BUILDING ELECTRICAL SYSTEM
VOLTAGE

CONTENTS PAGE

1. GENERAL

1.01 This section discusses important aspects of the voltage of power distribution systems in Telephone Company (Telco) buildings.

1.02 Whenever this section is reissued, the reason(s) for reissue will be given in this paragraph.

1.03 The voltage of the electrical distribution system will have an important bearing on the quality and cost of the power service provided.

2. DEFINITIONS

2.01 Definitions of commonly used terminology as it applies to electrical distribution in buildings (see Fig. 1) are described in the following paragraphs.

2.02 ***Nominal Voltage:*** The value assigned to the system or circuit for the purpose of conveniently designating its voltage class.

2.03 ***Primary Voltage:*** Refers to power supplied by the electric utility company from circuits at nominal voltages above 600 volts.

2.04 ***Secondary Voltage:*** Refers to power supplied by the electric utility company at nominal voltages below 600 volts.

2.05 ***Service Voltage:*** The voltage at the point where the electrical system of the supplier and the user are connected.

2.06 ***Distribution Voltage:*** The voltage which is distributed through the building from the electric service switchboard to either the load centers or directly to the utilization equipment.

2.07 ***Utilization Voltage:*** The voltage at the line terminals of the utilization equipment. This may be at a lower level voltage than the specific distribution voltage due to voltage drop.

2.08 ***Feeder Circuit:*** The circuit between the electric service switchboard and the branch circuit overcurrent device.

2.09 ***Branch Circuit:*** The circuit between the final overcurrent device and the utilization equipment (load).

2.10 ***Voltage Drop:*** The difference between the voltage at the source and the utilization end of the feeder or branch circuit. Usually expressed in percent.

2.11 Nominal system voltage is not a single voltage, but a range of voltages over which the actual voltage at any point in time may vary and still provide satisfactory operation of equipment connected to the system. The voltage range for all standard nominal system voltages in the utilization and distribution range of 120 volts through 34,500 volts is specified in ANSI C84.1- 1977 for two critical points on the distribution system:

(1) The point of delivery by the supply utility.

(2) The point of connection to utilization equipment.

2.12 The actual voltage measured at any point on the system will vary depending on the location of the measurement and the time the measurement is made. Fixed voltage changes take place in transformers in accordance with the transformer ratio, while voltage variations occur from the operation of voltage control equipment and the changes in voltage drop between the supply source and the point of measurement as a result of changes in the current flowing in the circuit.

2.13 The nominal system voltages listed below are officially designated as "Standard Nominal System Voltages" in the United States by ANSI C84.1 -1977. Manufacturers are encouraged to design utilization equipment to provide acceptable performance within the utilization tolerance limits specified in the standard where possible. Below 600 volts they are:

- 208Y/120
- 240/120
- 480Y/277
- 480

2.14 Actual voltages associated with each nominal system voltage lie within two voltage ranges designated A and B at the point of delivery by the supplying utility. Range A covers voltages that are within ± 5 percent of the nominal voltage. Range B covers voltages that are between 5 and 8.3 percent below and 5 and 5.8 percent above nominal. Since utilities are expected to maintain service voltage within Range A, the utilization equipment should be selected to operate within Range A's limits.

Occurrences of Range B voltages are limited in extent, frequency, and duration. Range B voltages result from a combination of design and operating conditions found in both utility and user systems. Utilization equipment (motors, lighting systems, etc) will usually give acceptable performance in Range B for short periods of time. A periodic check and adjustment (if necessary) of the operating voltage level at the utilization equipment should be made, especially when loading of the system increases. Refer to Section 760-400-310*, Transformers, for voltage adjustment. Also refer to Part 4 of this section for voltage drop considerations.

2.15 It is important to maintain the service voltage at the nominal value especially where computer equipment is served. By far the majority of computer malfunctions due to power irregularities are due to voltage sags. By starting with an adequate steady state voltage, the number of sags which will be beyond the tolerance of the computer equipment will be minimized.

3. SELECTION

3.01 Refer to Figures 2A through F for typical distribution voltage configurations and grounding of the service entrance. It is of utmost importance that the grounding system be established in accordance with the above mentioned figures. The neutral and ground should be kept electrically separate throughout the distribution system, joining together ***only*** at the source. Refer to Section 802-001-198, General Equipment Grounding Requirements for Alternating Current (AC) Distribution Systems, for additional information. No loads should be connected between phase conductors and ground. The ground lead is not a "normal" current return path.

