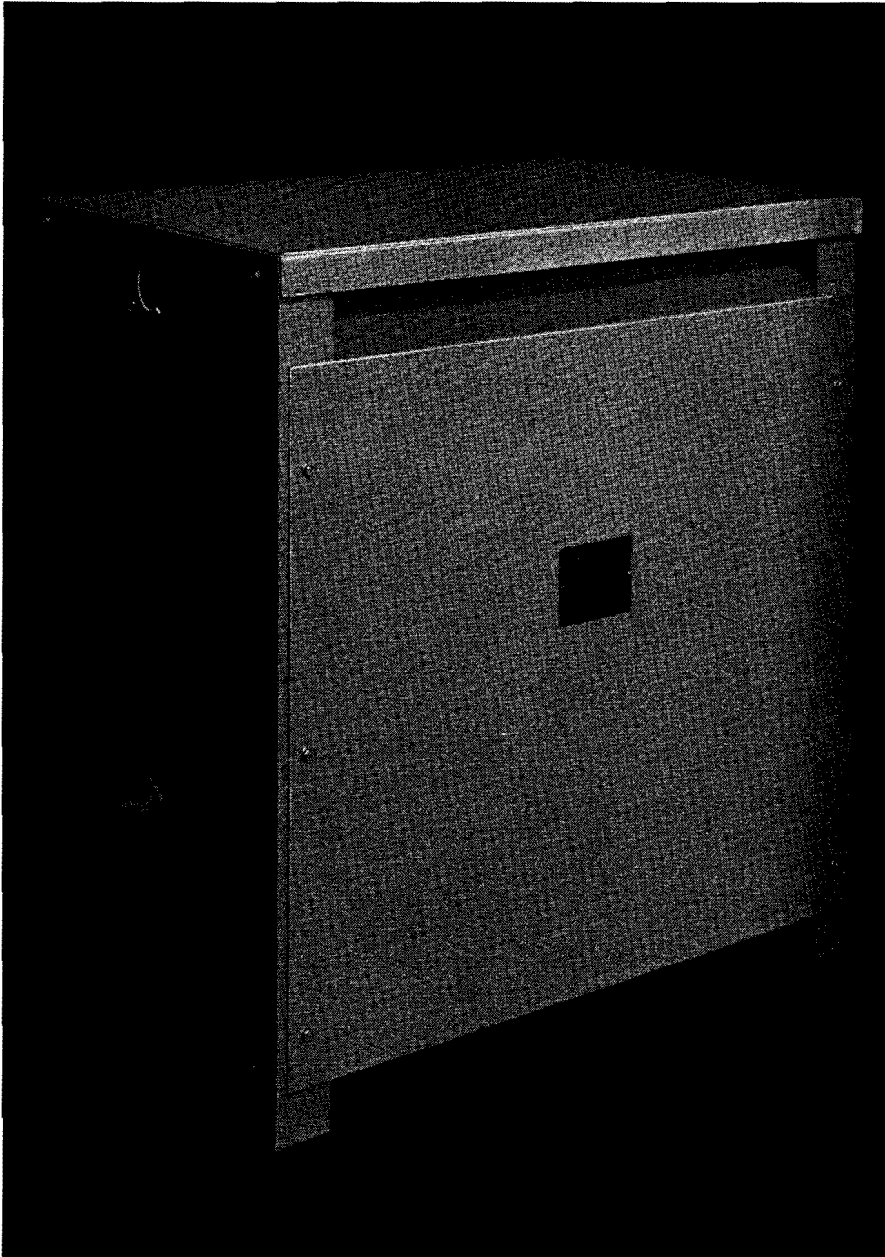


Westinghouse



Dry Type Transformers

Distribution Type 5000 Volts and Below
 Single Phase: 37½ to 250 Kva, Type DS-3
 25-100 Kva, Type DS-3E
 Three Phase: 45 to 1000 Kva, Type DT-3
 30 to 150 Kva, Type DT-3E

Proved Progress

Westinghouse research that dates back to the founding of the electrical industry has worked continuously for better, safer, transformers.

Because this research has been cooperative, working hand in hand with industrial customers and utilities, each step forward has been based on sound engineering, not only applied and tested in the lab, but field-tested under actual service conditions. This is your assurance that the development is practical and that the progress is proved.

As progress developed transformers with greater capacities, so grew the hazards that are inherent with these advances.

It was an early step that developed coils submerged in oil, to make higher ratings possible. Though oil, admittedly, was a fire hazard, it was negligible for most applications. Where ordinary oil was unsuitable, non-inflammable liquids were substituted. Still, this did not provide all the features desired and, in response to the demand for the maximum in safety, Westinghouse research achieved the . . .

Westinghouse Dry Type Transformer . . . Safest Transformer Ever Built

Successful uninterrupted operation of modern commercial, institutional and industrial buildings is dependent on adequate dependable electrical service. To minimize line voltage drop, higher distribution system voltages are being used. Here dry type transformers come into their own as a major part of the system, stepping down system voltages to utilization level at or near the center of the load.

Modern manufacturing methods and newer materials have brought about many changes in dry type transformer construction. New insulating methods have enabled us to build smaller, lighter and quieter transformer without changing the electrical characteristics of the transformer. The information contained in the following pages includes a detailed explanation of the various features necessary to assure accurate, dependable dry type transformer installations.

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Specification Guide

The following specification information should be used as a guide when discussing or negotiating dry type transformers.

Manufacturers Standards

Transformers must be built in accordance with the latest revisions of USA-C89 and NEMA ST1-4 for ratings 600 volts and below and NEMA TR27-1965 for ratings 601 to 5000 volts. Kva, voltage and tap arrangements should be in conformance with standards to facilitate future paralleling, banking or replacement.

Insulation Class

Transformers should be insulated with Class H materials with temperature rise not exceeding 150°C under full load in a maximum ambient of 40°C.

Construction

1. Transformer must be constructed with core materials of a high quality, low loss nature, to minimize no load losses and exciting current.
2. Coils must be wound with conductors of such a nature as to prevent burrs and slivers, and arranged in the winding so as to provide low reactance and minimize regulation drop.
3. The core-coil assembly must be mechanically braced to withstand short circuit stresses of 25 times normal load current for a period of two seconds.
4. Final insulation treatment should be total immersion in an insulating varnish dip of the class equal to the temperature rise, and should be cured at temperatures exceeding rated full load temperature for such a period of time as to assure complete curing and scouring of all volatiles in the varnish solvent.
5. Core and coils should be provided with an integral sound absorbing system to prevent necessity of special installation instructions for the installer.
6. Terminals must be located in an area of the enclosure where the temperature does not exceed 60°C over-all to avoid restrictions on cable insulation and avoid the need for special instructions to the installer. Terminals should be of such a size as to accommodate cable sizes compatible with N.E.C. current carrying capacities.
7. Enclosures should be of a minimum 16 gauge steel and should provide drip-proof and rodent-proof characteristics. Enclosures should be provided with facilities for lifting without removal of

any of the enclosure components. Conduit knock-outs should be provided, directly in line with terminals, and be of sufficient size and number to accommodate N.E.C. rated cable and conduit sizes.

Performance Data

Performance data should be provided prior to acceptance and submittal of prices. Performance data must contain information stating whether figures shown are average, typical, or guaranteed and must be corrected to the corresponding NEMA reference temperatures.

Performance data should indicate a minimum of 10% overload capacity at rated nameplate voltage on a continuous basis.

Certified test reports of similar standard ratings should be submitted with approval drawings certifying the following tests have been performed on the first rating of any new design:

Ratio, resistance, copper loss, iron loss, sound level, applied voltage, induced voltage, temperature rise, impulse test and short circuit test.

Where transformers are of a standard rating, certified test reports on the following tests should be submitted with final drawings: ratio, iron loss, sound level, applied voltage and induced voltage.

Sound Levels

Sound levels must fall within USA-NEMA Standard levels according to kva size. Evidence must be submitted as to whether sound levels are average, typical or guaranteed and must indicate the method of test and the ambient sound level of the test area. Minimum test area sound level must not exceed 24 DB₄₀.

General

Approval date to be submitted should include a listing of successful installations in service for over one year, preferably those convenient for inspection. In the event the transformers to be submitted are of a new design or, incorporate non-standard ratings or features, design data must be submitted to substantiate conformance to the specification above, 10 days prior to bid submittal.

Application

Dry type transformers are used in any application where transformers are located close to their load. Since there are no inflammable liquids or vapors, and no toxic fumes, they are ideal for installation indoors where concentrations of people are present. They are used in:

Hospitals
Theatres
Hotels
Churches
Mines

Office Buildings
Schools
Shipboard
Manufacturing areas
Many other applications

Westinghouse dry-type transformers are built in accordance with the latest revisions of USA, NEMA, and AIEE standards for transformers. Insulating materials used are those listed in USA standards. Units up through 10 kva are Underwriters' Laboratories approved, this being the entire scope of coverage by UL at the time of this writing. Reference to the use of dry-type transformers larger than this may be had by referring to National Electrical Code, paragraph 4521.

A sample specification is included here to list the important factors to be considered by specifying engineers in choosing dry-type transformer equipment.

Dry Type Transformers

Distribution Type, 5000 Volts and Below
 Single Phase: 37½ to 250 Kva, Type DS-3
 25-100 Kva, Type DS-3E
 Three Phase: 45 to 1000 Kva, Type DT-3
 30 to 150 Kva, Type DT-3E

Sample Specification

**WESTINGHOUSE ELECTRIC CORPORATION, SHARON, PA.
 DRY TYPE TRANSFORMER SPECIFICATION
 31 TO 1000 KVA. 5 KV AND BELOW**

- All transformers shall have the following rating:
 (a) Single phase, hv (), with (no taps) or (NEMA standard taps), to lv (), 60 Hertz.
 (b) Three phase, hv (), with (no taps) or (NEMA standard taps), to lv (), 60 Hertz.
- Transformers are to have Class H insulation with temperature rise not exceeding 150°C, under full load in a maximum ambient of 40°C.
- Transformers to be built in accordance with the latest revised standard of AIEE, USA and NEMA Standards.
 All units 600 volts and below shall have a BIL of 10 kv.
 All units 5-kv class shall have a BIL of 25 kv on the primary and 10 kv on the secondary.
 The following tests must be given at the factory:
 (a) Applied voltage test (to other winding and ground)
 600-Volt Class 5-Kv Class
 Hv - 4 kv 12 kv
 Lv - 4 kv 4 kv
 (b) Induced voltage test - 2 times normal voltage
 (c) Ratio and polarity.
- Transformers should have a minimum of 10% continuous overload capacity at rated voltage. Certified temperature test of electrical duplicate units should be supplied upon request.
- Preference will be given to those designs incorporating built-in vibration dampening systems such as utilized in Westinghouse types DS-3, DS-3E, DT-3 and DT-3E.
- Terminal compartment should be located in the bottom of the transformer to insure termination of cable leads in ambient temperature levels and to provide for side or bottom entrance of conduit.
- Transformers shall have the quality to meet the specification outlined above.
- Transformers shall be Westinghouse. Substitute designs must be approved in writing by the architect or engineer. Any substitute designs must have engineering data, dimensions and descriptive literature submitted, for approval, 10 days before bid date.

