BUILDING ELECTRICAL SYSTEMS
TRANSFORMERS
SELECTION AND APPLICATION

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1. GENERAL

1.01 This section contains guidelines to be used in the selection and application of transformers in the electrical distribution system of all telephone company buildings. In addition, transformers shall comply with all codes and standards.

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

1.03 The National Electrical Manufacturers Association (NEMA) and the Institute of Electrical and Electronics Engineers (IEEE) classify transformers as distribution and power types. A distribution transformer may have a rating between 3 and 500 kVA, inclusive. A power transformer is any transformer with a rating above 500 kVA.

2. IMPORTANT CONSIDERATIONS

2.01 Within the broad categories of distribution and power transformers, the following characteristics must be considered in the application:

- kVA rating
- Voltage
- Voltage taps
- Frequency rating
- Connections
- Insulation
- Basic impulse level (BIL)
- Noise
- Grounding
- Efficiency.

A. KVA Rating

2.02 The transformer kVA rating should satisfy the immediate load demand and provide for future growth (approximately 10 years). Oversizing should be avoided as this not only costs more, but also wastes energy.

B. Voltage

2.03 The voltage rating of a transformer is listed with an input and output rating, eg, 4160 volts input and 480 volts output. The standard distribution voltage levels for Bell System application are:

INPUT/OUTPUT	CURRENT RATING
480Y/277	3Ø
208Y/120	3Ø
240/120	3Ø—Not recommended
240/120	1Ø

Refer to Section 760-400-110* for details.

2.04 Normally, service entrance transformers have voltages between 5 and 13 kV. Distribution transformers in telephone company buildings are usually required only for a 480-volt distribution system using a step-down transformer to provide 120 volts for receptacles; incandescent lighting; and miscellaneous equipment such as printers, tape drives, fractional horsepower motors, etc.

C. Voltage Taps

2.05 Voltage taps are necessary to compensate for small changes in the primary supply to the transformer or to vary the secondary voltage with changes in load requirements.

2.06 To ensure rated secondary distribution voltage, most standard transformers rated 30 through 500 kVA are available with six voltage taps.

(a) Four taps, each of which corrects for a 2-1/2 percent below normal full capacity (BNFC) supply voltage

(b) Two taps, each of which corrects for 2-1/2 percent above normal full capacity (ANFC) supply voltage.

Refer to Fig. 1 for a simplified diagram of the tap adjustments and to Table A for standard tap values.

D. Frequency Rating

2.07 The almost universal frequency of ac supply systems in the United States is 60 Hz (cycles

*Check 760 Divisional Index for availability.

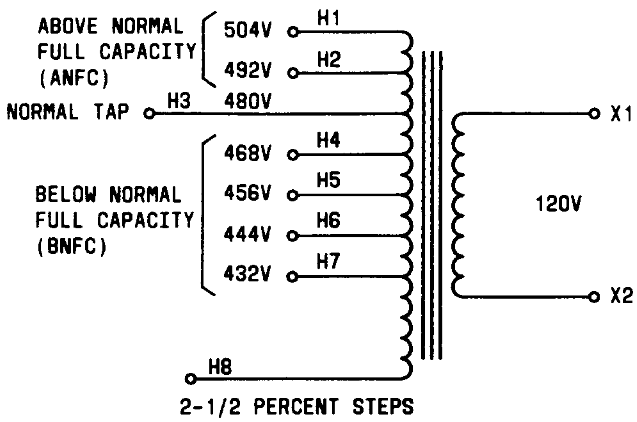

Fig. 1—Typical Voltage-Adjusting Taps

TABLE A

TAP SELECTOR CHART

PROPER TAP	NOMINAL TRANSFORMER INPUT VOLTAGE RATING				
	208	240	277	480	600
5%	218	252	291	504	630
+2½%	213	246	284	492	615
Rated	208	240	277	480	600
-2½%	203	234	270	468	585
-5%	198	228	263	456	570
-7½%	192	222	256	444	585
-10%	187	216	249	432	540

per second). Where other frequencies are used, care must be taken to assure the suitability of the transformers. Refer to Part 7 for special loads.