3.02 The choice of distribution voltage depends upon:

(a) Service voltage available from power utility

(b) Tariff structure of power utility

(c) Initial and ultimate building size

(d) Output voltage of stand-by power plant

(e) Voltage rating of equipment served

(f) Length of feeders

(g) Overall cost.

3.03 The following table provides a guide for selection of the economic voltage for a particular installation.

* Check Divisional Index 760 for availability.

TOTAL LOAD (KVA)	SERVICE VOLTAGE
10-80	240/120 - 1Ø
70-200	208Y/120 - 3Ø
100-5,000	480Y/277 - 3Ø

3.04 Low level secondary supply voltages (240/120 volt, 1Ø-3W and 208Y/120 volt, 3Ø-4W) are commonly used in smaller buildings, such as No. 2B Electronic Switching Systems (ESSs), small No. 5 ESS's, Digital Multiplex System (DMS)-10's, repeater stations, and work centers.

3.05 The 480Y/277 volt, 3Ø-4W systems should be used in all but the smallest buildings. It provides 480 volts for equipment loads such as rectifiers, HVAC, elevators, etc, and 277 volts for fluorescent lighting systems. Section 760-400-100, Planning, discusses possible circumstances for selecting other than 480 volts (eg, 208 volts for small computer buildings or medium voltage in large buildings with long feeder lengths).

3.06 Step-down transformers to 240/120 volts, 1Ø-3W or 208Y/120 volts, 3Ø-4W are required for incandescent lighting and appliance receptacles. Several will normally be required, located as close to the 120 volt loads as possible. However, in smaller buildings, it might prove economical to provide only one, near the electric service switchboard.

3.07 The prime advantage of using a 480Y/277 volt system instead of a 208Y/120 volt system is economy in conductor and equipment size because the current is reduced by more than half. A typical example:

200 KVA 208Y/120 Volts requires 600 Amperes

200 KVA 480Y/277 Volts requires 240 Amperes

The savings in cost is often much more than half because conductor and equipment size and strength vary in accordance with the square of the current.

3.08 The 480 volt system is also far superior for minimizing the effects of voltage drop. (See Part 4.)

4. VOLTAGE DROP

4.01 Voltage drop is a loss of voltage between the service voltage and the utilization equipment. The National Electrical Code limits the voltage drop on feeders and branch circuits to 3 percent for each portion of the circuit, with a total of 5 percent for the overall drop. Good engineering practice suggests that the overall drop be no greater than 3 percent, feeders being no more than 2 percent, and branch circuits no more than 1 percent.

Incorrect utilization voltage can affect equipment performance, life or energy consumption. Section 760-400-105, Building Energy Management and Redesign Retrofit (BEMARR) General Considerations for Electrical Systems, covers this subject in detail.

4.02 To determine percent voltage drop, the loss in the conductor length must be calculated first, then the actual percent drop can be computed.

$$\text{Voltage Loss} = \frac{\text{Length} \times \text{Load} \times \text{Table Value}}{10^6}$$

Length = one way distance
Load = current on conductor
Table value See Tables A & B

$$\%\ \text{Voltage Drop} = \frac{\text{Voltage Loss}}{\text{Circuit Voltage}} \times 100$$

Example: No. 6 copper wire in 180 feet of magnetic conduit, 208 volt-3Ø, 40 ampere load at 80 percent power factor.

$$\text{Voltage Loss} = \frac{180 \times 40 \times 735}{10^6}$$

$$= 5.292 \text{ Volts Loss}$$

$$\%\ \text{Voltage Drop} = \frac{5.292}{208} \times 100$$

$$= 2.544\% \text{ Voltage Drop}$$

5. REFERENCES

5.01 The material was based partially on the following references.

Industrial Power Systems Handbook - Beeman McGraw-Hill, 1965.

Recommended Practices For Electrical Power Distribution For Industrial Plants IEEE STD 141-1976 "Red Book".

Recommended Practices for Electrical Power Distribution In Commercial Buildings IEEE STD 241-1983 "Gray Book".

Mechanical and Electrical Equipment For Buildings - McGuiness, Stein, Reynolds - Wiley Press, 6th edition.

Electrical Protection Handbook Bulletin SPD-81 Bussman Division, McGraw-Edison Company.

ANSI C84.1-1977, Voltage Ratings for Electrical Power Systems and Equipment (60 Hz), including Supplement C84.1a-1980.

NFPA 70 National Electrical Code (NEC).

Section 760-400-100 - Planning

Section 760-400-105 - Building Energy Management and Redesign Retrofit (BEMARR) General Considerations for Electrical Systems.