Sample Typical Performance Specification

**DRY TYPE DISTRIBUTION TRANSFORMER
 PERFORMANCE SPECIFICATION**

FOR Smith Manufacturing Company - Boston, Massachusetts

REG. NO. NBSC-1234 SPECIFICATION NO. _____ DATE 4/1/68

RATING

PHASE	CYCLES	SELF COOLING	HIGH VOLTAGE	LOW VOLTAGE
3	60	Air	480	208Y/120

ADDITIONAL APPROXIMATE VOLTAGES

HIGH VOLTAGE	504 - 492 - 468 - 456 - 444 - 432 (F.C.)
LOW VOLTAGE	

CONNECTIONS FOR OPERATION

TRANSF. IN BANK	TO TRANSFORM FROM	PHASE	CON- NECTED	TO	PHASE	CON- NECTED
1	480	3	Delta	208Y/120v	3	Wye

DIELECTRIC TESTS

BASIC IMPULSE LEVELS: HV 10 kV LV 10 kV

APPLIED VOLTAGE TEST (TO OTHER WINDINGS AND GROUND)	INDUCED VOLTAGE TEST
HV WINDING LV WINDING	2 TIMES NORMAL VOLTAGE
4 kV 4 kV	

TEMPERATURE RISE BY RESISTANCE NOT TO EXCEED 150°C AT FULL LOAD CONTINUOUSLY

PERFORMANCE DATA at 170 degree C NEMA reference temperature

KVA	LOSSES IN WATTS		Z _{IMP.}	PER CENT REGULATION		EFFICIENCY			
	NO-LOAD	TOTAL		100% P.F.	80% P.F.	1/2 LOAD	1/2 LOAD	1/2 LOAD	FULL LOAD
45	300	1400	3.4	2.5	3.4	97.0	97.6	97.4	97.0

APPROXIMATE DIMENSIONS AND WEIGHTS (NOT FOR CONSTRUCTION PURPOSES)

KVA	STYLE NUMBER	DIMENSIONS IN INCHES				NET WT IN LBS.	KNOCKOUTS	
		OUTLINE FORM	A	B	C		D	H.V.	L.V.
45	V48M28T45C	587B119	27-3/8	26-3/8	15-3/4	500	2½	2½

SPECIFICATION NO. _____ PAGE 1 _____ PAGES CONTRACT PAGE _____ PREPARED BY A.L. Meyer 4/1/68
 WESTINGHOUSE FORM 2189
 NOT COMPLETE WITHOUT FORM 2184

Westinghouse



Nomenclature

The ratings listed below are those commonly used in network application:

Single Rated Winding 480 Volts

Suitable for connection on either 480 volts, single phase or 480 volts delta connected, three phase.

Series-Multiple 240 x 480

Suitable for connection either in parallel for 240 volts or in series for 480 volts.

Series-Multiple, Three Wire 240/480

Suitable for connection either in parallel for 240 volts or in series for 480 volts or in series with the mid-point brought out for three wire grounded neutral operation.

Three Wire Single Phase 240/120

A winding having a mid-tap and designed for one-half rated kva at the voltage from line to mid-tap.

Single Phase Grounded Wye (5-Kv Class) 2400/4160Y

Full winding voltage line to neutral indicated first with line-to-line wye connection rating second. Indicates winding is also insulated for wye rating.

Three Phase Wye Connected 208Y/120

Terminals brought out for three phase, four wire wye operation only

Three Phase Wye or Delta 120/208Y

Terminals arranged for either three phase, four wire wye or three phase, three wire delta.

Taps

RCBN – Reduced capacity below normal.

FCBN – Full nameplate capacity at all tap ratings below normal.

FCAN & BN – Full nameplate capacity above and below normal.

Standard system distribution voltages are:

4800
4160Y
2400
600
480
240
208Y
120

Test Data

Westinghouse transformers are tested in accordance with USA test code 12-90 from USA standards for transformers, regulators and current limiting reactors C57-12.

Routine commercial tests performed on production line models are as follows:

Ratio
Polarity
No load (core loss)
Applied and induced over-potential tests

Ratio and polarity tests are given to insure that proper voltage ratio is maintained and that the winding polarity is either additive or subtractive as required by the design and shown on the transformer nameplate.

No-load losses are checked to assure proper core assembly.

Applied voltage tests are made to check major insulation between windings and between windings and ground.

Induced over-potential tests are performed to check again turn-to-turn and layer-to-layer insulation.

Dry type distribution transformers are not required to withstand impulse tests according to NEMA standards. However, each Westinghouse dry type transformer rating has an established basic impulse level, for lightning arrester coordination.

Test Reports

Certified test data on duplicate units of a production line model is obtainable from the factory at no additional charge.

Special tests not called for in routine commercial procedure must be negotiated with the factory.

Sound Levels Why Are Transformer Sound Levels Important?

There has been a recent tendency on the part of architects and engineers to specify lower audible sound levels for dry type transformers. This is due to the fact that with increased power demands, transformers must be located nearer to their loads for more efficient power distribution. This inevitably results in bringing transformers into close proximity of occupants, where high noise level can be a problem.

What Is Transformer Noise?

The main source of sound in a transformer is magnetostriction. This is the property of electrical sheet steel which causes it to elongate and contract in the presence of a magnetic field. These periodic mechanical movements produce sound vibrations in the

core, having a fundamental frequency equal to twice the flux frequency. Due to a non-linear relationship between magnetostriction and flux density, a number of harmonically related higher frequencies are also produced. This results in a noise spectrum, composed of fundamental frequencies of 120 cycles per second and harmonics of 240, 360, 480, 600, etc.

The pulsations of the core also travel through other parts of the transformer, which have a tendency to vibrate at one or other of these same frequencies. These add to the overall sound level in the form of interlaminar core and coil vibrations, enclosure, and sub-assembly vibrations. The amount of this addition is dependent upon the surface area and resonant frequency of each component part.

How to Control Transformer Sound and Minimize Its Transmission

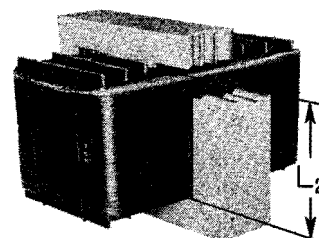
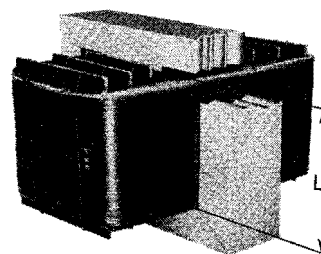
As outlined above, there are four main sources of sound in a transformer:

1. Core vibrations.
2. Interlaminar core and gap vibrations and coil vibrations.
3. Subassembly vibrations.
4. Enclosure vibrations.

In the following paragraphs we will show why these sources exist and how Westinghouse designs control and minimize their effect.

Core:

Ventilated designs with low temperature insulation require large air ducts in the coil



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Sound Levels Continued

to assure proper cooling, so that the temperature rise does not exceed the limitations of the insulation class, i.e., 80°C rise with class B materials (L₁). The larger the air ducts, the larger the coil and thus a longer core loop to accommodate the winding. Since the length of the core loop is determined primarily by the coil size, it follows that a smaller coil results in a smaller core and consequently, a completely smaller transformer. The longer the core loop, the greater the elongation and contraction factor and therefore, an increase in sound producing vibrations. Actually, a doubling of the core length results in a sound level increase of approximately 6 db. In the Westinghouse designs, high temperature silicone insulation, with a higher allowable temperature rise (150°C rise above ambient), reduces the required cooling duct area (L₂). This naturally results in a smaller coil and as outlined in the preceding paragraph, a shorter core loop and overall lighter, smaller transformer with minimum sound generating mass.

Interlaminar Core and Gap Vibrations and Coil Vibrations:

These contributing sources of sound level are due to the inherent structure and method of constructing the transformer core and coil assembly. Gap vibrations are kept to a minimum by interleaving the individual laminations. Interlaminar and coil vibrations are controlled by varnish dipping of the complete core and coil assembly and curing at a high temperature before assembly with the remaining components. This assures a compact assembly with minimum sound amplification.

Subassembly Vibrations:

The sound producing effect of subassembly components is a function of the surface area and the mode and amplitude of vibration. The most logical way to control this source of sound is to isolate these components from the inherent core vibrations.

Enclosure:

Even the most elaborate practical isolating system cannot contain all inherent vibrations. Large surface areas produce noise and add to the overall sound level. The smaller Westinghouse designs keep this surface area to a minimum. This, together with rigid case material, results in minimum sound generation from the transformer enclosure.

How To Measure Audible Sound

Sound level tests should be made in a laboratory with anechoic characteristics. The ambient sound level of this room should not exceed 24 db, to provide a true basis for measurement, unaffected by unrelated sources.

NEMA standards state that measurements shall be taken opposite each major sound producing surface at a distance one foot from the surface. Surface, in this case, means the surface of the enclosure of the completed unit.

In order to assure best performance, sound level measurements on Westinghouse dry-type transformers are taken with microphones, one foot from the transformer coil surface with the transformer cover panels removed. Replacing the cover panels on the transformer places a sound barrier between the noise source and the measuring instru-

ment. Tests performed in this manner assure operation at better than guaranteed values.

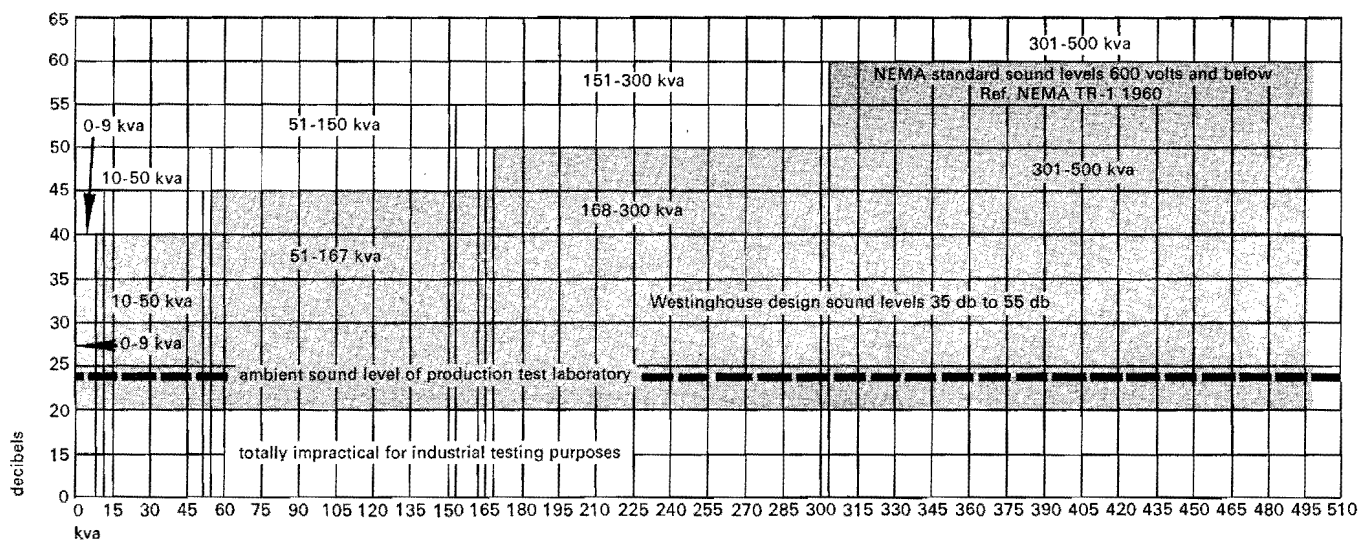
How to Minimize Sound Amplification in Installation

Sound amplification can be greatly reduced by using the following suggestions in installation:

- The transformers should be installed in an area where the sound would be the least objectionable.
- Nearby reflecting objects or enclosures which will resonate, or echo, should be avoided. It is well to avoid mounting the units in areas which tend to amplify voice noises, such as stairways, and hall areas.
- Tile, brick, concrete, masonry, or steel walls, as well as floors and ceilings, are excellent sounding boards, and should be avoided whenever possible. Acoustic absorbing materials may be used too, when they cannot be avoided.
- Avoid mounting the transformer on walls, partitions, balconies, floors and so forth, having a light mass. If the weight of the mounting surface, corresponding to the projected area of the transformer were greater than or equal to the weight of the transformer, the possibility of amplifying the sound waves in the structure would be greatly reduced.

