. 12. **q.** Positive Phase-Sequence, Undervoltage



5.7 E. 12. **r.** Negative Phase-Sequence, Overcurrent



5.7 E. 12. **s.** Gas Pressure (Bucholz)

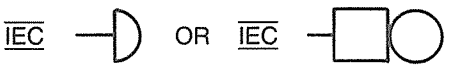


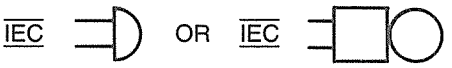
5.7 E. 12. **t.** Out of Step

5.8 Acoustic Devices

5.8 A. Audible-Signaling Devices

5.8 A. **1.** *Bell, Electrical F, Telephone Ringer F*
If specific identification is required, the abbreviation d-c or symbol *D,1*, or a-c or symbol *D,2* may be added in or adjacent to the device symbol.



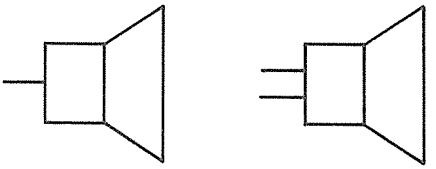


5.8 A. 1. **a.** Single stroke

5.8 A. **2.** *Buzzer* F

5.8 A. **3.** *Horn, Electrical* F, *Loudspeaker* F, *Siren* F, *Underwater Sound Transducer with Acoustic Output; Sound Reproducer*

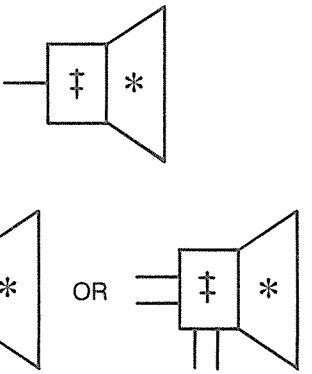
5.8 A. 3. **a.** General



5.8 A. 3. **b.** Specific Types

If identification of loudspeaker types is required, the following letter combinations may be added to the symbol at the locations indicated *‡.

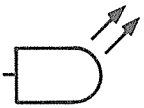
*HN horn, electrical F
*HW howler
*LS loudspeaker F
*SN siren F
‡EM electromagnetic with moving coil — moving coil leads should be identified.
‡EMN electromagnetic with moving coil and neutralizing winding - moving coil leads should be identified.
‡MG magnetic armature
‡PM permanent magnet with moving coil

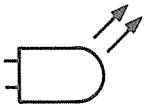


5.9 Lamps and Visual - Signaling Devices

5.9 A. Lamp, General; Light Source, General

This symbol may be used to represent one or more lamps with or without operating auxiliaries. If it is essential to indicate characteristics the letter or letters listed below may be inserted within or adjacent to the symbol.



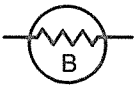


A	amber	Arc	arc
B	blue	EL	electro-luminescent
C	clear	FL	fluorescent
O	orange	HG	mercury vapor
OP	opalescent	IN	incandescent
P	purple	LED	light emitting diode
R	red	IR	infrared
W	white	NA	sodium vapor
Y	yellow	NE	neon
		UV	ultraviolet
		XE	xenon

5.9 B. Incandescent Lamp F

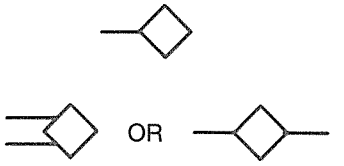
5.9 C. Ballast Lamp, Ballast Tube

The primary characteristic of the element within the circle is designed to vary nonlinearly with the temperature of the element.

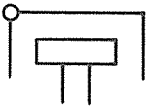


5.9 D. Visual Signaling Devices

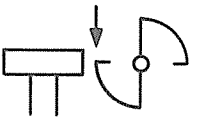
5.9 D. 1. *Annunciator* F *General*



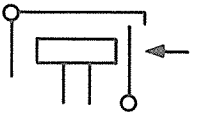
5.9 D. 2. *Annunciator Drop or Signal, Shutter or Grid Type*



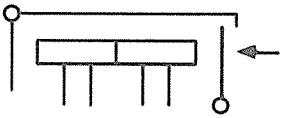
5.9 D. 3. *Annunciator Drop or Signal, Ball Type*



5.9 D. 4. *Manually Restored Drop*



5.9 D. 5. *Electrically Restored Drop*



5.9 D. 6. *Communication Switchboard-Type Lamp; Indicating Lamp*

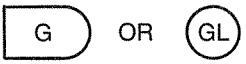
5.9 D. **7.** *Indicating, Pilot, Signaling, or Switchboard Light; Indicator Light F; Signal Light F*

The asterisk is not part of the symbol. Replace with letter or letters for colors within or adjacent to the symbol. To avoid confusion with meter or basic relay symbols add suffix L or IL to the letter or letters.

If confusion with other circular symbols may occur, use D-shaped symbol.

5.9 D. **8.** *Application*

5.9 D. 8. **a.** Green Signal Light



5.9 D. 8. **b.** Jeweled Signal Light

5.10 Readout Devices

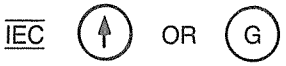
5.10 **A. Meter, Instrument**

The asterisk is not part of the symbol. Replace with one of the following letter combinations unless some other identification is provided in the circle and explained on the diagram.