Section 802-001-198 - General Equipment Grounding Requirements for AC Service Distribution Systems.

TABLE A

COPPER CONDUCTORS

CONDUIT	WIRE SIZE	VOLT LOSS FACTOR					
		THREE PHASE (60 CYCLE, LAGGING POWER FACTOR)			SINGLE PHASE* (60 CYCLE, LAGGING POWER FACTOR)		
		100%	90%	80%	100%	90%	80%
Steel	14	5280	4800	4300	6100	5551	4964
	12	3320	3030	2720	3828	3502	3138
	10	2080	1921	1733	2404	2221	2003
	8	1316	1234	1120	1520	1426	1295
	6	840	802	735	970	926	850
	4	531	530	487	614	613	562
	3	420	425	398	484	491	460
	2	331	339	322	382	392	372
	1	265	280	270	306	323	312
	0	208	229	224	241	265	259
	00	166	190	188	192	219	217
	000	132	157	158	152	181	183
	0000	105	131	135	121	151	156
	250M	89	118	123	103	136	142
	300M	74	104	111	86	120	128
	350M	63	94	101	73	108	117
	500M	45	76	85	52	88	98
	600M	38	69	79	44	80	91
	750M	31	62	72	36	72	83
Non-Magnetic (Aluminum Plastic, etc)	14	5280	4790	4280	6100	5530	4936
	12	3320	3020	2700	3828	3483	3112
	10	2080	1910	1713	2404	2202	1978
	8	1316	1220	1100	1520	1406	1268
	6	840	787	715	970	908	825
	4	531	517	466	614	596	538
	3	420	410	379	484	474	438
	2	331	326	303	382	376	350
	1	265	266	251	306	307	289
	0	208	216	206	241	249	237
	00	166	176	170	192	203	196
	000	132	145	141	152	167	163
	0000	105	119	118	121	137	136
	250M	89	105	106	103	121	122
	300M	74	92	95	86	106	109
	350M	63	82	85	73	94	98
	500M	45	64	69	52	74	80
	600M	38	57	63	44	66	73
	750M	31	51	56	36	59	65

* For line to neutral voltage (ie, 120, 277v) divide table value by 2.

TABLE B

ALUMINUM CONDUCTORS

CONDUIT	WIRE SIZE	VOLT LOSS FACTOR: THREE PHASE (60 CYCLE, LAGGING POWER FACTOR) 100%	90%	80%	SINGLE PHASE* (60 CYCLE, LAGGING POWER FACTOR) 100%	90%	80%
Steel	12	5230	4760	4260	6040	5500	4920
	10	3291	3005	2690	3800	3470	3110
	8	2070	1905	1725	2390	2200	1990
	6	1325	1238	1126	1530	1430	1300
	4	837	795	726	966	918	838
	2	526	511	473	606	590	546
	1	415	414	386	480	478	446
	0	331	336	317	382	388	366
	00	262	272	260	302	314	300
	000	210	225	217	242	260	250
	0000	168	185	182	194	214	210
	250M	142	163	163	164	188	188
	300M	119	141	142	137	163	164
	350M	102	126	128	118	146	148
	500M	74	100	104	85	115	120
	600M	62	88	95	72	102	110
	750M	52	79	85	60	91	98
Non-Magnetic (Aluminum, Plastic, etc)	12	5230	4750	4250	6040	5490	4900
	10	3290	3000	2680	3800	3460	3100
	8	2070	1900	1701	2390	2190	1970
	6	1325	1230	1110	1530	1420	1280
	4	837	787	715	966	908	826
	2	525	504	462	606	580	534
	1	416	405	376	480	468	434
	0	331	328	307	382	378	354
	00	262	265	251	302	306	290
	000	208	217	206	240	250	238
	0000	166	177	171	192	204	197
	250M	139	153	151	161	177	174
	300M	116	133	132	134	153	152
	350M	100	117	117	115	135	135
	500M	70	89	92	81	103	106
	600M	59	79	83	68	91	96
	750M	48	68	73	55	79	84

* For line to neutral voltage (ie, 120, 277v) divide table value by 2.