E. Connections

2.08 Connections for the 3-phase standard, 2-winding transformers are preferably delta (Δ) primary and wye (y) secondary. The "y" secondary connection, specified with external neutral bushing, provides a convenient neutral point for establishing a system ground and a neutral point for phase-to-neutral loading.

F. Insulation

2.09 The rating of the insulation used in a dry-type transformer is related to the winding temperature that the insulation is subjected to. Transformers with windings designed to reach a high temperature will require a higher-rated insulation.

2.10 Winding temperature can be broken down into two components:

- Average rise above ambient
- Hot-spot rise above average rise.

2.11 Catalog references to temperatures relate to the average rise above the ambient temperature. The standard values are 55°, 80°, 115°, and 150°C.

Note: This temperature rise applies ***only*** to the windings (not to the core, outside surface, or any other part of the the transformer).

2.12 The values for insulation temperature ratings include the sum of the ambient temperature (40°C), the average rise above the ambient temperature (55°, 80°, 115°, or 150°C), and the hot-spot rise above average rise (10° or 30°C).

2.13 The NEMA and the American National Standards Institute (ANSI) standards now employ numeric designations for both winding temperature and insulation temperature ratings. The previous designation system used alphabetic symbols for each. Refer to Table B for a listing of old and new designations.

G. Basic Impulse Level (BIL)

2.14 The transformer winding BIL rating signifies the design and tested capability of winding insulation to withstand transient overvoltages (crest values in kV) from lightning and other surges. Although the BIL ratings of dry-type transformers are relatively low (10 kV) compared to those of liquid-filled transformers, they can be adequately protected by surge arresters.

2.15 Surge protection shall be provided for ***all*** transformers (service entrance and distribu-

TABLE B

TRANSFORMER TEMPERATURE RATINGS (NOTE)

WINDING					INSULATION	
AMBIENT TEMP	AVG COIL RISE	HOT-SPOT RISE	HOTTEST COIL TEMP	OLD DESIG	TEMP RATING	OLD DESIG
40	55	10	105	A	105	A
40	80	30	150	B	150	F
40	115	30	185	F	185	H
40	150	30	220	H	220	C

Note: All temperatures are expressed in °C.

tion type), except where service is obtained from an underground network. Refer to Section 760-400-520* for lightning and surge protection procedures; to Section 876-100-100 for electrical protection principles; and to SD-81968-01 for specific application data.

H. Noise

2.16 Noise is inherent in any transformer. The noise (vibrations) is caused by the steel core laminations being magnetized and demagnetized 120 times per second for a 60-Hz system. This noise is transmitted as follows:

- Through the air, with accompanying reflection of sound waves
- By conduction throughout the structure.

Secondary noise is created when transformer vibrations cause other objects such as housing covers, close coupled switchboard sections, conduit, etc, to vibrate.

2.17 Transformer noise may be reduced by using short lengths (less than 6 feet) of flexible metal conduit (Greenfield) in the primary and secondary feeds and/or by specifying vibration dampeners. Dampeners are provided to isolate the core and coil from the mounting brackets inside the transformer as well as to provide isolation between the transformer housing and the building structure.

2.18 Airborne noise can be reduced by locating the transformer as far as possible from, and not parallel with, any walls, corners, or reflecting surfaces.

I. Grounding

2.19 The enclosures of all transformers must be solidly grounded in accordance with National Electric Code (NEC) Article 250 on enclosure grounding. The transformer core is grounded to the enclosure by the manufacturer; this connection should be inspected periodically.

2.20 The transformer neutral on all 2-winding transformers shall be solidly grounded. This ground shall be installed in accordance with NEC Article 250. If the transformer is part of a separately derived system, it must be grounded to the nearest effective building ground (eg, central office ground bar). It is ***not*** necessary to ground this neutral to the building service entrance ground. (See Fig. 2.)

2.21 When using an autotransformer, the midpoint of the "y" connection shall ***not*** be grounded. Since the neutral is continous in this application, the autotransformer is not considered a separately derived source. (See Fig. 2.)

J. Efficiency

2.22 One of the most important considerations in transformer selection is efficiency. What appear to be very small differences in efficiency can add up to large differences in annual energy costs. In

* Check 760 Divisional Index for availability.