A	ammeter F IEC
AH	ampere-hour meter
C	coulombmeter
CMA	contact making (or breaking) ammeter
CMC	contact making (or breaking) clock
CMV	contact making (or breaking) voltmeter

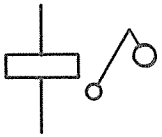
CRO	oscilloscope F cathod-ray oscillograph
DB	decibel meter audio level meter
DBM	decibels referred to 1 milliwatt, meter
DM	demand meter
DTR	demand-totalizing relay
F	frequency meter F
GD	ground detector
I	indicating meter
INT	integrating meter
μA or uA	microammeter
MA	milliammeter
NM	noise meter
OHM	ohmmeter
OP	oil pressure meter
OSCG	oscillograph, string
PF	power factor meter
PH	phasemeter F
PI	position indicator
RD	recording demand meter
REC	recording meter
RF	reactive factor meter
SY	synchroscope
t°	temperature meter
THC	thermal converter
TT	total time meter elapsed time meter
V	voltmeter F IEC
VA	volt-ammeter
VAR	varmeter
VARH	varhour meter
VI	volume indicator audio-level meter F
VU	standard volume indicator audio-level meter F
W	wattmeter F IEC
WH	watthour meter

5.10 **B. Galvanometer** F

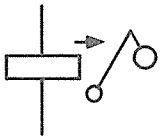


5.10 **C. Electromechanically Operated Counters**

5.10 C. **a.** General



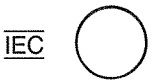
5.10 C. **b.** With Make Contact



5.11 Rotating Machinery

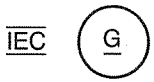
5.11 A. Rotating Machine

5.11 A. **1.** *Basic*



5.11 A. **2.** *Generator* F, *General*

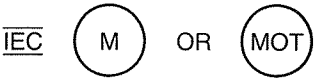
5.11 A. 2. **a.** Generator, Direct-Current



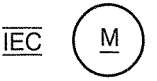
5.11 A. 2. **b.** Generator, Alternating-Current

5.11 A. 2. **c.** Generator, Synchronous

5.11 A. **3.** *Motor F, General*



5.11 A. 3. **a.** Motor, Direct-Current

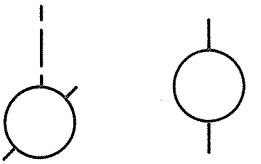


5.11 A. 3. **b.** Motor, Alternating Current

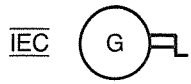
5.11 A. 3. **c.** Motor, Synchronous

5.11 A. 3. **d.** Motor, Multispeed
Show Speeds

5.11 A. 3. **e.** Rotating Armature with Commutator Brushes
The broken line indicates line connection to a symbol is made and is not part of the symbol.



5.11 A. 3. **f.** Hand Generator



5.11 B. Field, Generator or Motor

5.11 B. **1.** *Compensating or Commutating*

5.11 B. **2.** *Series*

5.11 B. **3.** *Shunt or Separately Excited*

5.11 B. **4.** *Permanent Magnet*

5.11 C. Winding Connection Symbols

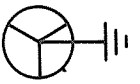
Motor and generator winding connection symbols may be shown in the basic circle using the following representations.

5.11 C. **1.** *1-Phase*

5.11 C. **2.** *2-Phase*

5.11 C. **3.** *3-Phase WYE, Ungrounded*

5.11 C. **4.** *3-Phase WYE, Grounded*



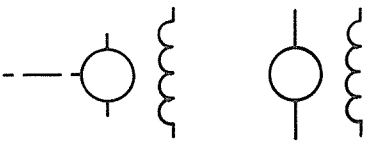
5.11 C. **5.** *3-Phase Delta*

5.11 C. **6.** *6-Phase Diametrical*

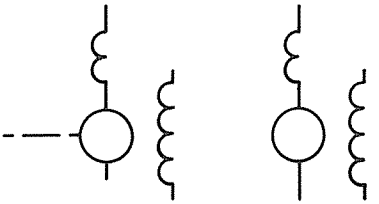
5.11 C. **7.** *6-Phase Double Delta*

5.11 D. Symbol Applications: Direct-Current Machines

5.11 D. **1.** *Separately Excited Direct-Current Generator or Motor*①

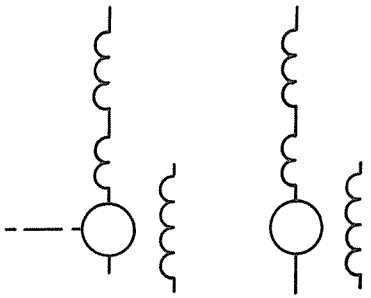


5.11 D. **2.** *Separately Excited Direct-Current Generator Motor, with Commutating or Compensating Field Winding*① *or Both.*

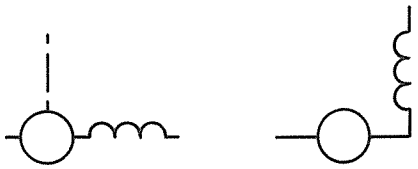


①The broken line is not part of the symbol, it indicates where line connection to the symbol is made.

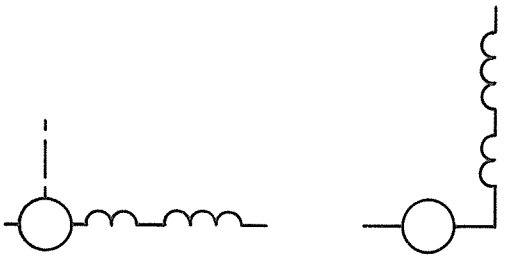
5.11 D. **3.** *Compositely Excited Direct-Current Generator or Motor, with Commutating or Compensating Field Winding① or Both.*



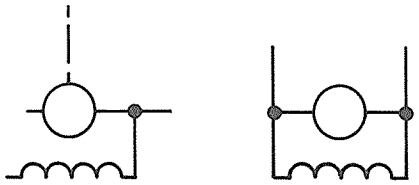
5.11 D. **4.** *Direct-Current Series Motor or 2-Wire Generator①*



5.11 D. **5.** *Direct-Current Series Motor or 2-Wire Generator, with Commutating or Compensating Field Winding,① or Both*

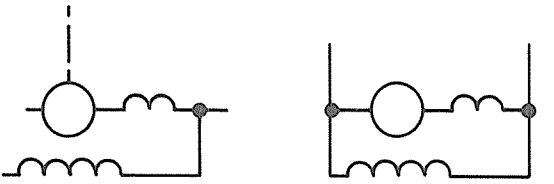


5.11 D. **6.** *Direct-Current Shunt Motor or 2-Wire Generator①*

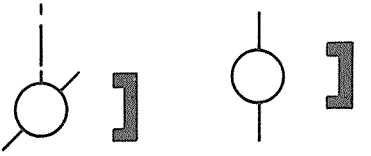


①The broken line is not part of the symbol, it indicates where line connection to the symbol is made.