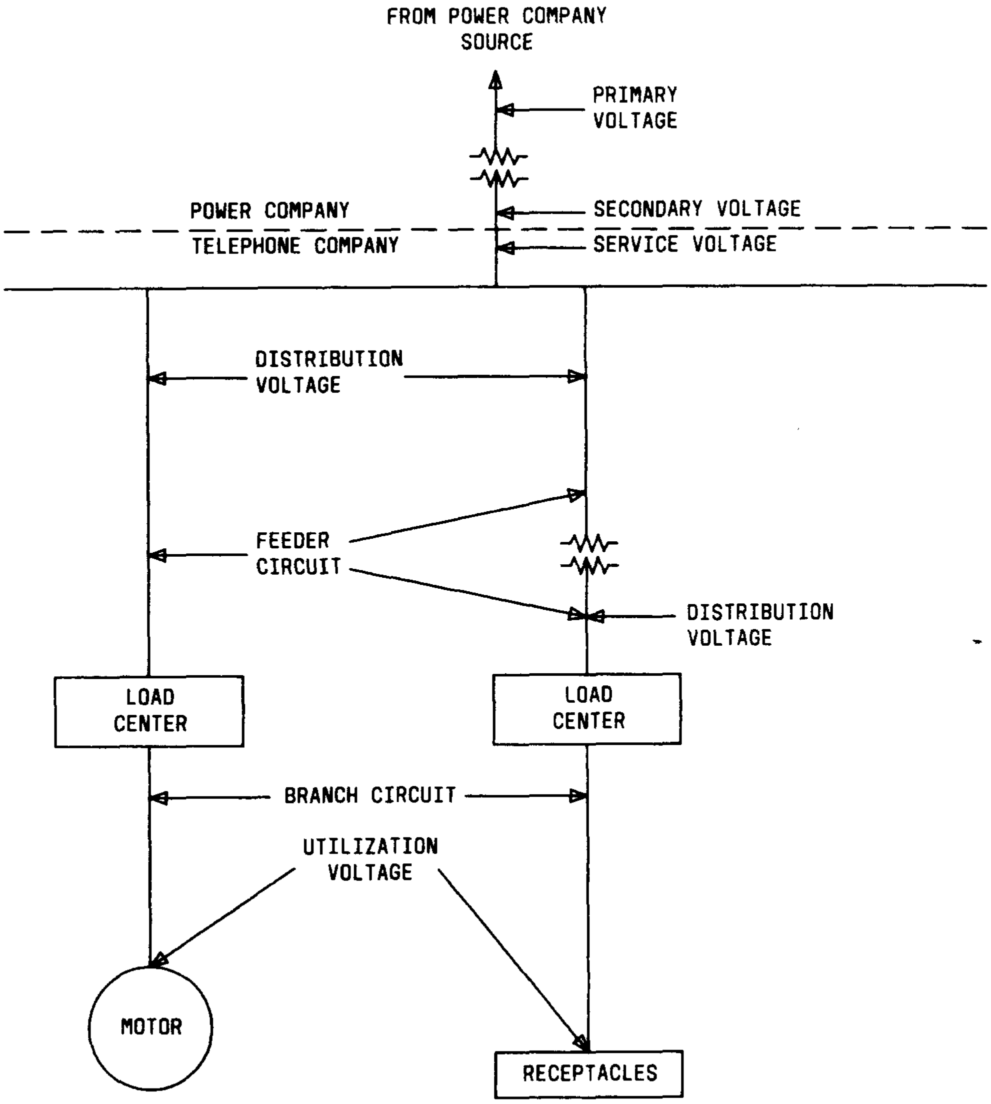
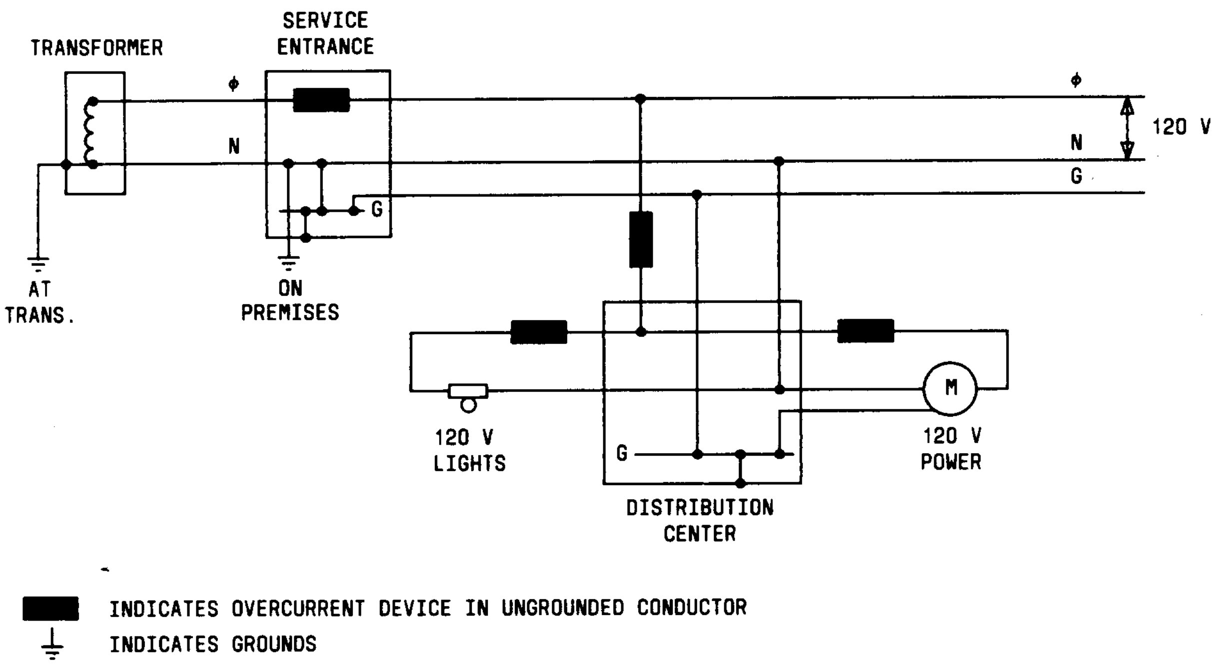