Summary

The use of transformers designed, manufactured, and tested in accordance with the above practices, will assure the fact that the most quiet transformer available will be

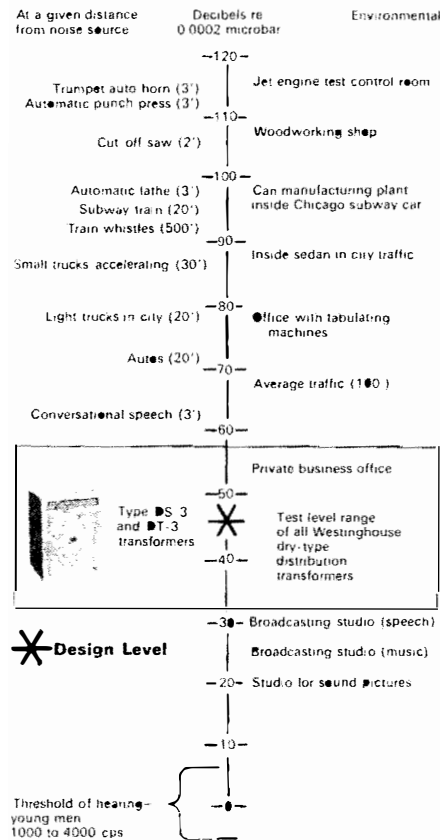


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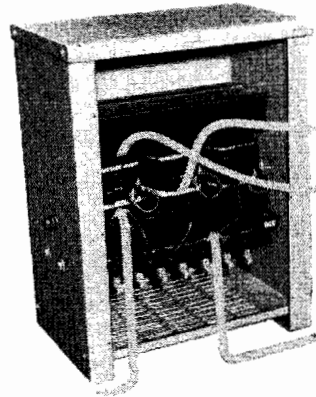
supplied. Such a transformer, together with good installation practices, will guarantee customer satisfaction and the ultimate in sound control.

Typical Over-all Sound Levels



Performance

Temperature



terminal
compartment
cooling
coil
cooling

The Westinghouse dry type transformer, using Class H insulation, can withstand 150°C rise above ambient temperature. The ventilated transformer, however, is so designed as to keep case temperatures at a minimum. Test data on comparable kva sizes shows that the highest case temperature of the 150°C rise designs varies only 4°C from the highest case temperature of the 80°C design. The average case temperature rise from these tests is below 32°C. On an average basis these are approximately the same as in 80°C rise transformer. These values are based on the assumption that the transformers are continuously loaded at full nameplate capacity. Terminal compartments are located in the bottom of the transformer case, where cool ambient air is entering the enclosure. Average air temperatures in the terminal compartment are approximately 5°C rise above ambient air temperature. This eliminates the necessity of high temperature cable insulation required here, where terminal compartment temperatures are the sum of ambient plus the temperature rise of the transformer.

Class	Group	Associated Temperature Rise	Material
A	I	55°C	Organic
B	II	80°C	Organic and inorganic
H	III	150°C	Silicone

Maximum ambient temperature – 40°C
Average ambient temperature – 30°C

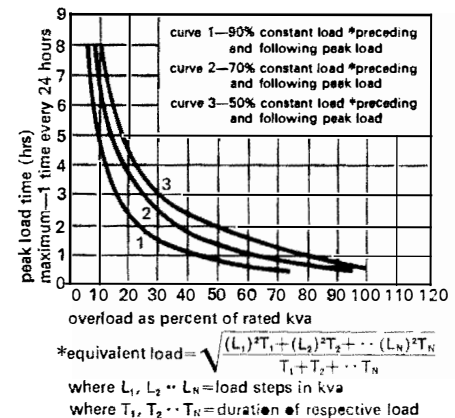
Altitude Limitations

Dry type transformers are suitable for use at altitudes above sea level with the following limitations:

600 volts and below Up to 10,000 ft. max.
600 to 5000 volts Up to 7000 ft. max.

Nameplate kva must be derated .5 percent for each 330 feet above 3300 feet, to allow for decreased cooling capability in thinner air.

Overload and Ambient Temperature Curve



Lighting Tap

On transformer secondary windings

A single phase lighting tap on one section of a transformer secondary has a limit of 5 percent of the three-phase bank capacity.

If this tap is positioned on a 240-volt winding, the three-phase bank capacity must be reduced 25 percent.

If this tap is positioned on a 480-volt winding, the three-phase bank capacity must be reduced 55 percent.

As such, these single-phase lighting taps are not considered practical and are more costly than a separate single-phase transformer to perform this function.

Frequency

Standard Westinghouse dry type transformer designs are for 60-cycle operation only. Where transformers for other frequencies are called for, refer to Westinghouse.

Dry Type Transformers

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Transformer Connections

Standard

Single Phase Connections

Single Phase Three-wire Secondary (Series Connection)

See figure 1: The most commonly used connection for small distribution transformers is that where a three-wire secondary is supplied at 120/240 volts. A similar connection may be used for 240/480 volt transformers. The primary may be supplied from a single-phase line, two wires of a three phase line or one line wire and a neutral of a three phase line.

The 120 volt loads should preferably be balanced in order that both halves of the low-voltage winding will be equally loaded. It would not be desirable with this connection to draw more than 50 percent of the transformer rated load from either half of the low-voltage winding, as by so doing that half of the winding would be overloaded.

Although most of the following diagrams show two-wire (per phase) secondary systems, many of these connections can be used to supply a single phase three-wire system by using the mid-point of the secondary winding. In many of the following diagrams it is also possible to supply combined two or three phase and single phase (2 or 3 wire) loads. In such cases it may be desirable to use unequal kva ratings for the different transformers in order that all transformers carry the same percentage of rated load.

Single Phase Parallel Operation of Two Single Phase Units

See figure 2: The parallel operation of transformers having the same high-voltage and low-voltage ratings is often utilized in those cases when it is necessary to increase the total bank capacity and a single unit of the correct capacity is not available.

Economically it is not efficient to operate two transformers in parallel where a single unit could be used, as by so doing the losses of two units in parallel will be greater than the losses of a single unit of the same equivalent capacity.

When the ratio of reactance to resistance is about the same for both transformers the maximum safe bank capacity may be obtained as the smaller of the two values obtained from the following two formulae:

Bank capacity (based on not overloading transformer no. 1)

$$= \frac{C_1 Z_2 + C_2 Z_1}{Z_2}$$

Bank capacity (based on not overloading transformer no. 2)

$$= \frac{C_1 Z_2 + C_2 Z_1}{Z_1} \text{ where } C_1 \text{ and } C_2 \text{ are}$$

nameplate kva ratings and Z_1 and Z_2 are nameplate percentage impedances for transformers no. 1 and no. 2 respectively.

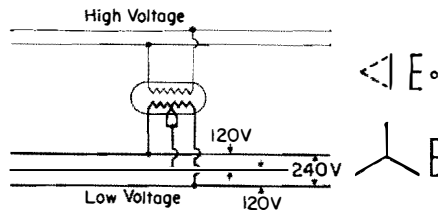


Fig. 1. Three-wire secondary (series connected)

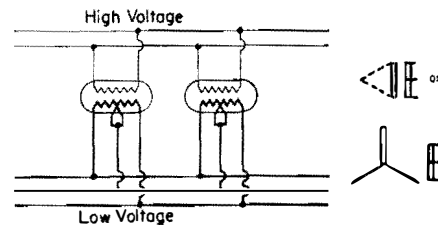
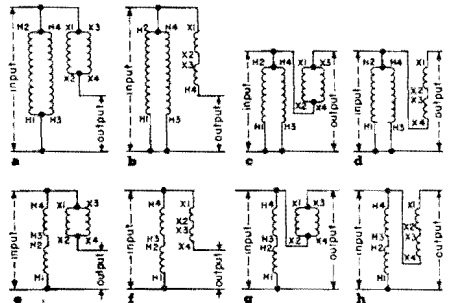


Fig. 2. Parallel operation of two single-phase units.

Transformer as Booster

See figure 3: The purpose of a booster transformer is to raise the voltage of the circuit from which the transformer is excited. The primary winding is connected in multiple and the secondary winding in series with the line. By reversing the secondary winding its action can be changed from boosting to bucking. In this connection the low-voltage winding is subjected to the overvoltages of the high voltage circuit. Transformers specially designed for booster operation are insulated to take care of these voltages. Caution should be used, therefore, in applying standard two-winding transformers as boosters. However, if this connection is used on such transformers with 1.2 kv class secondaries, it is recommended that one end of the secondary winding be grounded.

Consideration should also be given to the reduction in effective transformer impedance when connected as a booster. This may involve the addition of series impedance to limit short circuit currents to permissible values.



Nominal Circuit Voltage	Transformer Function	Percent Change of Circuit Voltage	Fig. No.	Kva Output ^① in Terms of Nameplate Rating
120	Boost	10	a	10 Times
	Boost	20	b	5 Times
	Buck	10	c	10 Times
	Buck	20	d	5 Times
240	Boost	5	e	20 Times
	Boost	10	f	10 Times
	Buck	5	g	20 Times
	Buck	10	h	10 Times

① If actual voltage differs from nominal, multiply kva output by ratio of actual voltage to nominal.

Fig. 3. Buck or boost autotransformer connections.

Westinghouse



Transformer Connections

Continued

Autotransformer

For General Light and Power Service How to Use Two-Winding Dry Type Transformers As Autotransformers to Change Voltage on Single-Phase Circuits

Single-phase transformers of standard service voltage ratings can be applied as autotransformers to provide step-up or step-down service.

In some territories local codes prohibit the use of autotransformers. For some applications it is necessary that the load circuit be completely isolated from the supply circuit, since supply circuit faults will affect load circuits when autotransformers are used for voltage transformation. Autotransformers are not usually recommended for step-down service because of the danger of destroying a device by having a voltage greater than its rated voltage accidentally impressed upon it.