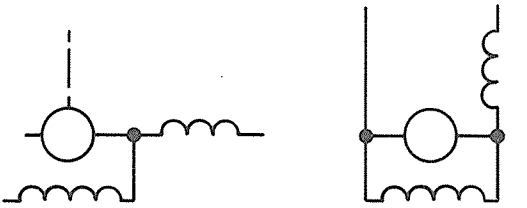
5.11 D. **7.** *Direct-Current Shunt Motor or 2-Wire Generator, with Commutating or Compensating Field Winding, or Both*①



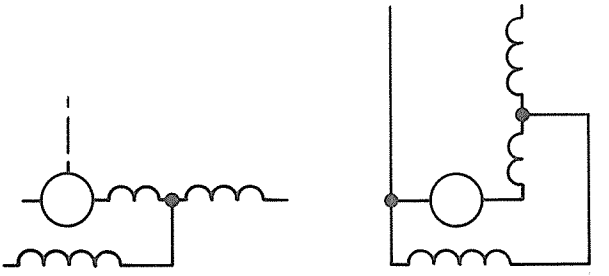
5.11 D. **8.** *Direct-Current Permanent-Magnet-Field Generator or Motor*①



5.11 D. **9.** *Direct-Current Compound Motor or 2-Wire Generator or Stabilized Shunt Motor*①

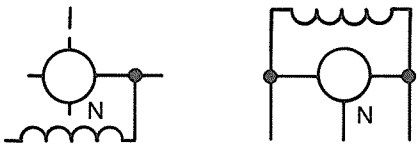


5.11 D. **10.** *Direct-Current Compound Motor or 2-Wire Generator or Stabilized Shunt Motors with Commutating or Compensating Field Winding, or Both*①

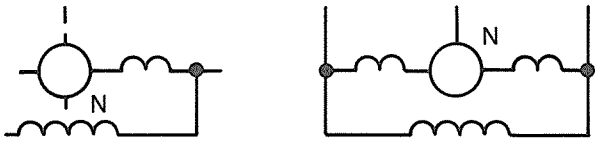


①The broken line is not part of the symbol, it indicates where line connection to the symbol is made.

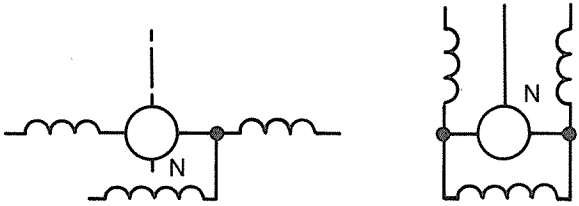
5.11 D. **11.** *Direct-Current 3-Wire Shunt Generator*①



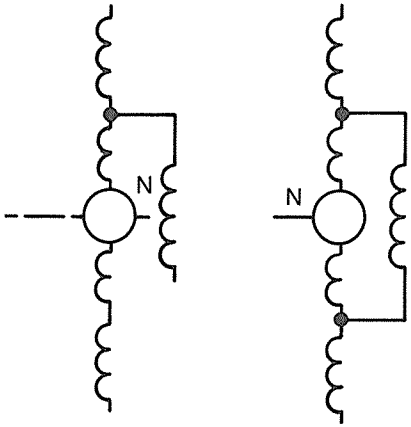
5.11 D. **12.** *Direct-Current 3-Wire Shunt Generator, with Commutating or Compensating Field Winding, or Both*①



5.11 D. **13.** *Direct-Current 3-Wire Compound Generator*①

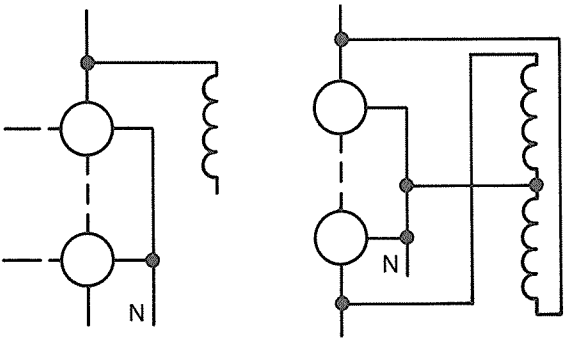


5.11 D. **14.** *Direct-Current 3-Wire Compound Generator, with Commutating or Compensating Field Winding, or Both*①

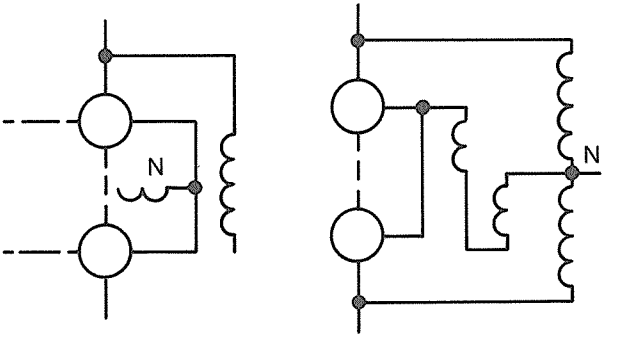


①The broken line is not part of the symbol, it indicates where line connection to the symbol is made.

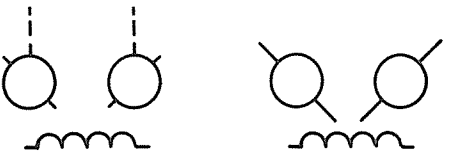
5.11 D. **15.** *Direct-Current Balancer, Shunt Wound*①



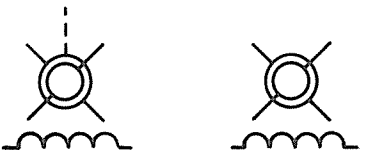
5.11 D. **16.** *Direct-Current Balancer, Compound Wound*①



5.11 D. **17.** *Dynamometer*①

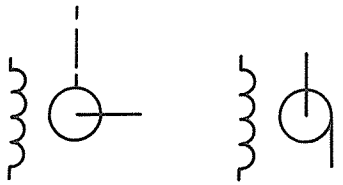


5.11 D. **18.** *Double-Current Generator*①

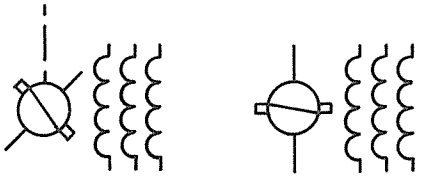


①The broken line is not part of the symbol, it indicates where line connection to the symbol is made.