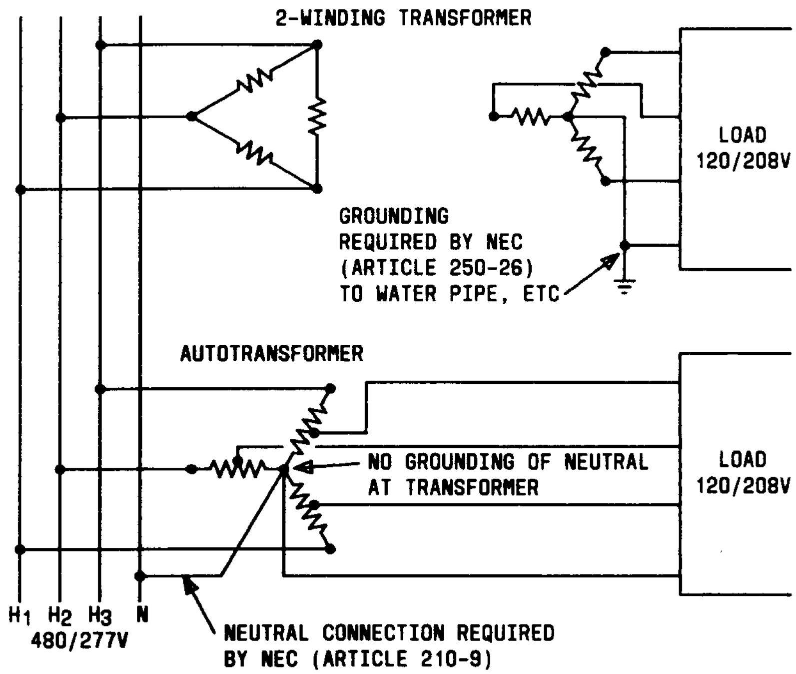

Fig. 2—3-Phase Transformer Connections

many cases, a more efficient transformer can be justified.

2.23 Low-loss transformers are wound with larger wire, thereby reducing the I^2R losses. To accommodate this larger wire, the transformer usually requires a larger core and therefore has larger core losses. Since the core losses are continuous throughout the year and are not a function of the load, the transformer might actually use more energy on an annual basis than a standard transformer. This would be the case with a low load factor, ie, operation at light load for many hours in the year.

2.24 For transformers used with a standby generator only, efficiency is of little importance.

2.25 Refer to Exhibit 1 for a formula and sample calculation that can be used to estimate the annual energy costs of transformer losses.

3. SERVICE ENTRANCE

3.01 Most of the transformers serving telephone company buildings in this category are owned by the electric utility company. Telephone company ownership of the service entrance equipment usually cannot be justified. The foremost advantage of utility ownership is their obligation to replace promptly a failed transformer. Another advantage is maintenance by experienced utility company personnel.

3.02 Under certain conditions, the telephone company may choose to buy the service entrance transformers. For outdoor use, or where a suitable vault is available at no extra cost, oil-filled transformers are usually the best choice. For indoor use, dry-type transformers or nonflammable liquid transformers must be used.

4. AUTOTRANSFORMERS

4.01 When using a 480-volt distribution system, it will be necessary to provide some power at the 208Y/120-volt utilization level for receptacles, incandescent lighting, and other miscellaneous equipment. If the 480-volt service is installed to take the place of an inadequate 208-volt service, it may be necessary to supply larger amounts of 208-volt power for existing equipment. (See Part 6.) Computer equipment may also require larger amounts of 208-volt power. Autotransformers are the best choice for this application.