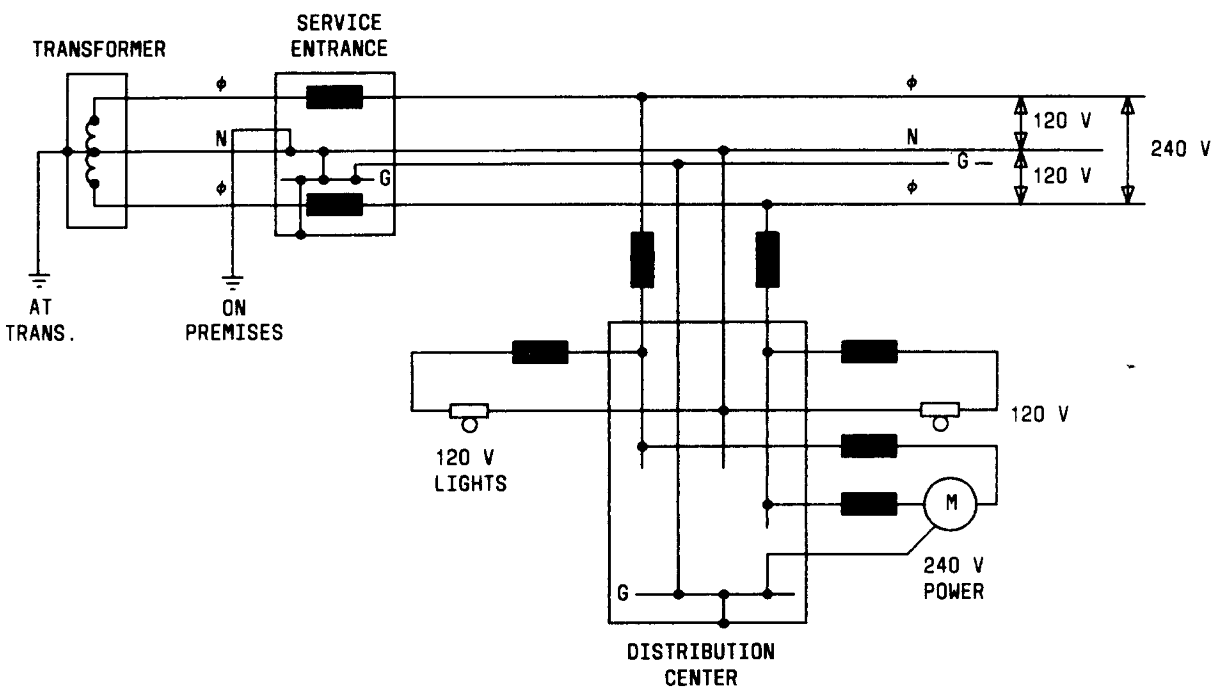