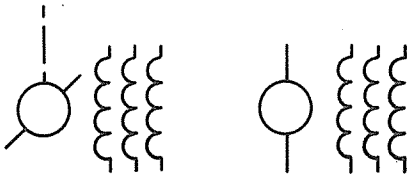
5.11 D. **19.** *Acyclic Generator, Separately Excited*①



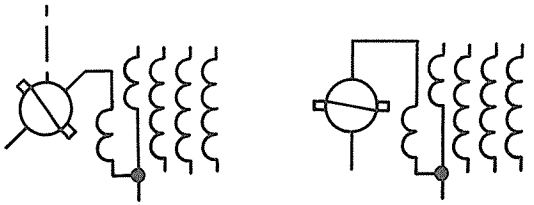
5.11 D. **20.** *Regulating Generator (Rotary Amplifier), Shunt Wound, with Short-Circuited Brushes*①



5.11 D. **21.** *Regulating Generator (Rotary Amplifier), Shunt Wound, without Short-Circuited Brushes*①

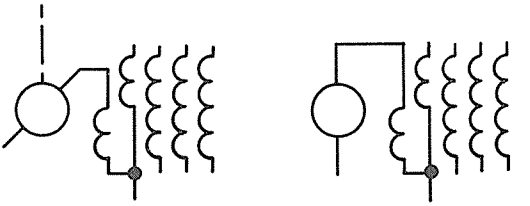


5.11 D. **22.** *Regulating Generator (Rotary Amplifier), Shunt Wound with Compensating Field Winding, and Short-Circuited Brushes*①



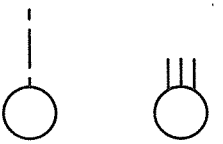
①The broken line is not part of the symbol, it indicates where line connection to the symbol is made.

5.11 D. **23.** *Regulating Generator (Rotary Amplifier), Shunt Wound, with Compensating Field Windings, without Short-Circuited Brushes*①

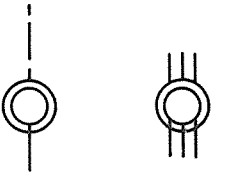


5.11 E. Symbol Applications: Alternating-Current Machines

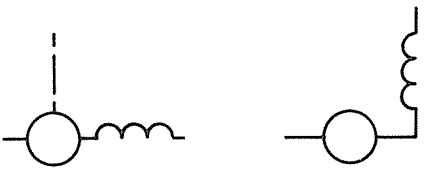
5.11 E. **1.** *Squirrel-Cage Induction Motor or Generator, Split-Phase Induction Motor or Generator, Rotary Phase Converter, or Repulsion Motor*①



5.11 E. **2.** *Wound-Rotor Induction Motor, Synchronous Induction Motor, Induction Generator, or Induction Frequency Converter*①

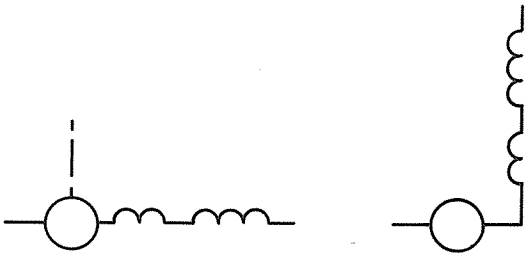


5.11 E. **3.** *Alternating-Current Series Motor*①



①The broken line is not part of the symbol, it indicates where line connection to the symbol is made.

5.11 E. **4.** *Alternating-Current Series Motor, with Commutating or Compensating Field Winding, or Both*①



5.11 E. **5.** *Single-Phase Shaded-Pole Motor*①

5.11 E. **6.** *Single-Phase Repulsion Start Induction Motor*①

5.11 E. **7.** *Single-Phase Hysteresis Motor*①

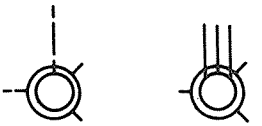
5.11 E. **8.** *Reluctance Motor*①

5.11 E. **9.** *Single-Phase Synchronous Reluctance Motor*①

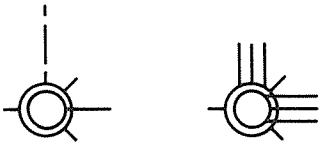
5.11 E. **10.** *Magnetoelectric, Single-Phase, Telephone Magneto*①

①The broken line is not part of the symbol, it indicates where line connection to the symbol is made.

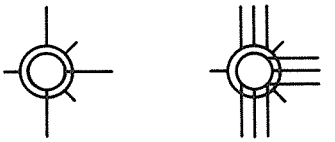
5.11 E. **11.** *Shunt-Characteristic, Brush-Shifting Motor*①



5.11 E. **12.** *Series-Characteristic, Brush-Shifting Motor with 3-Phase Rotor*①

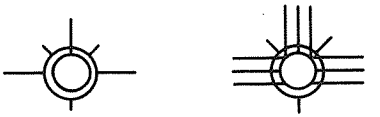


5.11 E. **13.** *Series-Characteristic, Brush-Shifting Motor with 6- or 8-Phase Rotor*



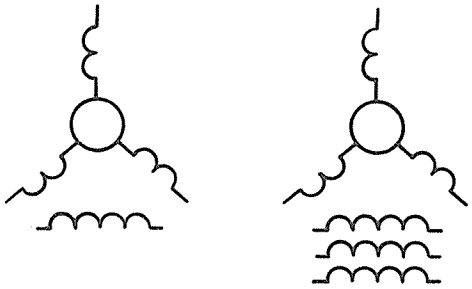
5.11 E. **14.** *Ohmic-Drop Exciter with 3- or 6-Phase Input*

5.11 E. **15.** *Ohmic-Drop Exciter with 3- or 6-Phase Input, with Output Leads*

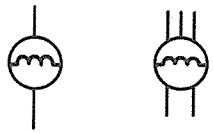


①The broken line is not part of the symbol, it indicates where line connection to the symbol is made.