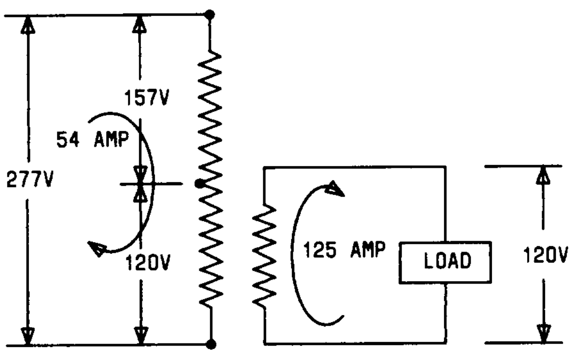

Fig. 3—Dual-Winding Transformer

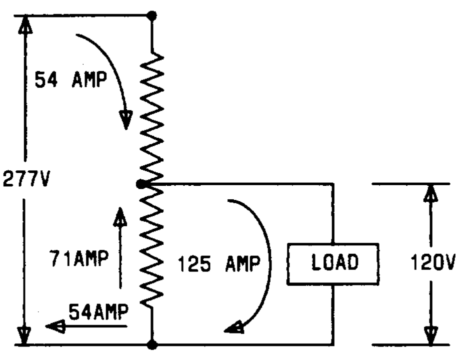

Fig. 4—Autotransformer

4.02 When the primary and secondary circuits of a transformer have part of a winding in common, the unit is called an autotransformer. See Fig. 3 and 4.

4.03 Essentially, all advantages of an autotransformer derive from the fact that the common winding carries only the difference between the primary and secondary currents. As the transformation ratio increases, the advantages of autotransformers decrease. Beyond a 3-to-1 ratio, autotransformers are seldom used.

4.04 For 480- to 208-volt transformation, the autotransformer contains less copper and core material. There is less current and less magnetic flux, therefore less copper and core losses. There is less noise since a smaller amount of material is vibrating. Consequently, a more efficient and quieter transformation occurs. The autotransformer is smaller, lighter, and costs less than its equivalent 2-winding transformer. See Fig. 5, 6, and 7 for comparisons.

4.05 In an autotransformer, grounding requirements are simplified because the neutral is continuous and therefore it is not considered a separately derived source. (See Fig. 2.)

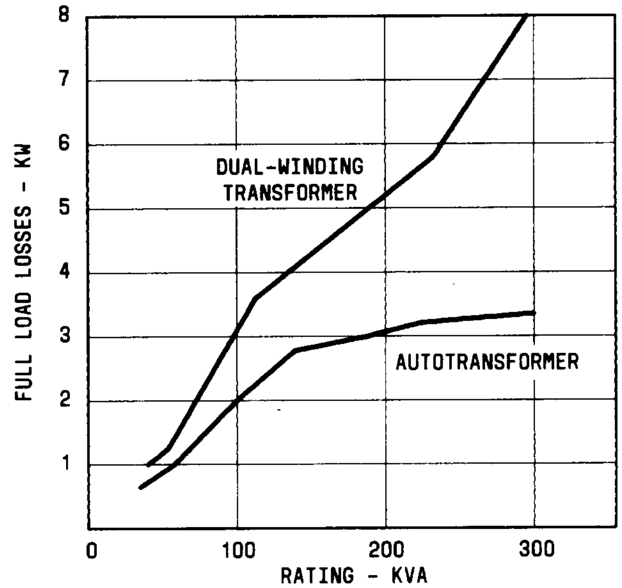

Fig. 5—Full-Load Loss Comparison

4.06 The supply source must have a neutral that is connected to the transformer neutral. (See Fig. 2.)

4.07 Although autotransformers are not widely used in buildings today, no valid reason has been found for not using them for ordinary step-down or step-up application in the 480Y/277-volt and 208Y/120- volt ranges, provided they are properly selected and installed. Numerous installations inside and outside the Bell System bear this out.

4.08 The impedance of an autotransformer is quite a bit lower than that of a 2-winding transformer. Although this provides better voltage regulation, it must be considered (because of higher short-circuit values) when evaluating short circuits for proper protective devices.