Single Phase Transformers Applied As Autotransformers

Voltage Transformation	Ratio of Low Voltage to High Voltage	Fig. No.	Transformer Rating: Volts	
			Primary	Secondary
240 to 480	0.5	4	240 x 480	120/240
240 to 480	0.5	5	120 x 240	120/240
120 to 240	0.5	6	120 x 240	120/240
480 to 600	0.8	7	240 x 480	120/240

The table provides data on standard dry type, low voltage (600-volt class), single-phase, two-winding transformers used as autotransformers. For step-up service, the ratio of low voltage to high voltage in the first three cases is 0.5 and therefore, the amount of kva transformed is $(1 - 0.5 = 0.5)$ 50 percent of the total kva; in the last case, the ratio is 0.8 and the kva transformer is $(1 - 0.8 = 0.2)$ 20 percent. Output kva to the load is then 200 percent of the transformer nameplate rating in the first three cases and output is 500 percent for the fourth case.

For the accompanying diagrams, lead markings indicate relative directions in the windings. Thus, if H_1 is the start of one high-voltage winding, H_2 is the finish. H_3 is the start and H_4 is the finish of the other high-voltage winding. X_4 is then the start of the first low-voltage winding, and X_3 is the start of the other low-voltage winding.

The two high-voltage windings are connected in multiple by connecting H_1 to H_3 and H_2 to H_4 . The two low-voltage windings are connected in series by connecting X_2 to X_3 . The two windings thus formed are connected in series aiding by connecting

H_4 to X_1 and the autotransformer is complete. This same reasoning can be applied for dropping voltages as well as stepping up by just applying the high-voltage connections to the supply and the load to the low-voltage connections.

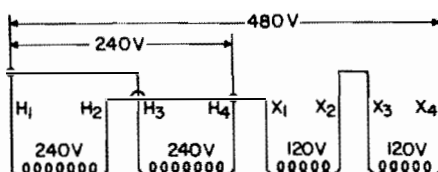


Fig. 4

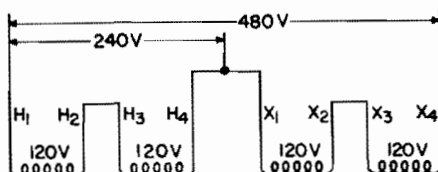


Fig. 5

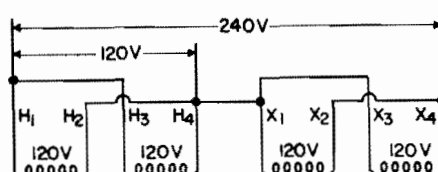


Fig. 6

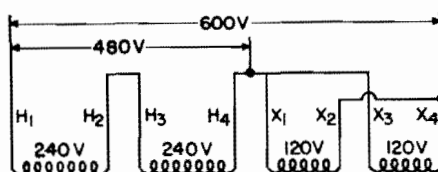


Fig. 7

How to Use Two-Winding Dry Type Transformers As Autotransformers to Change Voltage on Three-Phase Circuits

Single-phase transformers of standard service voltage ratings can be combined into banks of three-phase autotransformers in several ways. Perhaps the most satisfactory and economical connections are the "T" and open delta. Each requires two units to make up the three-phase bank. Other connections, *not recommended for use* are the wye, the closed delta, and the extended delta—each requiring three units.

When using standard transformers to make an autotransformer bank in wye, each of the units composing the legs of the wye is under-excited. Assume a desired three-phase ratio of 240 volts to 480 volts. Each standard transformer is then connected as a single-phase autotransformer for the ratio of 240 to 480 volts. When placed in the *wye connection*, however, each autotransformer has impressed on it $240/\sqrt{3}$ volts and its output is $480/\sqrt{3}$ volts. Thus, the *maximum economy is not available* since the output kva is only 115 percent of the combined nameplate ratings of the transformers.

Use of the *closed-delta connection* is *not recommended* when utilizing standard transformers since the saving realized is small due to phase shift.

Extended-delta connection presents odd voltage ratios and phase shift is present. It therefore is recommended only in certain special applications.

Figure 8 shows the connections for two autotransformers in an open-delta bank for three-phase conversion from 240 volts to 480 volts, using transformers rated 240 x 480 volts primary, 120/240 volts secondary. Lead markings indicate relative directions in the windings. The high-voltage windings are connected in multiple, and the low-voltage windings are connected in series. The two groups of windings are connected series aiding (boost) to form the autotransformers, and the H_1 points are connected together for the common line to form the three-phase bank. This connection provides a bank output kva equal to 173 percent of sum of nameplate ratings of the two transformers.

Figure 9 shows the connections for the same transformers in an open-delta autotransformer bank to provide three-phase conversion from 480 to 600 volts. This connection provides a bank output kva equal to 433 percent of the sum of the nameplate ratings of the two transformers.

Figure 10 shows the T-connection for two autotransformers to provide three-phase

Dry Type Transformers

Distribution Type, 5000 Volts and Below
 Single Phase: 37½ to 250 Kva, Type DS-3
 25-100 Kva, Type DS-3E
 Three Phase: 45 to 1000 Kva, Type DT-3
 30 to 150 Kva, Type DT-3E

conversion from 240 to 480 volts, using transformers rated 120 x 240 primary, 120/240 volts secondary. All windings of each transformer are connected series aiding (boost) and the teaser unit is connected at midpoint of the main unit. In this connection the nameplate rating of each transformer should represent at least 28.85 percent of the bank output kva desired; in other words, the bank output kva is equal to 173 percent of the sum of the nameplate ratings of the two transformers (same as Figure 8).

As with single phase circuits, three-phase arrangements may be used to drop voltages by placing the load on low voltage connections and the line on high voltage connections.

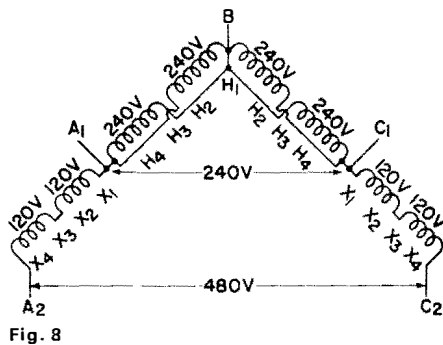


Fig. 8

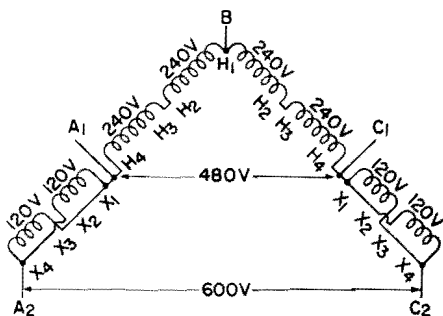


Fig. 9

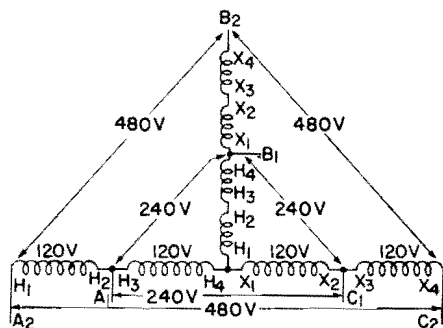


Fig. 10

60-Hz Transformers on 25 Hz

See figure 11: When using a 60-Hz transformer on a 25-Hz circuit, a transformer rated at approximately double the voltage of the circuit would be required to prevent magnetic saturation of the iron core. The same result can be accomplished by connecting two transformers of the same voltage in series.

Two-phase Connections Two Phase Four Wire

See figure 12: In this connection two phase, four wire is transformed to two phase, four wire of a different voltage with no connection between the two phases.

Two Phase Four Wire to Two Phase Three Wire

See figure 13: The two phases on the low-voltage side are electrically tied together. The common third wire is sometimes grounded. With balanced load the current in the common wire is $\sqrt{2}$ times that in the outside.

Two Phase Three Wire Interconnected

See figure 14: In this connection the two phases are electrically tied together by the common third wire. This is permissible in certain cases and not in others. This third or common wire is sometimes grounded. With balanced load, the current in the common wire is $\sqrt{2}$ times that in the outside wires.

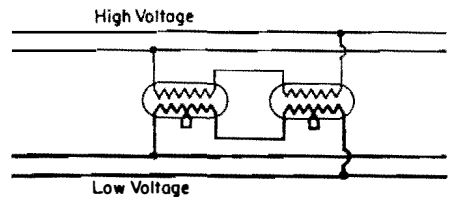


Fig. 11. 60-Hz transformers on 25 Hz.

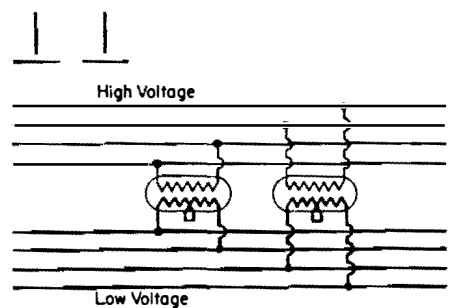


Fig. 12. Two-phase: four-wire.

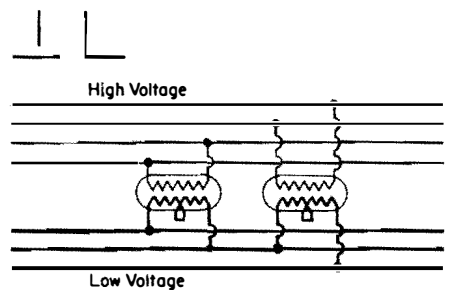


Fig. 13. Two-phase, four-wire to two-phase, three-wire.

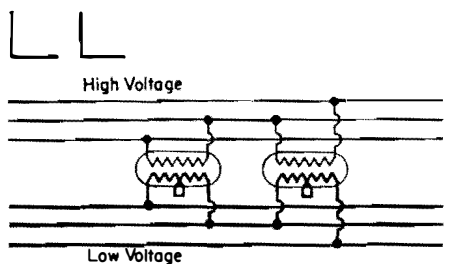


Fig. 14. Two-phase; three-wire interconnected.

Westinghouse



Transformer Connections

Continued

Three Phase Connections

Three Phase Closed Delta

See figure 15: When three transformers are operated in a closed delta bank, care should be taken to make certain that the impedances of the three units are practically the same. Transformers having more than 10 percent difference in impedance rating should not be operated together in a closed delta bank unless a reactor is used to increase the impedance of the unit having the lower impedance rating to a value equal to the other units.

If the voltage ratio of all three of the transformers is not the same a voltage will tend to circulate inside the delta. The current will be limited by the impedance of the three transformers considered as a series circuit.

It is always best before connecting up three transformers in closed delta to insert a fuse wire between the ends of the two transformers closing the delta bank. The fuse wire should be of sufficient size to carry the exciting current of the transformers. The use of this fuse wire offers a very simple means of making certain that the transformers have the proper polarity.

Three Phase Open Delta

See figure 16: Three to three phase may be transformed by the use of two similar transformers in open delta. In this connection the units will transform 86 percent of their rating, i.e., two 100 kva units in open delta transforming three phase, 2300 volts to three phase 230-115 volts will have a bank capacity of 172 kva.

In the open delta connection it is not necessary that the impedance characteristics be the same, although it is preferable when it becomes necessary to close the open delta bank with a third unit. Then all three units must have identical impedances.