5.11 E. **16.** *Three-Phase Regulating Machine*

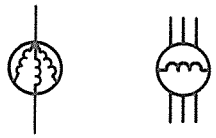


5.11 E. **17.** *Phase Shifter with Single-Phase Output*



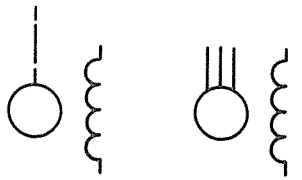
5.11 E. **18.** *Phase Shifter with 3-Phase Output*

See *Phase Shifter 5.13, K, 6* and *Transformer 5, 6, D.*



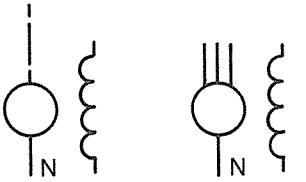
5.11 F. Symbol Applications: Alternating-Current Machines with Direct-Current Field Excitation

5.11 F. **1.** *Synchronous Motor, Generator, or Condenser*①

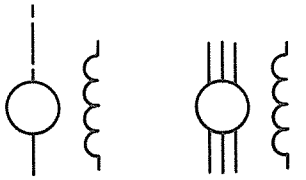


①The broken line is not part of the symbol, it indicates where line connection to the symbol is made.

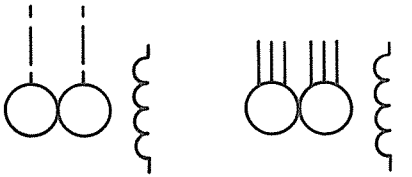
5.11 F. **2.** *Synchronous Motor, Generator, or Condenser, with Neutral Brought Out*①



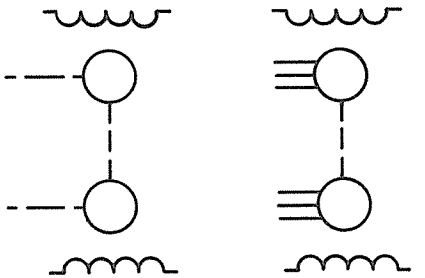
5.11 F. **3.** *Synchronous Motor, Generator, or Condenser, with Both Ends of Each Phase Brought Out*①



5.11 F. **4.** *Double-Winding Synchronous Generator, Motor, or Condenser*①

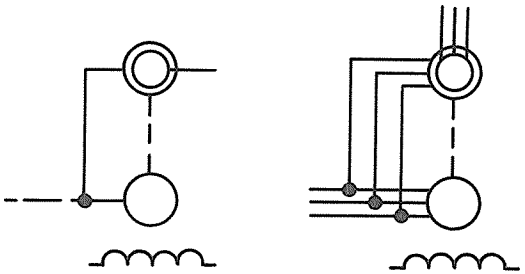


5.11 F. **5.** *Synchronous-Synchronous Frequency Changer*①



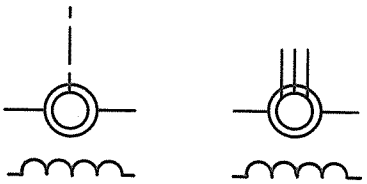
①The broken line is not part of the symbol, it indicates where line connection to the symbol is made.

5.11 F. **6.** *Synchronous-Induction Frequency Changer*①

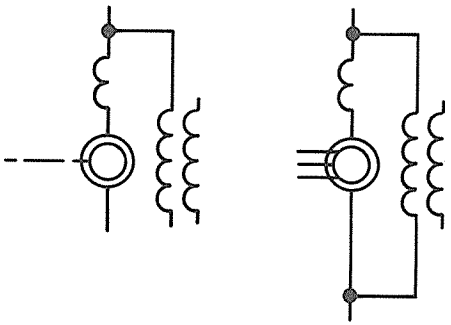


5.11 G. Symbol Applications: Alternating and Direct-Current Composite

5.11 G. **1.** *Synchronous or Regulating-Pole Converter*①

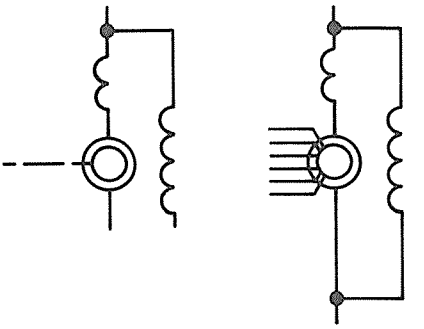


5.11 G. **2.** *Synchronous Booster or Regulating-Pole Converter, with Commutating or Compensating Field Windings, or Both*①

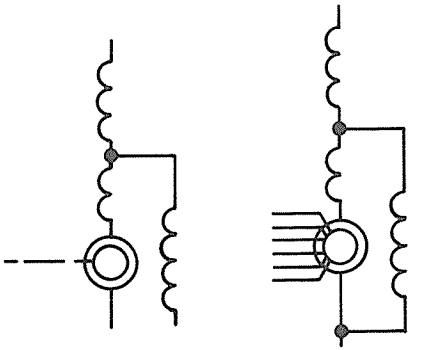


①The broken line is not part of the symbol, it indicates where line connection to the symbol is made.

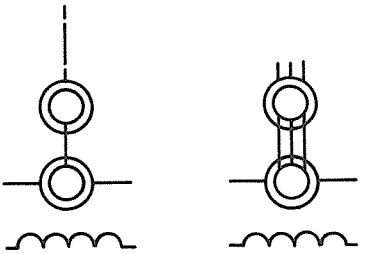
5.11 G. **3.** *Synchronous Converter, Shunt Wound, with Commutating or Compensating Field Winding, or Both*①



5.11 G. **4.** *Synchronous Converter, Compound Wound, with Commutating or Compensating Field Windings, or Both*①



5.11 G. **5.** *Motor Converter*①



①The broken line is not part of the symbol, it indicates where line connection to the symbol is made.