Fig. 1—Nomenclature of Distribution System



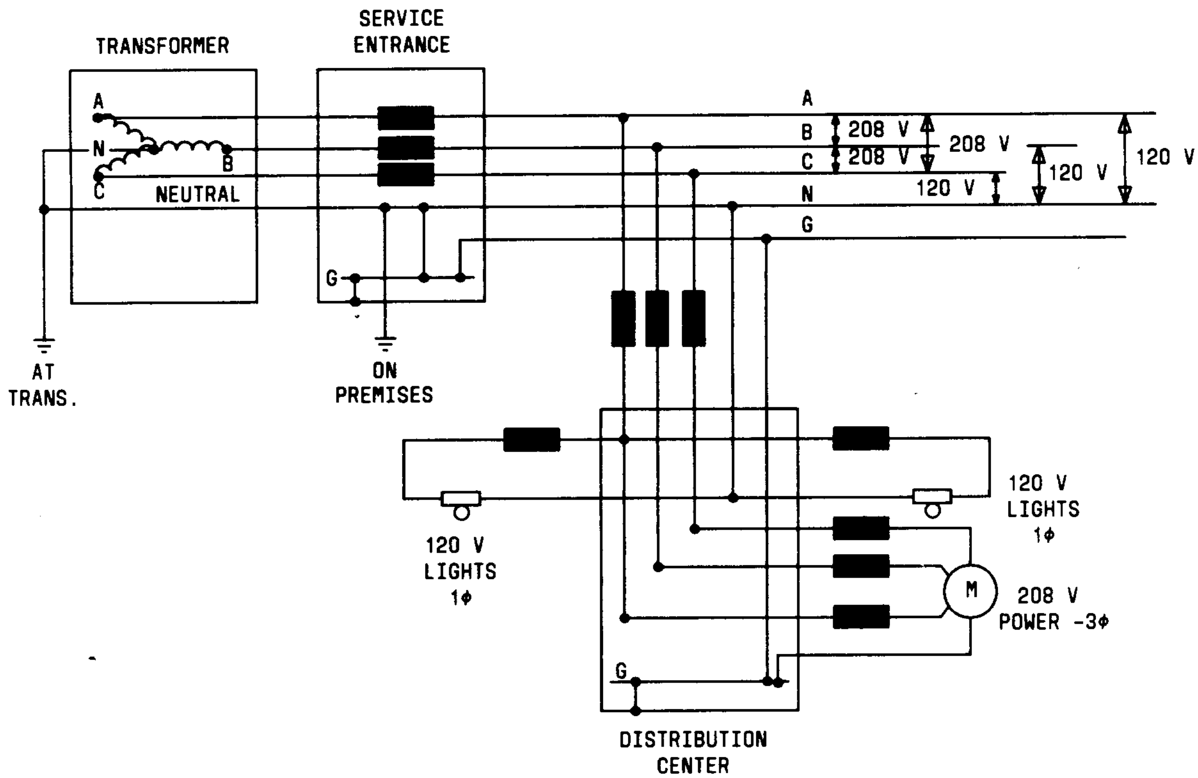
A - SINGLE PHASE, 2 WIRE, 120 VOLTS
(GROUNDED SYSTEM)

Fig. 2A— Types of Distribution Voltages for Buildings 600 Volts or Less



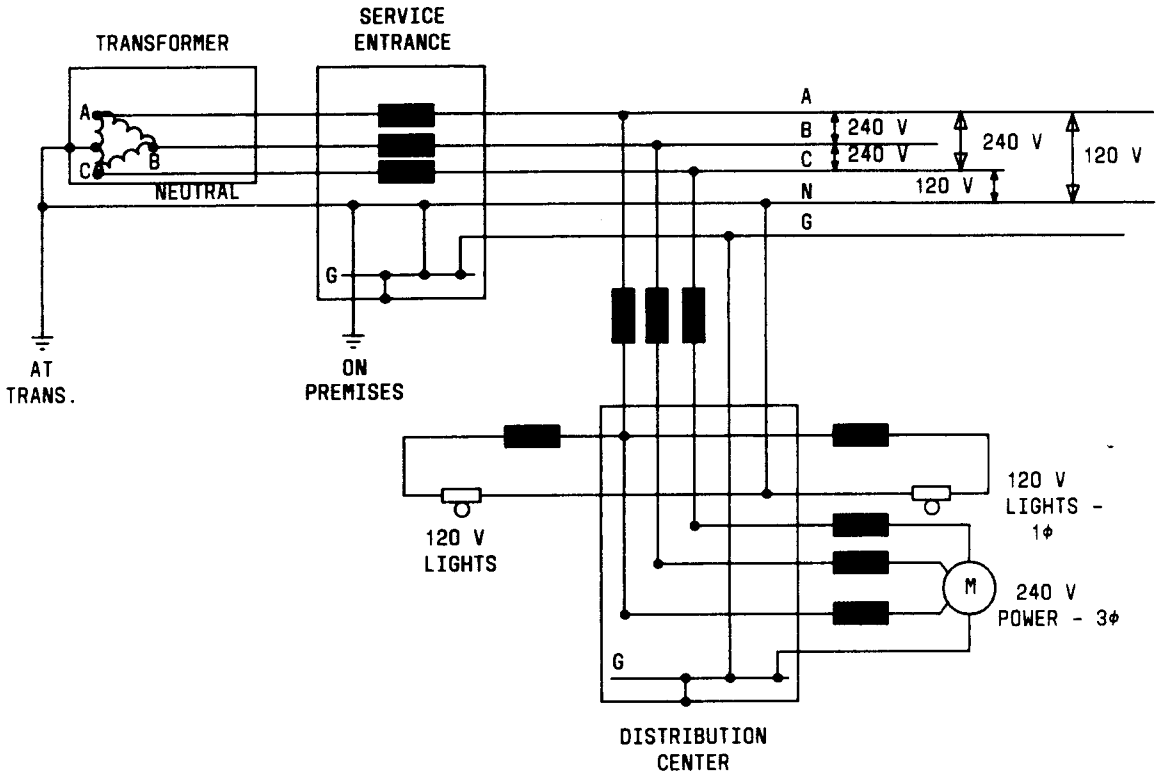
B - SINGLE PHASE, 3 WIRE, 240/120 VOLTS
(GROUNDED SYSTEM)