4.09 Only 3-legged core construction should be specified. This construction minimizes third

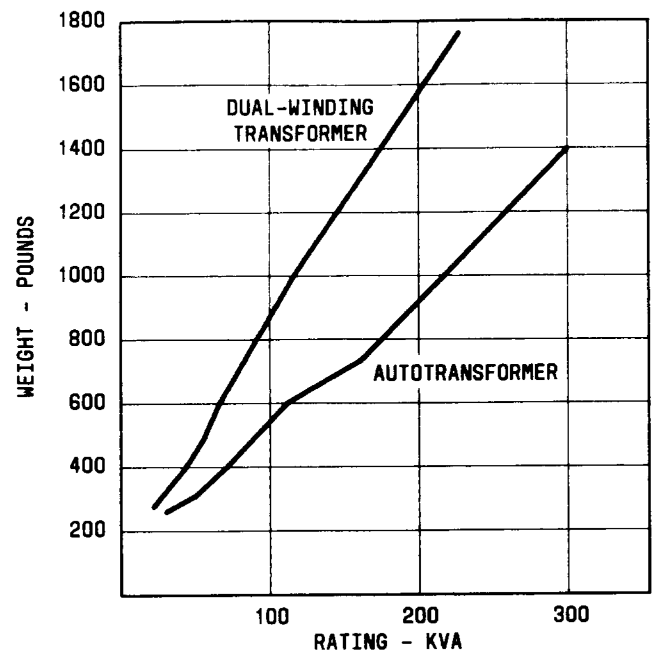

Fig. 6—Weight Comparison

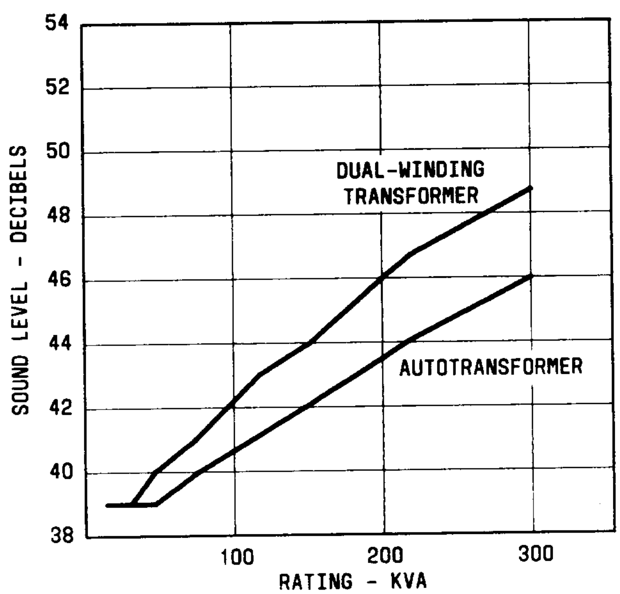

Fig. 7—Sound Level Comparison

harmonic currents and is also more tolerant of unbalanced phase loads. Three single phase units should not be used to derive a 3-phase, 4-wire system.

4.10 Since the source and load share a common winding, there is no isolation of the source from the load. However, if the quality of the ac supply is a problem, it will rarely be corrected by a common 2-winding transformer. Other corrective methods, which really place this consideration outside the question of a simple transformation device, must be employed.

5. INSTALLATION

5.01 Transformers must be installed in locations that provide a free flow of air for cooling purposes. For installation of transformers in vaults, refer to Section 760-550-151 for ventilation requirements and to Sections 760-630-200 and 760-630-400 for design and construction requirements.

5.02 Dry-type, ventilated transformers shall be installed in accordance with NEC Article 450-21.

6. TRANSFORMERS FOR TELEPHONE POWER PLANTS.

6.01 Power for telephone equipment should never be supplied by only a single transformer. Despite the fact that transformers are unusually reliable devices, a single transformer poses a risk to telephone service. In the event of a transformer failure, a method must be available to replace power before the batteries are discharged.

6.02 The methods to ensure continuous service at reasonable cost depend upon the distribution scheme. Some suggested methods are:

(a) Charging equipment with two ac supplies, use a separate transformer for each. (See Fig. 8.)

(b) If the transfer switches have been left in the old switchboard, the engine bus can be tied to the engine bus in the new switchboard. (See Fig. 9.)

(c) If a separate transformer is provided for building power, that transformer can be tied to the telephone supply transformer. (See Fig. 10.)