The open delta connection is often used as a temporary expedient pending a contemplated increase of load and offers a very simple means of handling this matter. By adding a third 100 kva unit in the above mentioned example the resultant bank capacity will be increased from 172 kva to 300 kva.

The regulation of an open delta bank is not as good as a closed delta bank. The drop across the open delta is greater than across each of the separate transformers.

Three Phase, Star Three Wire - High Voltage; Delta Three Wire Low Voltage

See figure 17: When three transformers are operated with their high-voltage windings

in star the incoming line voltage is the $\sqrt{3}$ or 1.732 times the transformer winding voltage. This connection is very popular and presents a very convenient way of boosting the transmission voltage without purchasing additional transformers.

Three Phase, Star Four Wire - High Voltage; Delta Three Wire Low Voltage

See figure 18: This connection permits three phase power to be transmitted at the star voltage. At the same time single-phase power may be taken from the mains by connecting the transformer between the neutral and any of the three phase wires. In this connection it is not necessary that the impedance of the three transformers be the same. The high-voltage neutral is usually ungrounded.

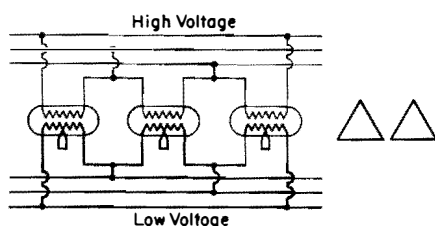


Fig. 15. Three-phase; closed delta.

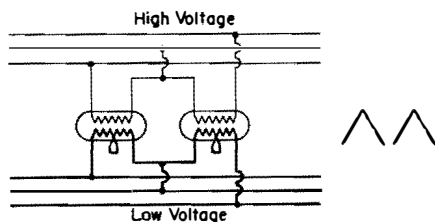


Fig. 16. Three-phase; open delta

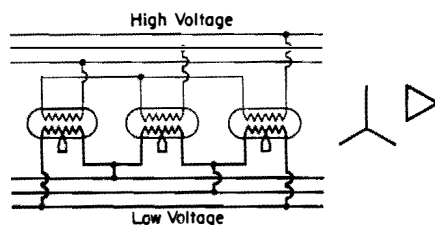


Fig. 17. Three-phase; star, three-wire (high voltage) - delta, three-wire (low voltage)

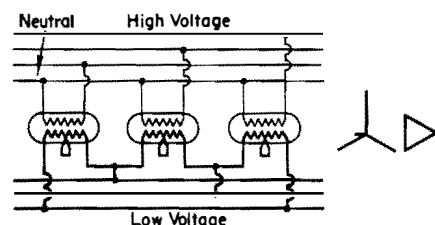


Fig. 18. Three-phase; star, four-wire (high voltage) - delta, three-wire (low voltage)

Miscellaneous

Three Phase; Star Four Wire One Leg Out - High Voltage; Open Delta Three Wire - Low Voltage

See figure 19: This is similar to a V connection. The primary of each transformer is connected between the neutral and one of the three-phase wires. The secondaries are connected to the secondary mains, the same as for the delta connection, except that the third transformer is not used. (The secondaries are in open delta.) The two transformers will provide 86.6 percent of their combined rated capacity.

Three Phase; Secondary Star Interconnected

See figure 20: The primary side of this group may be connected either in star or in delta. Each half of the secondary winding of each transformer has a voltage of 57.7 percent of the interconnected star voltage. A bank of transformers designed for connection in this manner must have a capacity $7\frac{1}{2}$ percent greater than the kva to be transformed. The purpose of the interconnected star winding is to permit the unbalanced dc current from the third wire of the three-wire circuit of a rotary converter to get back into the alternating-current system feeding the converter. Since this dc current divides into two equal parts in each transformer and also these parts flow in opposite directions magnetically in the two parts, the dc current does not magnetize the core. If this current would flow in one direction through the winding, the dc magnetic flux would add to the ac flux and perhaps saturate the core.

Three Phase; Three or Four Wire Star-Star With Autotransformers

See figure 21: In this connection the high and low-voltage windings are electrically connected together, and for this reason the low-voltage side and connected apparatus will under fault conditions be subjected to the voltage of the high voltage circuit. The material in the autotransformer is less than that in a two-winding transformer, transforming the same power. The saving in material is quite large when there is but a small difference in the primary and secondary voltages, and the saving becomes less and less as the difference between the primary and secondary voltages increases.

Three Phase; Three Wire Open Delta With Autotransformer

See figure 22: In this connection the high and low-voltage windings are electrically connected together, and for this reason the low-voltage side and connected apparatus will under fault conditions be subjected to the voltage of the high-voltage circuit. The

Dry Type Transformers

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 Single Phase: 37½ to 250 Kva, Type DS-3
 25-100 Kva, Type DS-3E
 Three Phase: 45 to 1000 Kva, Type DT-3
 30 to 150 Kva, Type DT-3E

material in the autotransformer is less than that in a two-winding transformer, transforming the same power. The saving in material is quite large when there is but a small difference in the primary and secondary voltages, and the saving becomes less and less as the difference between the primary and secondary voltages increases. This connection requires 17 percent larger transformer capacity than the star-star autotransformer connection.

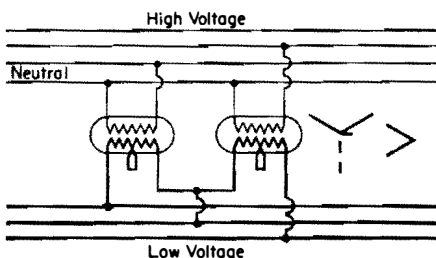


Fig. 19. Three phase; star, four wire, one leg out (h. v.) - open delta, three wire (l. v.).

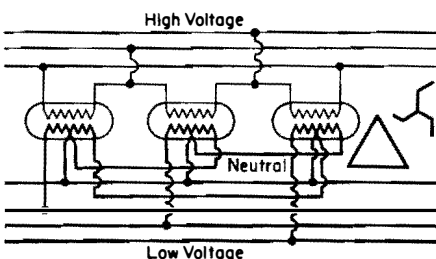


Fig. 20. Three phase; secondary star, interconnected.

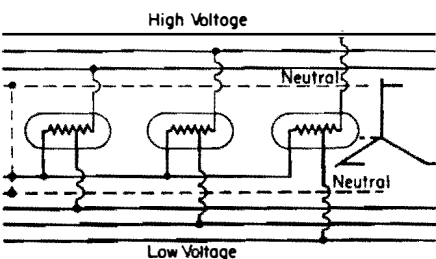


Fig. 21. Three phase; three or four wire; star-star with autotransformers.

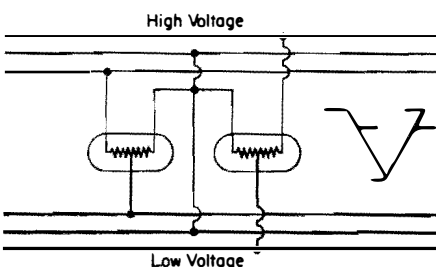


Fig. 22. Three phase; three wire open delta with autotransformers.

Autotransformers for Phase Transformation; Three Phase to Two Phase Four Wire Interconnected

See figure 23: When a phase transformation is desired without any considerable stepping up or down of voltage, the autotransformer is the most simple and cheapest arrangement. The connection shown has the windings on the two-phase side electrically connected together at their middle point.

Phase Transformation, Scott: Two Phase Three Wire to Three Phase Three Wire or Scott: Three Phase Three Wire to Two Phase Three Wire

See figure 24: This is a phase transformation from three phase to two phase or from two phase to three phase. Either the primary or secondary side may be made three phase. The three-phase side must have special taps to make this transformation. One unit must have an 86.6 percent tap, and the other unit a 50 percent tap. A three-wire circuit is used on the two-phase side. This is formed by merely joining together two of the wires forming the two phases. In this manner the two phases are electrically connected together.

Dry-type transformers are ordinarily designed so that the full rated capacity of the bank can be utilized without exceeding normal temperature rises.

If the transformers are to be used with motors interconnected at mid-points, the connection illustrated in figure 25 is recommended.

Phase Transformation, Scott: Three Phase Three Wire to Two Phase Four Wire or Scott: Two Phase Four Wire to Three Phase Three Wire

See figure 25: This connection is exactly the same as the previous one except the two-phase side is made four-wire. In this manner the two 2-phase circuits are electrically separated.

Scott Transformation; Standard 10 to 1 Ratio Used

See figure 26: If a Scott transformation is desired, and a transformer having an 86.6 percent tap is not available, a unit having a 10 percent tap or two 5-percent taps may be used to give approximate results. With this arrangement the two-phase voltages will be unbalanced by about 4 percent.

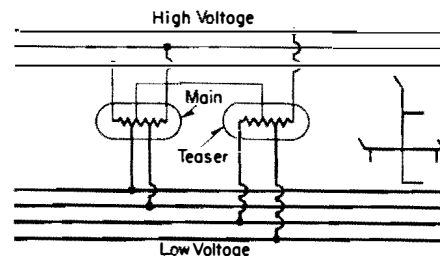


Fig. 23. Three phase to two phase, four wire interconnected, by autotransformers.

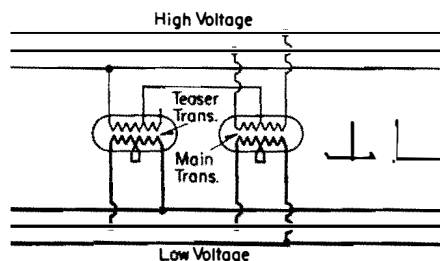


Fig. 24. Phase transformation; two phase, three wire to three phase, three wire or Scott; three phase to two phase.

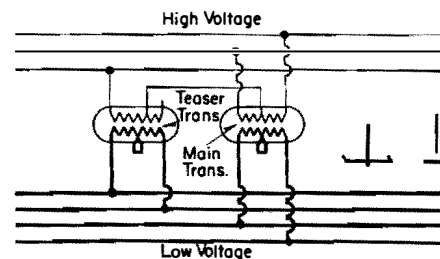


Fig. 25. Phase transformation, Scott.

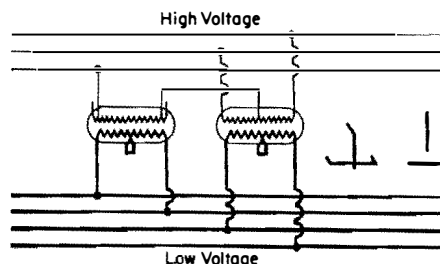


Fig. 26. Scott transformation; standard 10 to 1 ratio used.

Westinghouse



Transformer Connections

Continued

Miscellaneous Continued

Phase Transformation;

Fortesque Connection

See figure 27: This is a transformation from three phase to two phase by the use of three transformers, one of which is standard and the other two have special taps on the low-voltage side. One advantage of this connection is that both two and three phase current may be delivered at the same time. The sum of the power delivered at two phase and at three phase must be somewhat less than the normal rating of the transformers, in order not to overload the transformers.

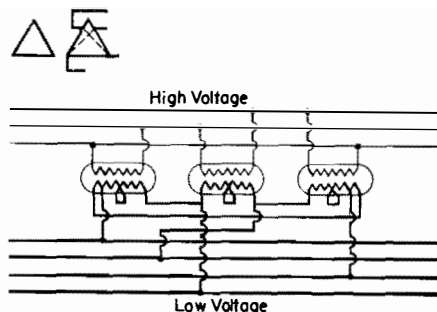


Fig. 27. Phase transformation, Fortesque connection.