Fig. 2B— Types of Distribution Voltages for Buildings 600 Volts or Less



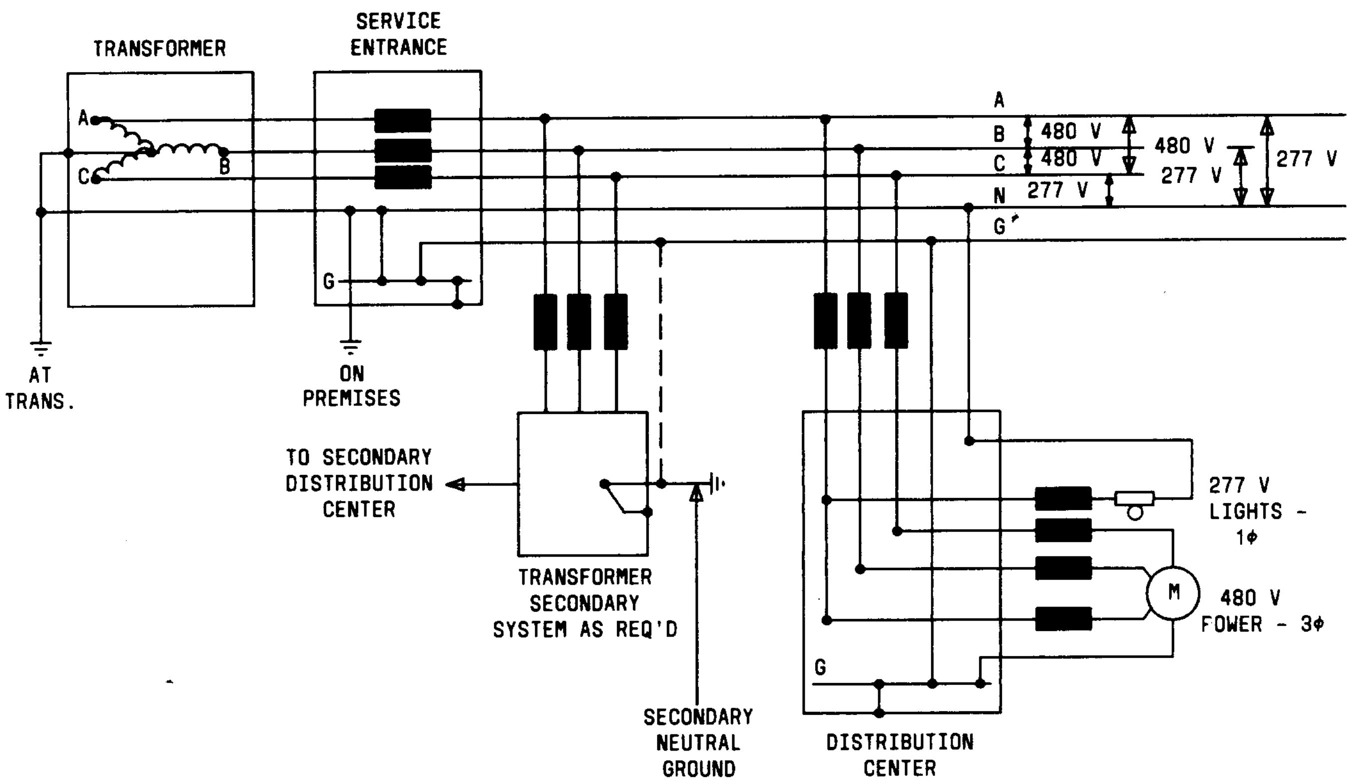
C - THREE PHASE, 4 WIRE WYE 208Y/120 VOLTS
(GROUNDED SYSTEM)