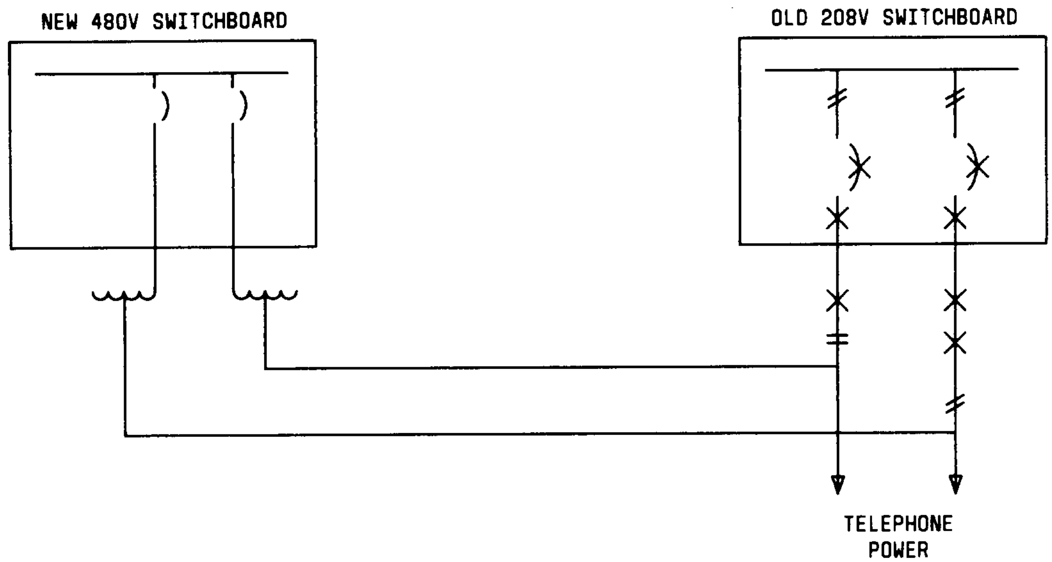

Fig. 8—Two AC Supplies With Separate Transformers

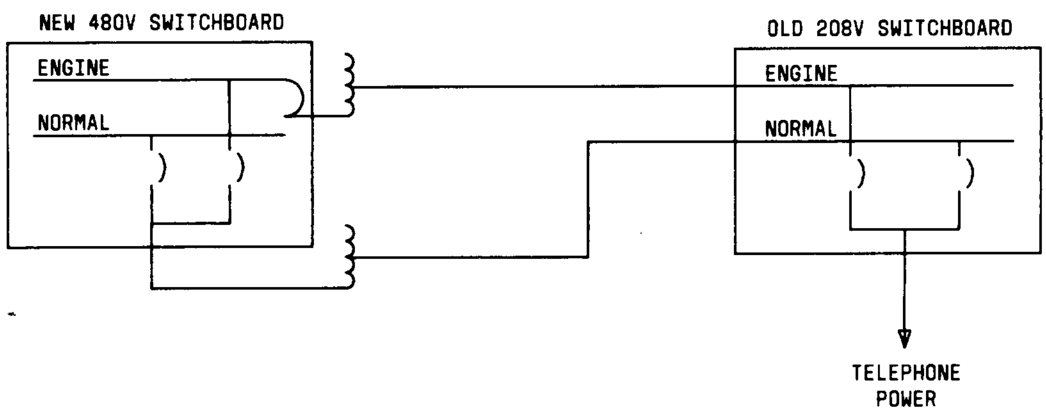

Fig. 9—Transfer Switches in Old Switchboard Tied to New Switchboard

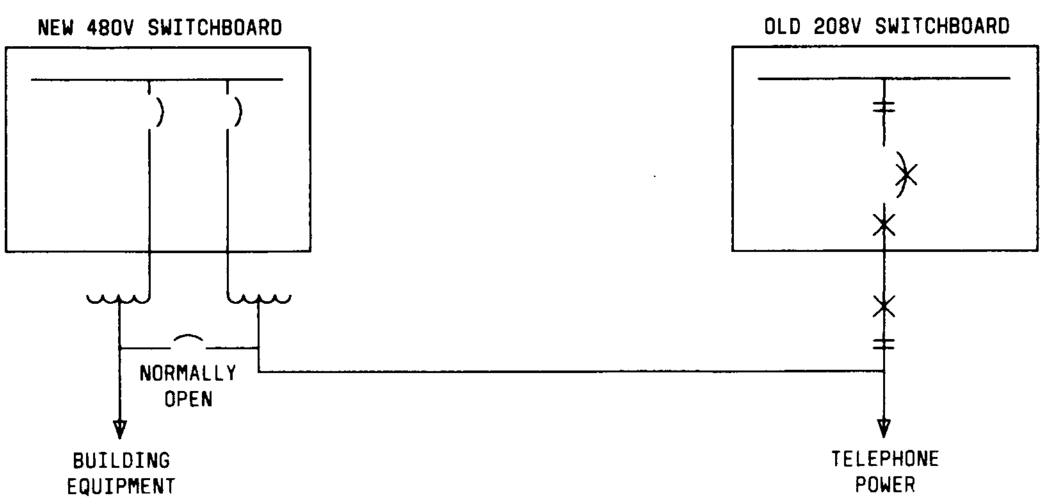

Fig. 10—Building Power Transformer Tied to Telephone Supply Transformer

6.03 There are many variations for setting up a temporary power supply; the essential point is that at least a portion of the charging equipment must be energized promptly and kept supplied while the failed transformer is replaced.

6.04 In sizing a temporary circuit, it might be possible to allow for some battery discharge (ie, not connecting all charging units to the temporary circuit). Central office power engineers can assist in sizing temporary circuits.

7. SPECIAL LOADS

7.01 The (kVA) rating of a transformer supplying an uninterruptible power supply (UPS) may be lower than its rating in other service. This is due to the nonsinusoidal waveshape of the input current to the UPS.

7.02 When specifying transformers for a UPS supply, the transformer manufacturer should be requested to recommend the kVA capacity and to guarantee that the capacity will meet requirements for the proposed UPS. Information on the design and operating characteristics of the proposed UPS system must be furnished to the transformer manufacturer.

8. REFERENCES

8.01 This section was based on information from the following references:

IEEE Recommended Practice for Electric Power Distribution for Industrial Plants, IEEE STD 141-1976 "Red Book"

IEEE Recommended Practice for Electric Power Systems in Commercial Buildings, IEEE STD 241-1983 "Gray Book"

National Fire Protection Association (NFPA) 70 National Electrical Code (NEC)