H. Synchro F

If identification is required, a letter combination from the following list may be placed adjacent to the symbol to indicate the type of synchro.

CDX	controlled-differential transmitter
CT	control transformer
CX	control transmitter
TDR	torque-differential receiver
TDX	torque-differential transmitter
TR	torque receiver
TX	torque transmitter
RS	resolver

If the outer winding is rotatable in bearings, the suffix B should be added to the above letter combinations.

1. *General*

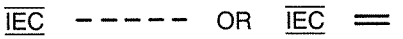
2. *Synchro, Control Transformer; Synchro, Receiver F, Synchro, Transmitter F*

3. *Synchro, Differential Receiver; Synchro, Differential Transmitter F*

5.12 Mechanical Functions

5.12 **A. Mechanical Connection, Mechanical Interlock.**
The preferred location of the mechanical connection is as shown, other locations may equally be acceptable.

5.12 A. **1.** *Mechanical Connection*
The symbol on the left consists of short dashes. The symbol on the right should be used only where there is insufficient space for the short dashes in a series.



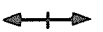
5.12 A. **2.** *Mechanical Connection or Interlock with Fulcrum*
These are short dashes.

5.12 A. **3.** *Mechanical Interlock, Other*
Indicate by note.

5.12 **B. Mechanical Motion**

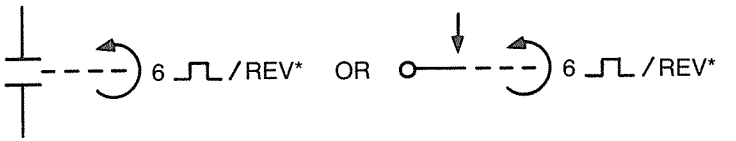
5.12 B. **1.** *Translation, One Direction*

5.12 B. **2.** *Translation, Both Directions*



5.12 B. **3.** *Rotation, One Direction*

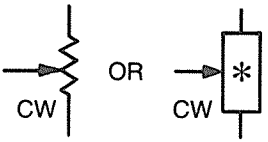
5.12 B. 3. **a.** Angular Motion①
Applied to Open Contact (make) Symbol *(5.4, C, 2).*



①The asterisk is not part of the symbol. Explanatory information may be added if necessary to explain circuit operation.

5.12 B. **4.** *Rotation, Both Directions*

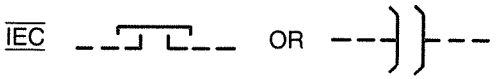
5.12 B. **5.** *Rotation Designation (Applied to a Resistor)*
CW indicates position of adjustable contact at the limit of clockwise travel viewed from knob or actuator and unless otherwise indicated. ②



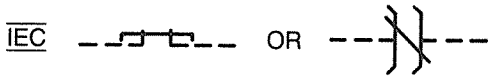
5.12 B. **6.** *Rotational Speed or Angular Velocity Dependence*
See *5.4, 26, d* for application

5.12 C. Clutch, Brake

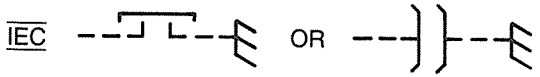
5.12 C. **1.** *Clutch Disengaged when Operating Means (not shown) is De-energized or Non-operated*



5.12 C. **2.** *Clutch Engaged when Operating Means (not shown) is De-energized or Non-operated*



5.12 C. **3.** *Brake Applied when Operating Means (not shown) is Energized*



②The asterisk is not part of the symbol. Replace with identification or explanation if necessary.

5.13 Composite Assemblies

5.13 A. Circuit Assembly, Circuit Subassembly, Circuit Element

The use of a general circuit-element symbol is restricted to:

Diagrams drawn in block form.

A substitute for complex circuit elements when the internal operation of the element is not important to the purpose of the diagram.

Applications where a specific graphic symbol, or the parts to devise a suitable build-up, are not available.

5.13 A. 1. *General*

5.13 A. 1. **a.** Accepted abbreviations from ANSI Z32.13-1950 may be used in the rectangle to replace the asterisk which is not part of the symbol.

5.13 A. 1. **b.** The following letter combinations may be used in the rectangle:

CLK	clock
EQ	equalizer
FAX	facsimile set F
FL	filter
FL-BE	filter, band-elimination
FL-BP	filter, bandpass F
FL-HP	filter, high-pass F
FL-LP	filter, low-pass
IND	indicator
PS	power supply
RG	recording unit
RU	reproducing unit
ST-INV	static inverter
DIAL	telephone dial
TEL	telephone station
TPR	teleprinter
TTY	teletypewriter

5.13 A. 2. *Amplifier* F

5.13 A. 2. **a.** General

The triangle is pointed in the direction of transmission.

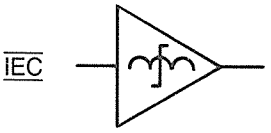
The symbol represents any method of amplification (solid-state device, electron tube, magnetic device, etc.).

If identification, electrical values, location data, and similar information must be noted within a symbol, the size of the symbol may be altered provided its distinctive shape is retained.