Autotransformers For Phase Transformation; Three Phase to Two Phase, Four Wire

See figure 28: This connection is the same as the one shown previously except that the windings on the two-phase side are not connected together at their middle points, but the end of one phase is connected to the middle of the other phase.

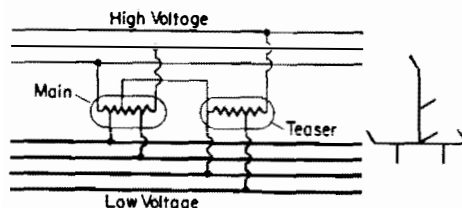


Fig. 28. Three phase to two phase, four wire, by autotransformers.

Autotransformers; Three Phase to Three Phase, Three Wire

See figure 29: Where the voltage change from primary to secondary is small, the use of an autotransformer for a voltage transformation is cheaper than the use of two-winding transformers. The primary and secondary windings are tied together electrically, which may be an objection in some cases.

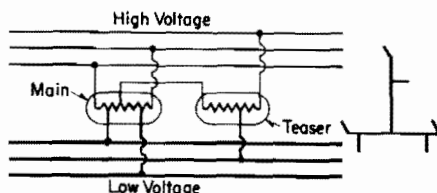


Fig. 29. Three phase to three phase, three wire, by autotransformers.

Phase Transformation; Three Phase to Two Phase Using An Autotransformer

See figure 30: This shows how two phase voltages may be taken from a delta bank by the simple application of an autotransformer. The auto is connected between the apex of the delta and the mid-point of the opposite side. This gives a 1 to 1 ratio which means that the two phase and three phase voltages on the low-voltage side are equal. The high-delta winding of the bank may be connected star or delta. The two phase and three phase loads may be taken off simultaneously. If no load is drawn off at three phase, approximately 75 percent of the bank rating may be taken off at two phase.

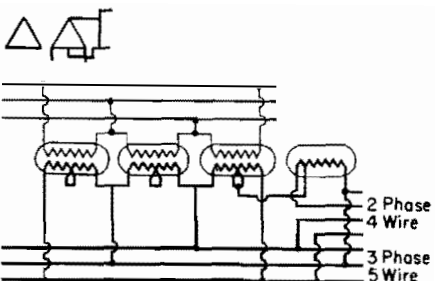


Fig. 30. Three phase to two phase from delta bank by autotransformer.

Phase Transformation Using Standard Transformers of Different Voltage Ratings

See figure 31: This is a phase transformation from three-phase to two phase employing standard transformers. Transformer no. 1 is rated 4160 volts to 240/120 volts. Transformer no. 2 is rated 2400 to 240/120 volts. Each transformer will have a rating equal to one-half the two-phase load.

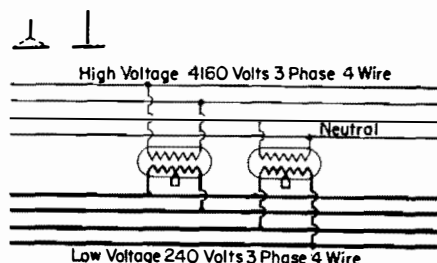


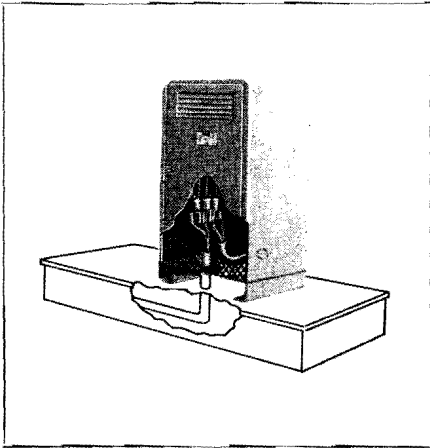
Fig. 31. Phase transformation using standard transformers of different voltage ratings.

Dry Type Transformers

Distribution Type, 5000 Volts and Below
Single Phase: 37½ to 250 Kva, Type DS-3
25-100 Kva, Type DS-3E
Three Phase: 45 to 1000 Kva, Type DT-3
30 to 150 Kva, Type DT-3E

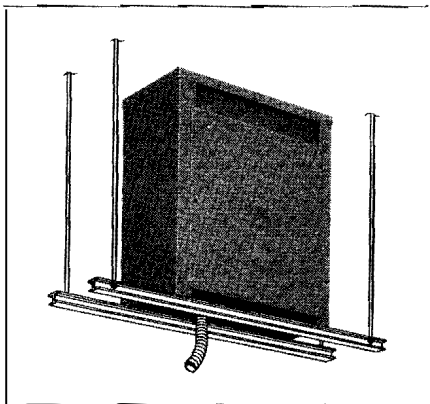
Mounting and Installation

The installations shown here demonstrate the versatility of Westinghouse dry type transformer designs.



Floor or Platform Mounting Types DS-3 and DT-3

Terminal compartments located in the bottom of the case make connection easy. Conduit may be stubbed up through the ventilating screen or connected through conventional knockouts.

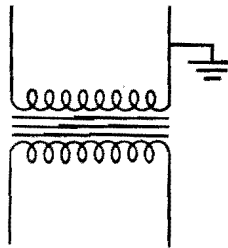


Ceiling Mounting or Trapeze Type Assembly Types DS-3 and DT-3

Small size and light weight make these transformers ideal for this type of mounting. Built-in sound absorbing features make external vibrating eliminators unnecessary.

For the same reasons these units are also ideal for wall mounting in ratings through 100 kva single phase and 112½ kva, three phase.

Special Application Isolating Transformers



Some electrical installations, especially hospital operating and x-ray rooms, require complete isolation of electrical apparatus. This is required for various reasons outlined in the National Electrical Code.

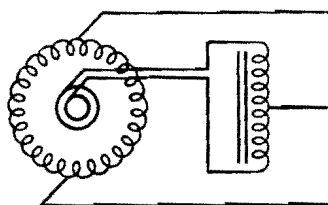
Some engineers specify that a metallic shield be placed between primary and secondary windings to prevent leakage of current, or an actual fault between the primary and secondary turns. National Electrical Code, Article 510, Section 5135 F-1 states, "Such isolation may be obtained by means of one or more transformers, having no electrical connection between primary and secondary windings."

There is some doubt that the introduction of a shield improves the isolation, but rather, is detrimental to complete isolation. There is more danger of a winding becoming faulted to the shield than a fault occurring between primary and secondary winding with no shield present.

For these applications, we recommend the use of a standard Westinghouse two-winding transformer. This recommendation is based on our standard testing procedure. All transformers are tested at 4000 volts, winding to winding to ground for all voltage ratings. NEMA standards for specialty transformers states that for voltages 250 volts or less, the potential test should be only 2500 volts. On this premise then, we believe our standard transformers meet the conditions set forth in the National Electrical Code.

Where ground detection is required, the equipment is supplied by the electrical contractor.

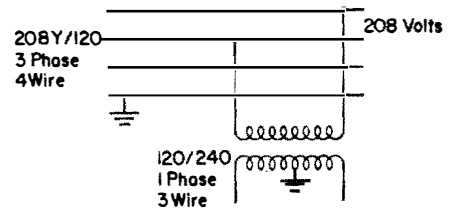
D-c Generator Balance Coils



Three-wire dc circuits pose a problem of unbalance to the dc generator source. A dry type transformer can be used to distribute this unbalance current evenly in the generator. For correct application, the following characteristics must be known:

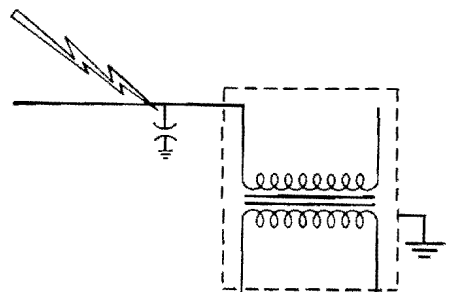
- Generator kw and voltage rating
- Speed - rpm
- Number of poles
- Unbalance (in percent of generator kw rating)
- Number of slip rings

Range Application



Electric ranges generally call for 120/240, single phase, grounded neutral supply. Often only 208Y/120 is the source of power. Normally 120 volts can be supplied from line to neutral of the 208Y/120 system. Often a customer requests a transformer rated 208 to 240 volts, single phase to supply the 240-volt requirement. Since this is a small voltage transformation, an autotransformer is suggested. In this case, however, an autotransformer cannot be used. Therefore, when a range application is specified, a two-winding transformer rated 208 to 120/240 should be used.

Lightning Arresters



In general, dry type transformers, 600 volts and below are not exposed to the effects of voltage surges. They are normally protected adequately by substation and/or power center protective devices. As such, lightning arresters need not be considered for this class of transformer.

Westinghouse



Special Applications

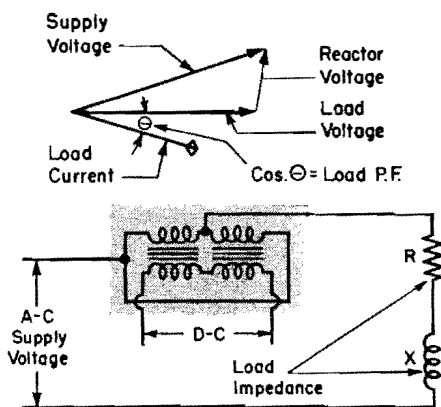
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For dry type transformers in the 5000-volt class, some consideration should be given to surge voltage protection. As in the 600-volt, these transformers are usually protected by substation devices. Caution should be exercised when transformers are separated from the protective devices by long cable spans, either exposed or sheltered. Naturally, exposed lines are subject to direct lightning strokes and RM valve type arresters should be applied at the transformer terminals even where valve type station arresters or expulsion arresters are used. Even on sheltered cable spans, care should be used to protect the transformer from excessive surge voltages which occur when terminating impedances do not match the surge impedance of the cable.

If the line between transformers is not cable, there will ordinarily be sufficient attenuation of surge voltage so that arresters will not be required.

In all cases where doubt occurs, Westinghouse engineers should be consulted. They have the necessary information for safe, practical and economical application, based on years of research and development on transformers and protective devices.

Saturable Core Reactors



Dry type transformer construction lends itself easily to construction of the saturable core reactor. Basically, a saturable core reactor is a device which, when placed in series with a load, varies the load voltage from a minimum of 10 percent to a maximum of approximately 95 percent. This is accomplished by saturating the core with d-c flux which in turn decreases the reactance of the device.

It may be likened to a two-winding transformer, where the low voltage is in series with load and acts as the ac reactance coil,

and the high voltage carries a dc current which saturates the core with dc flux.

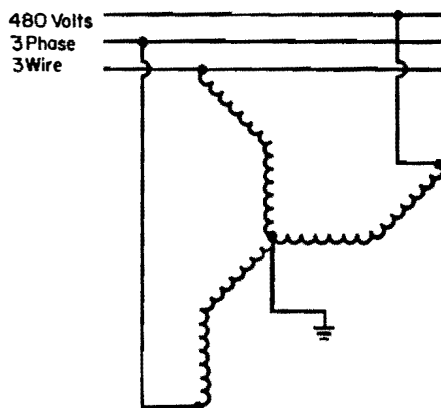
There are many applications for these reactors, such as:

- Motor control (ac and dc)
- Resistance furnace control
- Theater lighting control

Refer to Descriptive Bulletin 46-957 for further information.