Fig. 2C — Types of Distribution Voltages for Buildings 600 Volts or Less



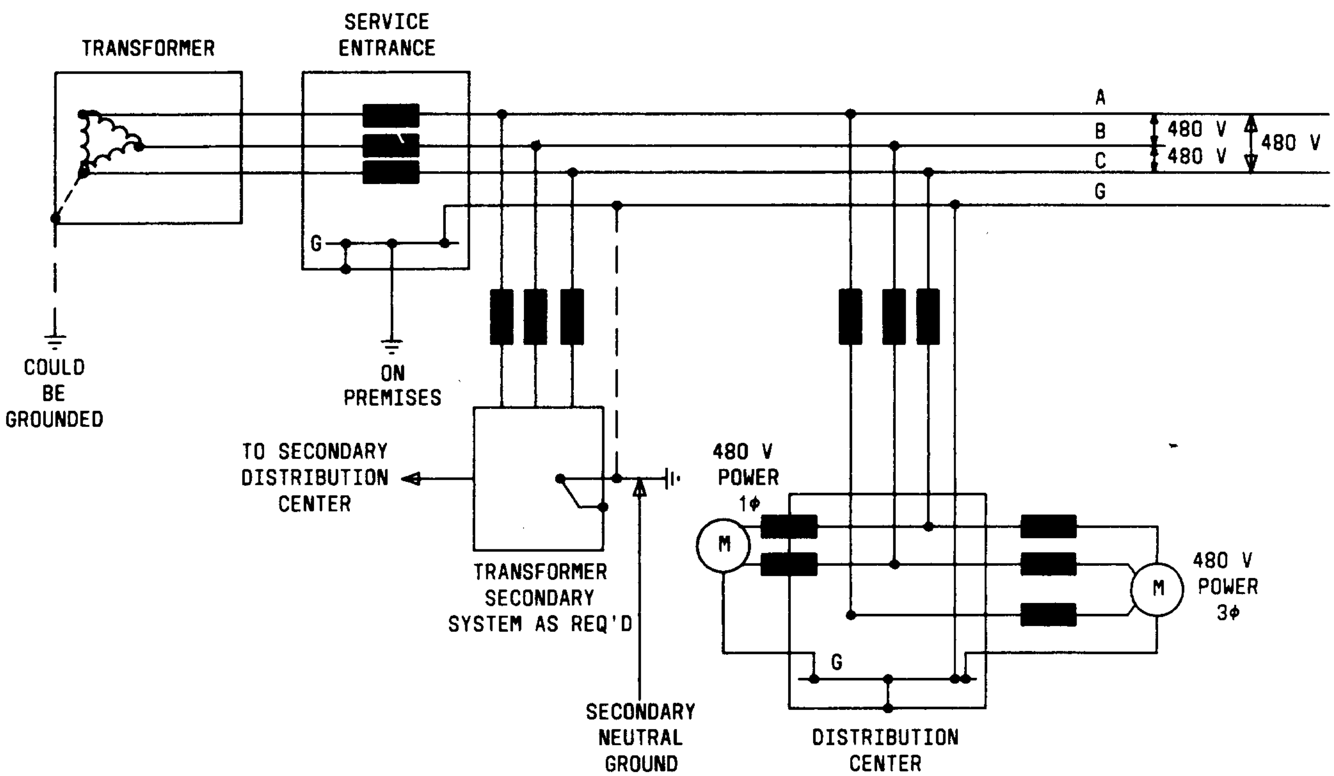
D - THREE PHASE, 4 WIRE DELTA 240/120 VOLTS
(GROUNDED SYSTEM)

Fig. 2D — Types of Distribution Voltages for Buildings 600 Volts or Less



E - THREE PHASE, 4 WIRE WYE 480Y/277 VOLTS
(GROUNDED SYSTEM)

Fig. 2E — Types of Distribution Voltages for Buildings 600 Volts or Less



F - THREE PHASE, 3 WIRE DELTA 480 VOLTS

Fig. 2F — Types of Distribution Voltages for Buildings 600 Volts or Less