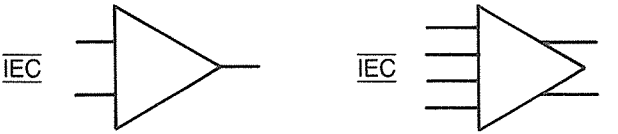
Amplifier use may be indicated in the triangle by words, standard abbreviations, or a letter combination from the following:

BDG	bridging
BST	booster
CMP	compression
D-C	direct-current
EXP	expansion
LIM	limiting
MON	monitoring
PGM	program
PRE	preliminary
PWR	power
TRQ	torque

5.13 A. 2. **b.** Magnetic Amplifier

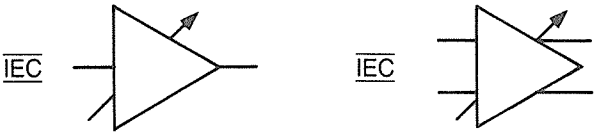


5.13 A. 2. **c.** Amplifier with Two Inputs

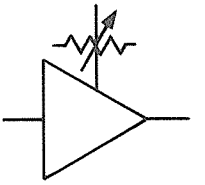


5.13 A. 2. **d.** Amplifier with Two Outputs

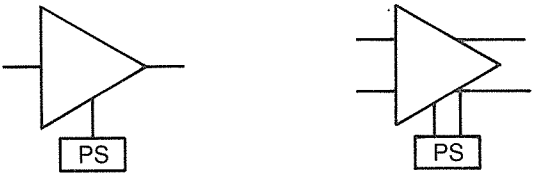
5.13 A. 2. **e.** Amplifier with Adjustable Gain



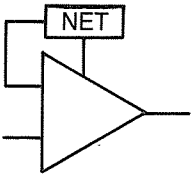
5.13 A. 2. **f.** Amplifier with Associated Attenuator



5.13 A. 2. **g.** Amplifier with Associated Power Supply



5.13 A. 2. **h.** Amplifier with External Feedback Path



5.13 A. **3.** *Rectifier*

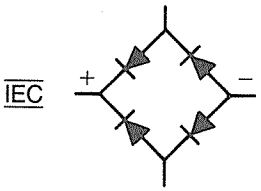
5.13 A. 3. **a.** General

The triangle points in the direction of forward (easy) current as indicated by the direct-current ammeter, unless otherwise noted adjacent to the symbol. Electron flow is in the opposite direction.

This symbol represents any method of rectification (solid-state device, electron tube, electrochemical device, etc.).

5.13 A. 3. **b.** Controlled

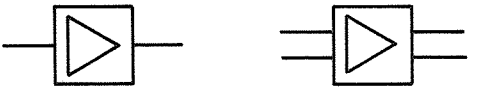
5.13 A. 3. **c.** Bridge-Type Rectifier



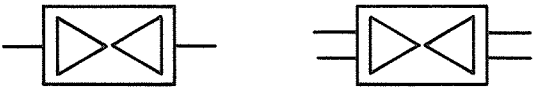
5.13 A. 3. **d.** For Connection or Wiring Diagram
On connection or wiring diagrams, rectifier may be shown with terminals and polarity marking. The heavy line may be used to indicate nameplate or positive-polarity end.

5.13 A. **4.** *Repeater, Including Telephone Repeater* F

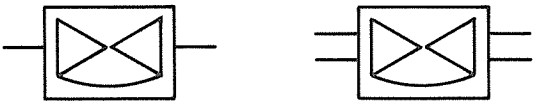
5.13 A. 4. **a.** One-Way Repeater
Triangle points in direction of transmission



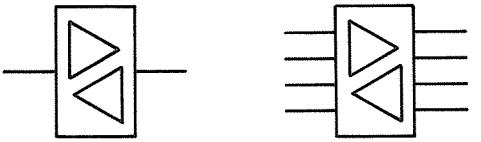
5.13 A. 4. **b.** Two-Wire, Two-Way Repeater



5.13 A. 4. **c.** Two-Wire, Two-Way Repeater with Low-Frequency Bypass



5.13 A. 4. **d.** Four-Wire, Two-Way Repeater

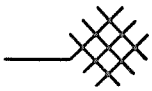


5.13 A. **5.** *Network, Artificial Line Other than Delay Line*

5.13 A. 5. **a.** General

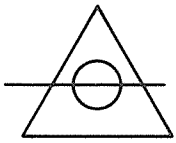
NET

5.13 A. 5. **b.** Network, Low-Voltage Power

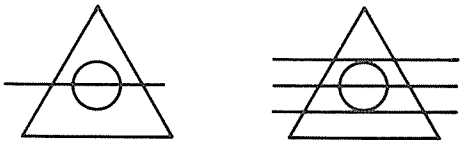


5.13 A. **6.** *Phase Shifter, Phase-Changing Network for Power Circuits, see Alternating-Current Machines.*

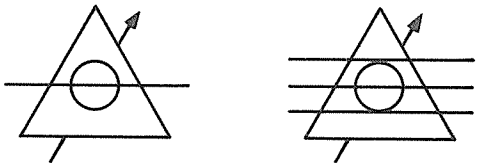
5.13 A. 6. **a.** General



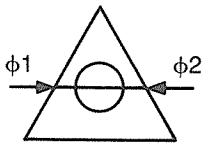
5.13 A. 6. **b.** Three-Wire for Three-Phase



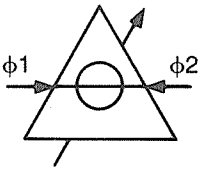
5.13 A. 6. **c.** Adjustable Three-Wire or Three-Phase



5.13 A. 6. **d.** Differential Phase Shifter
Phase shift Ø in direction of arrow, magnitudes indicated.



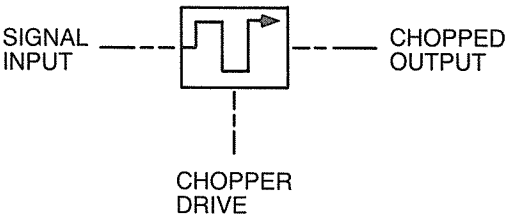
5.13 A. 6. **e.** Adjustable Differential Phase Shifter



5.13 A. **7.** *Chopper* F

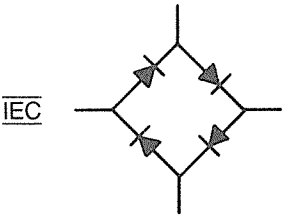
The explanatory words are not part of the symbol.

When diagram is other than single line, show connections as required for a specific device.