Consult your nearest Westinghouse office for details.

Zig-Zag Grounding Transformers



Many existing 480 volt, 3-phase distribution systems are delta connected and ungrounded. These do not offer the fault protection or system stability provided by neutral grounding. A stabilized neutral must be established for operation of 277 volt fluorescent lighting loads on this type of system.

A zig-zag connected, 3-phase autotransformer can be used very successfully to establish a stable neutral for fault protection and provide a means of distributing 277 volt unbalanced loads equally on all three phases of the system. This also provides a path for third harmonic currents in fluorescent ballasts.

Zig-zag autotransformers should be applied according to the kva rating of the substation. The percent reactance of the substation should be known to provide a means of calculating the maximum available fault current to which the grounding transformer can be subjected. This fault current is calculated on the basis of a 10 second duration for steady state values.

In order to establish the continuous kva rating of a grounding transformer, the amount of 277 volt lighting current per phase must be known, or the maximum unbalance current including third harmonic

ballast currents. Zig-zag grounding transformer designs are available for 480-volt delta systems of 300, 500, 750, 1000 and 1500 kva based on substation reactance of 5 percent for 300 and 500 kva, and 5.5 percent for 750 through 1500 kva. Nameplate ratings on transformers indicate fault kva, and continuous rating is expressed as a percentage of this value. Continuous rating is defined as phase current x line-to-neutral voltage x 3, or neutral current x line-to-neutral voltage.

Example:

If the 10 second ground fault rating on nameplate reads 2000 kva, and the percent load continuous is 3, then the unbalanced load kva is 60. This means that the maximum allowable neutral current cannot exceed:

$$\frac{60000}{277} = 216.6 \text{ Amps.}$$

The neutral current does not affect the amount of balanced load. Actually, at 3 phase balanced load, no current flows in the transformers with the exception of third harmonics in the lamp ballasts and exciting current of the transformer. Refer to Price List 46-922.

Dry Type Transformers

Distribution Type, 5000 Volts and Below
 Single Phase: 37½ to 250 Kva, Type DS-3
 25-100 Kva, Type DS-3E
 Three Phase: 45 to 1000 Kva, Type DT-3
 30 to 150 Kva, Type DT-3E

Reference Tables**Table 1: Current-carrying capacities of insulated copper conductors in amperes^①**

Size AWG MCM	Temperature Rating of Conductor. See Table 310-2(a) ^②					
	60°C (140°F)	75°C (167°F)	85°-90°C (185°F)	110°C (230°F)	125°C (257°F)	200°C (392°F)
14	15	15	25	30	30	30
12	20	20	30	35	40	40
10	30	30	40	45	50	55
8	40	45	50	60	65	70
6	55	65	70	80	85	95
4	70	85	90	105	115	120
3	80	100	105	120	130	145
2	95	115	120	135	145	165
1	110	130	140	160	170	190
0	125	150	155	190	200	225
00	145	175	185	215	230	250
000	165	200	210	245	265	285
0000	195	230	235	275	310	340
250	215	255	270	315	335	....
300	240	285	300	345	380	....
350	260	310	325	390	420	....
400	280	335	360	420	450	....
500	320	380	405	470	500	....
600	355	420	455	525	545	....
700	385	460	490	560	600	....
750	400	475	500	580	620	....
800	410	490	515	600	640	....
900	435	520	555	...	....	....
1000	455	545	585	680	730	....
1250	495	590	645	....	....	....
1500	520	625	700	785	....	....
1750	545	650	735	....	....	....
2000	560	665	775	840	....	....

Correction factors, room temperatures over 30°C, 86°F

°C	°F						
40	104	.82	.88	.90	.94	.95	....
45	113	.71	.82	.85	.90	.92	....
50	122	.58	.75	.80	.87	.89	....
55	131	.41	.67	.74	.83	.86	....
60	140	....	.58	.67	.79	.83	.91
70	158	....	.35	.52	.71	.76	.87
75	167	....	....	.43	.66	.72	.86
80	176	....	....	.30	.61	.69	.84
90	194	....	....	....	.50	.61	.80
100	212	....	....	....	....	.51	.77
120	248	....	....	....	....	....	.69
140	284	....	....	....	....	....	.59

① These values based on not more than three conductors in raceway or cable and on room temperature of 30°C 86°F.

② National Electrical Code, 1965.

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**Table 2: Rated Line Amperes
For Kva and Voltages of Single Phase Transformers**

Kva	Rated Line Amperes						
	120V	240V	480V	600V	2400V	4160V	4800V
1	8.33	4.17	2.08	1.67	0.42	0.24	0.21
1½	12.50	6.25	3.13	2.50	0.63	0.36	0.31
2	16.67	8.33	4.17	3.33	0.83	0.48	0.42
3	25.00	12.50	6.25	5.00	1.25	0.72	0.63
5	41.67	20.83	10.42	8.33	2.08	1.20	1.04
7½	62.50	31.25	15.63	12.50	3.13	1.80	1.56
10	83.33	41.67	20.83	16.67	4.17	2.40	2.08
15	125.00	62.50	31.25	25.00	6.25	3.61	3.13
25	208.33	104.17	52.09	41.67	10.41	6.01	5.21
37½	312.50	156.25	78.13	62.50	15.62	9.01	7.81
50	416.67	208.33	104.17	83.33	20.83	12.02	10.42
75	625.00	312.50	156.25	125.00	31.25	18.03	15.63
100	833.33	416.67	208.33	166.67	41.67	24.04	20.83
167	1391.67	695.83	347.92	278.33	69.58	40.14	34.79
250	2083.33	1041.67	520.83	416.67	104.17	60.10	52.08
333	2775.00	1387.50	693.75	555.00	138.75	80.05	69.38
500	4166.67	2083.33	1041.67	833.33	208.33	120.19	104.17

For Calculation Purposes

$$\text{Single Phase Line Amps} = \frac{\text{Kva}}{\text{Line Voltage}}$$

For Kva and Voltages of Three Phase Transformers

Kva	Rated Line Amperes						
	208V	240V	480V	600V	2400V	4160V	4800V
3	8.33	7.22	3.61	2.89	0.72	0.42	0.36
9	25.00	21.60	10.80	8.70	2.17	1.25	1.08
15	41.63	36.08	18.04	14.43	3.61	2.08	1.80
30	83.30	72.17	36.10	28.90	7.23	4.17	3.61
45	125.00	108.40	54.20	43.30	10.85	6.26	5.41
75	208.17	180.42	90.21	72.17	18.04	10.41	9.02
112½	312.50	271.60	135.30	108.20	27.10	15.60	13.53
150	416.34	360.84	180.42	144.33	36.08	20.82	18.04
225	625.00	541.90	270.70	216.50	54.20	31.30	27.07
300	832.68	721.67	360.83	288.66	72.17	41.63	36.08
500	1387.81	1202.79	601.39	481.09	120.28	69.39	60.14
750	2081.89	1804.27	902.14	721.71	180.43	104.09	90.21
1000	2775.85	2405.70	1202.85	962.28	240.57	138.79	120.29

For Calculation Purposes

$$\text{Three Phase Line Amps} = \frac{\text{Kva}}{\text{Line Voltage} \times \sqrt{3}}$$

Dry Type Transformers

Distribution Type, 5000 Volts and Below
 Single Phase: 37½ to 250 Kva, Type DS-3
 25-100 Kva, Type DS-3E
 Three Phase: 45 to 1000 Kva, Type DT-3
 30 to 150 Kva, Type DT-3E

Table 3: Breaker style numbers and ratings for application in the field to standard transformers

Kva	120 Volts Single Phase or 208 Volts 3 Phase			240 Volts			480 Volts			600 Volts		
	Full- Load Amps.	2-Pole 1-Phase or 3-Pole 3-Phase Breaker	ABI Breaker Catalog Number	Full- Load Amps.	2-Pole 1-Phase or 3-Pole 3-Phase Breaker	ABI Breaker Catalog Number	Full- Load Amps.	2-Pole 1-Phase or 3-Pole 3-Phase Breaker	ABI Breaker Catalog Number	Full- Load Amps.	2-Pole 1-Phase or 3-Pole 3-Phase Breaker	ABI Breaker Catalog Number
Single Phase												
37½	312.5	400-LAB	S-LAB2400	156.3	200-JA	S-JA2200	78.1	100-EH	S-EH2100	62.5	90-F	S-F2090
50	416.7	500-MA	S-MA2500	208.4	250-LAB	S-LAB2250	104.2	125-JA	S-JA2125	83.3	100-F	S-F2100
75	625.0	800-MA	S-MA2800	312.5	400-LAB	S-LAB2400	156.0	200-JA	S-JA2200	125.0	150-JA	S-JA2150
100	833.3	1000-MA	S-MA21000	416.7	500-MA	S-MA2500	208.0	250-LAB	S-LAB2250	167.0	200-JA	S-JA2200
167	1391.7	.....	.....	695.9	800-MA	S-MA2800	348.0	400-LAB	S-LAB2400	278.3	350-LAB	S-LAB2350
250	2083.3	.....	.....	1041.7	1200-MA	S-MA21200	521.0	700-MA	S-MA2700	416.7	500-MA	S-MA2500
Three Phase												
45	125.0	150-JA	S-JA3150	108.2	125-JA	S-JA3125	54.2	70-EH	S-EH3070	43.3	50-F	S-F3050
75	208.3	250-LAB	S-LAB3250	180.2	225-JA	S-JA3225	90.3	125-JA	S-JA3125	72.1	90-F	S-F3090
112½	312.5	400-LAB	S-LAB3400	270.4	350-LAB	S-LAB3350	135.4	175-JA	S-JA3175	108.1	125-JA	S-JA3125
150	416.7	500-MA	S-MA3500	360.5	500-MA	S-MA3500	180.5	225-JA	S-JA3225	144.2	175-JA	S-JA3175
225	625.0	800-MA	S-MA3800	540.7	700-MA	S-MA3700	270.8	350-LAB	S-LAB3350	216.3	300-LAB	S-LAB3300
300	833.3	1000-MA	S-MA31000	721.0	800-MA①	S-MA3800	361.0	500-MA	S-MA3500	288.3	350-LAB	S-LAB3350
500	1387.8	.....	.....	1202.8	.....	.....	601.4	800-MA	S-MA3800	481.1	600-MA	S-MA3600
750	2082.0	.....	.....	1804.2	.....	.....	902.1	1000-MA①	S-MA31000	721.6	800-MA①	S-MA3800
1000	2776.0	.....	.....	2405.7	.....	.....	1202.9	.....	.....	962.3	1200-MA	S-MA31200

For breaker mounting in field be certain to check breaker dimensions versus transformer dimensions to be certain that breaker will fit on the side.

Ambient compensated breakers are available and should be used where the ambient temperature is in excess of normal.

① Ambient compensated breaker only.

Table 4: Motor terminal amperes at full load②

Average values for all speeds and frequencies (1965 N. E. C.)