National Electrical Manufacturers Association (NEMA) Dry Type Transformers for General Applications, ST-20 (ANSI C89.2)

Section 760-400-110*—Building Electrical Systems—Voltage

Section 760-400-520*—Lightning and Surge Protection

Section 760-550-151—Ventilation of Transformer Vaults, Heating Plants, Power Rooms, Internal Combustion Engine Rooms, and Gas Meter Compartments

Section 760-630-200—Firesafety—Fire Resistance Ratings of Structural Elements

Section 760-630-400—Firesafety — Compartmentation

Section 876-100-100—Principles of Electrical Protection—Engineering Considerations

*Check 760 Divisional Index for availability.

The annual cost of transformer losses can be estimated by using the following formula:

$$\text{Annual Energy Cost} = R\ [8760 \times L_c + L_w(H_F + H_P \times P^2)]$$

Where:

R = Electric rate ($/KWH)

L_c = Core loss (KW)

L_w = Full load winding loss (KW)

H_F = Annual hours at full load

H_P = Annual hours at partial load

$P = \dfrac{\text{Partial load (KVA)}}{\text{Transformer rating (KVA)}}$

Assuming $0.05 per KWH for power with operation half the time at full load and half the time at half load, the losses for a typical 300-KVA transformer would be as follows:

150°C INSULATION:

$$\$0.05 \left[8760 \times 1.0 + 5.585 \left(\frac{8760}{2} + \frac{8760}{2} \times \frac{1}{4}\right)\right] = \$1966$$

80°C INSULATION:

$$\$0.05 \left[8760 \times 1.4 + 4.382 \left(\frac{8760}{2} + \frac{8760}{2} \times \frac{1}{4}\right)\right] = \$1813$$

AUTO:

$$\$0.05 \left[8760 \times 0.96 + 4.12 \left(\frac{8760}{2} + \frac{8760}{2} \times \frac{1}{4}\right)\right] = \$1548$$

Exhibit 1 — Formula for Estimating Annual Energy Cost of Transformer Losses