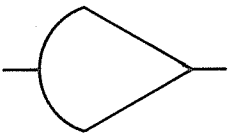
5.13 A. **8.** *Diode-Type Ring Demodulator*

Diode-Type Ring Modulator



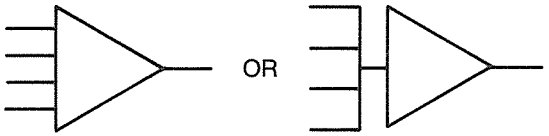
5.14 Analog and Digital Logic Functions

5.14 A. Operational Amplifier



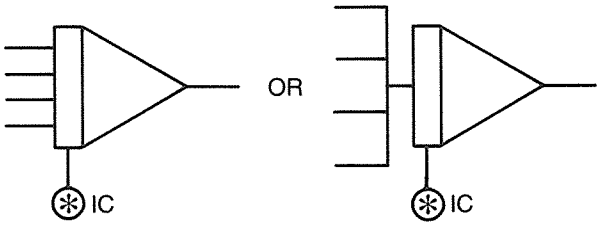
5.14 **B. Summing Amplifier**

Four inputs and one output shown.

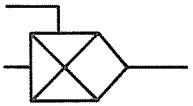


5.14 **C. Integrator (Amplifier)**

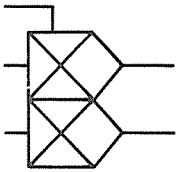
Four inputs, one output shown.
The asterisk is not part of the symbol.
Replace with identification within the circle.
The letters IC indicate initial condition.



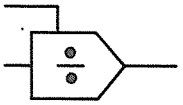
5.14 **D. Electronic Multiplier**



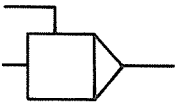
5.14 **E. Two Dependent Multipliers**



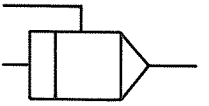
5.14 **F. Electronic Divider**



5.14 **G. Electronic Function Generator**

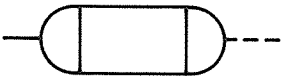


5.14 **H. Generalized Integrator**

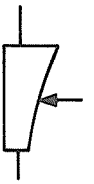


5.14 **I. Position Servo Mechanism**

Dashed line indicates positioned in accordance with an input signal.



5.14 **J. Function Potentiometer**



5.15 Mathematical Symbols

+	Plus
−	Minus
×	Multiplied by
÷	Divided by
=	Equal to
±	Plus or minus
∓	Minus or plus
≛	Plus or equal
⧺	Double plus
≏	Difference between
−:	Difference excess
≡	Identical with, congruent
≢	Not identical with
≠	Not equal to
≈	Nearly equal to
≅	Equals approximately
≌	Equals aproximately
≧	Equal to or greater than
≦	Equal to or less than
<	Less than
⊐	Less than
>	Greater than
⊏	Greater than
≷	Greater than or less than
≮	Not less than
≯	Not greater than
⩽	Less than or equal to
≤	Less than or equal to
≦	Less than or equal to
≤	Less than or equal to
≶	Less than or greater than
⩾	Greater than or equal to
≥	Greater than or equal to
≧	Greater than or equal to
≥	Greater than or equal to
≎	Equivalent to
≠	Not equivalent
≠	Not equivalent
⊂	Included in
⊃	Excluded from
∼	Difference
∽	Difference
⌗	Equal and parallel
≒	Approaches a limit
≙	Is measured by
⊥	Perpendicular to
⊥s	Perpendiculars
∥	Parallel
∥s	Parallels
∦	Not parallels
∠	Angle
∟	Angle
∢	Angle
∡	Angles
∟	Right angle
≝	Equal angles
△	Triangle
△s	Triangles
/	Rising diagonal
\	Falling diagonal
//	Parallel rising diagonal
\\	Parallel falling diagonal
///	Rising parallels
\\\	Falling parallels
⫼	Triple vertical
≣	Quadruple parallels
⌒	Arc
⌣	Arc
▽	Sector
⌓	Segment

○ Circle
Ⓢ Circles
0 Ellipse
∅ Diameter
□ Square
[S] Squares
▭ Rectangle
[S] Rectangles
⊞ Cube
▱ Rhomboid
[S] Rhomboids
⬠ Pentagon
⬡ Hexagon
∴ Hence, therefore
∵ Because
· Multipled by
: Ratio
:: Proportion
∺ Geometrical proportion
′ Minute
″ Second
° Degree
⁝ Dotted minute
⁖ Dotted second
⁘ Dotted degree
‴ Canceled second
‴ Triple prime
√ Square root
∛ Cube root
∜ Fourth root
$\sqrt[n]{}$ *n*th root
⏤ Horizontal radical
Σ Summation of
Π Product sign
π Pi (3.1416)

∪ Union sign
∩ Intersection sign
! Factorial sign
∅ Empty set; null set
∈ Is an element of
∉ Is not an element of
e Base (2.718) of natural system of logarithms
e Charge of the electron
Δ Delta
∇ Nabla; del
∝ Variation
∞ Infinity
₥ Mills
⊢ Assertion sign
h Planck's Constant
ℏ $h/2\pi$
k Boltzmann's Constant
$\bar{c}$ Mean value of *c*
∂ Partial differential
∂ Partial differential
∫ Integral
∮ Contour integral
⌠ Horizontal integral
‿ Mathmodifier
‿ Mathmodifier
∿ Cycle sine
⨌ Quantic
/ Single bond
| Single bond
\ Single bond
| Single bond
| Single bond (punched to right)
⫽ Double bond

‖ Double bond

// Double bond

‖ Double bond

⋮ Triple bond

↔ Reaction goes both right and left

↕ Reaction goes both up and down

⇆ Equilibrium reaction beginning at right

⇄ Equilibrium reaction beginning at left

⇌ Reversible reaction beginning at left

⇆ Reaction begins at right and is completed to left

⇆ Reaction begins at right and is completed to right

⇄ Reaction begins at left and is completed to right

⇄ Reaction begins at left and is completed to left

⇋ Reversible reaction beginning at right

↕ Reversible

∩ Elimination

∪ Absorption

⇵ Exchange

↯ Electrolysis

C Ring opening

∩ Repositioning

○ Ring cycle

↙ Reversible reaction

↘ Reversible reaction