Hp	Single-Phase Ac			Polyphase Ac (Induction Type) Squirrel-Cage and Wound Rotor								Direct Current	
	115 Volts	230 Volts③	440 Volts	110 Volts		220 Volts⑤		440 Volts		550 Volts		120 Volts	240 Volts
				3-Ph.	2-Ph. 4-Wire④	3-Ph.	2-Ph. 4-Wire④	3-Ph.	2-Ph. 4-Wire④	2-Ph.	2-Ph. 4-Wire④		
¼	5.8	2.9	..	...	...	...	...	...	...	...	...	2.9	1.5
½	7.2	3.6	..	...	...	...	...	...	...	...	...	3.6	1.8
¾	9.8	4.9	..	4	4	2	2	1	1	.8	.8	5.2	2.6
1	13.8	6.9	..	5.6	4.8	2.8	2.4	1.4	1.2	1.1	1	7.4	3.7
1½	16	8	..	7	6.4	3.5	3.2	1.8	1.6	1.4	1.3	9.4	4.7
2	20	10	..	10	8.8	5	4.4	2.5	2.2	2	1.8	13.2	6.6
3	24	12	..	13	11.2	6.5	5.6	3.3	2.8	2.6	2.2	17	8.5
5	34	17	..	...	...	9	8	4.5	4	4	3.2	25	12.2
7½	56	28	..	...	...	15	13	7.5	7	6	6	40	20
10	80	40	21	...	...	22	19	11	9	9	8	58	29
15	100	50	26	...	...	27	24	14	12	11	10	76	38
20	...	...	...	...	...	40	34	20	17	16	14	110	55
25	...	...	...	...	...	52	45	26	23	21	18	144	72
30	...	...	...	...	...	64	55	32	28	26	22	178	89
40	...	...	...	...	...	78	67	39	34	31	27	212	106
50	...	...	...	...	...	104	88	52	44	41	35	280	140
60	...	...	...	...	...	125	108	63	54	50	43	346	173
75	...	...	...	...	...	150	129	75	65	60	52	412	206
	...	...	...	...	...	185	158	93	79	74	63	510	255

② These values of full-load current are for motors running at speeds usual for belted motors and motors with normal torque characteristics. Motors built especially for low speeds or high torques may require more running current, in which case the nameplate current rating should be used.

③ 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.

④ Current in common conductor of 2-phase, 3-wire system will be 1.41 times value given.

⑤ For full-load currents of 208 and 200-volt motors, increase the corresponding 220-volt motor full-load current by 6 and 10 percent respectively.

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Reference Tables, Continued

Table 5: Maximum Number of Conductors in Trade Sizes of Conduit or Tubing^①

New Work or Rewiring – Types RF-2, RFH-2, R, RH, RW, RHH, RHW, RH-RW

New Work – FEP, FEPB, RUH, RUW, T, TF, THHN, THW, THWN, TW

Derating factors for more than three conductors in raceways, see Note 8, Tables 310-12 through 310-15, N.E.C. 1965

Size AWG or MCM	Maximum Number of Conductors in Conduit or Tubing											
	½ Inch	¾ Inch	1 Inch	1¼ Inch	1½ Inch	2 Inch	2½ Inch	3 Inch	3½ Inch	4 Inch	5 Inch	6 Inch
18	7	12	20	35	49	80	115	176	....	....	....	....
16	6	10	17	30	41	68	98	150	....	....	....	....
14	4	6	10	18	25	41	58	90	121	155	....	....
12	3	5	8	15	21	34	50	76	103	132	208	....
10	1	4	7	13	17	29	41	64	86	110	173	....
8	1	3	4	7	10	17	25	38	52	67	105	152
6	1	1	3	4	6	10	15	23	32	41	64	93
4	1	1	1	3 ^②	5	8	12	18	24	31	49	72
3	....	1	1	3	4	7	10	16	21	28	44	63
2	....	1	1	3	3	6	9	14	19	24	38	55
1	....	1	1	1	3	4	7	10	14	18	29	42
0	....	....	1	1	2	4	6	9	12	16	25	37
00	....	....	1	1	1	3	5	8	11	14	22	32
000	....	....	1	1	1	3	4	7	9	12	19	27
0000	....	....	....	1	1	2	3	6	8	10	16	23
250	....	....	....	1	1	1	3	5	6	8	13	19
300	....	....	....	1	1	1	3	4	5	7	11	16
350	....	....	....	1	1	1	1	3	5	6	10	15
400	....	....	....	....	1	1	1	3	4	6	9	13
500	....	....	....	....	1	1	1	3	4	5	8	11
600	....	....	....	....	....	1	1	1	3	4	6	9
700	....	....	....	....	....	1	1	1	3	3	6	8
750	....	....	....	....	....	1	1	1	3	3	5	8
800	....	....	....	....	....	1	1	1	2	3	5	7
900	....	....	....	....	....	1	1	1	1	3	4	7
1000	....	....	....	....	....	1	1	1	1	3	4	6
1250	....	....	....	....	....	....	1	1	1	1	3	5
1500	....	....	....	....	....	....	....	1	1	1	3	4
1750	....	....	....	....	....	....	....	1	1	1	2	4
2000	....	....	....	....	....	....	....	1	1	1	1	3

^① From 1965 National Electrical Code.^② Where an existing service run of conduit or electrical metallic tubing does not exceed 50 ft. in length and does not contain more than the equivalent of two quarter bends from end to end, two No. 4 insulated and one No. 4 bare conductors may be installed in 1-inch conduit or tubing.

Dry Type Transformers

Distribution Type, 5000 Volts and Below
 Single Phase: 37½ to 250 Kva, Type DS-3
 25-100 Kva, Type DS-3E
 Three Phase: 45 to 1000 Kva, Type DT-3
 30 to 150 Kva, Type DT-3E

Common Transformer Terms

Ambient Noise Level—The noise level of the surrounding area measured in decibels.

Ambient Temperature—Ambient temperature is temperature of surrounding atmosphere into which the heat of the transformer is dissipated.

ASA 61—An ASA designation for color of paint, usually written in specifications as "must be ASA-61 light gray paint."

Autotransformer—An autotransformer is a transformer in which part of the winding is common to both the primary and the secondary circuits.

BIL—Basic Impulse Level, (see Impulse Tests).

Buck-Boost Application—The name of a standard, stock two-winding, one-phase transformer with low-voltage secondary windings which can be connected as an autotransformer for boosting and bucking single- and three-phase supply voltages in small amounts.

Certified Tests—Actual values taken during production tests and certified as applying to a given unit shipped on a specific order.

Class A, B, F, & H—Refers to the class of insulation system in a transformer.

Continuous Rating—Continuous rating defines the constant load which a transformer can carry at rated primary voltage and frequency without exceeding the specified temperature rise.

Copper Losses—See Load Losses.

Corrosion Resistant—(Also see Rust Resistant and Rust Inhibiting); specifically prepared or treated to resist corrosion and rusting.

Current Transformer—A transformer generally used in instrumentation circuits for measuring or controlling current.

Decibel (DB)—A term used in sound measurement. A change of one db in sound level is the smallest change the human ear can detect. A busy office might measure from 60-75 db. DB is a measure of sound intensity.

Delta (Δ)—A standard three-phase connection with the ends of each phase winding connected in series to form a closed loop with each phase 120 degrees from the other. Sometimes referred to as 3-wire.

Delta Wye (Δ -Y)—A term or symbol indicating the primary connected in delta and the secondary in wye when pertaining to a three-phase transformer or transformer bank.

Dielectric Tests—Dielectric tests are tests which consists of the application of a voltage higher than the rated voltage for a specified time for the purpose of determining the adequacy against break-downs of insulating materials and spacings under normal conditions.

Dry-type—A dry-type transformer is one in which the transformer core and coils are not immersed in liquid.

DS-3—Single phase dry type class H Insul 150°C Rise enclosed natural draft ventilation.

DT-3—Three phase dry type class H Insul 150°C rise enclosed natural draft ventilation.

DS-3E—Single phase dry type class H Insul 150°C rise totally enclosed non-ventilated.

DT-3E—Three phase dry type class H Insul 150°C rise totally enclosed non-ventilated.

Electrostatic Shield—Copper or other conducting sheet placed between primary and secondary and grounded to prevent electrical interference and to provide additional protection.

Exciting Current (No-Load Current)—Exciting current is current which flows in any winding used to excite the transformer when all other windings are open-circuited and is usually expressed in per cent of the rated current of a winding in which it is measured.

Extended Winding—A winding made longer than necessary so that it can perform some of the duties normally expected of another winding or windings. The best example is an extended primary transformer. Its primary winding is continued on up the core beyond the point where it will do its rated job. In this additional section of the winding, taps can be added for the purpose of regulating the secondary voltage.

FCBN—"Full capacity below normal" taps. An abbreviation which, when pertaining to transformers, designates that they are suitable for full-rated power at voltages below rated level.

FCAN—Like FCBN taps, except full capacity above normal nameplate voltage.

Flexible Connection—A non-rigid connection designed to eliminate transmission of noise, in contrast to rigid conduits, etc.

Frequency—On ac circuits, designates number of times that polarity alternates from positive to negative and back again . . . such as 60 cycles per second.

Full-capacity Tap—A full-capacity tap is one through which the transformer can deliver its rated kva output without exceeding the specified temperature rise.

Grounding Transformer—A special 3-phase autotransformer for establishing a neutral on a 3-wire delta secondary.

Grounds or Grounding—Connecting one side of a circuit to the earth through low-resistance or low-impedance paths. This helps prevent transmitting electrical shock to personnel.

Group II and Group III Insulation—NEMA designations for insulation systems which are commonly classified as B and H.

High-voltage and Low-voltage Windings—Terms used to distinguish the winding having the greater voltage rating from that having the lesser in two-winding transformers. The terminations on the high-voltage windings are identified by H1, H2, etc., and on the low-voltage by X1, X2, etc.

Impulse Tests—Impulse tests are dielectric tests consisting of the application of a high-frequency steep-wave-front voltage between windings and between windings and ground.

Impedance—Retarding forces of current flow in ac circuits.

Indoor Transformer—An indoor transformer is one which, because of its construction, is not suitable for outdoor service.

Induced Test—A standard high-frequency test of transformer insulation.

Insulating Materials—Those materials used to electrically insulate the transformer windings from each other and ground. Usually Class A, B, F, and H.

Insulating Transformer—An insulating transformer is one which insulates the primary from the secondary winding.

Insulation System—Balancing of insulation materials to properly insulate a given product.

Isolating Transformer—(See Insulating Transformer); isolating primary circuit from secondary circuit.

Dry Type Transformers

Distribution Type, 5000 Volts and Below
Single Phase: 37½ to 250 Kva, Type DS-3
25-100 Kva, Type DS-3E
Three Phase: 45 to 1000 Kva, Type DT-3
30 to 150 Kva, Type DT-3E

Knockout – Easily removed circle of metal which eliminate the need for drilling holes for conduits.

KVA or Volt-ampere Output Rating – The kva or volt-ampere output rating designates the output which a transformer can deliver for a specified time at rated secondary voltage and rated frequency without exceeding the specified temperature rise (1 kva=1000 va).

Load – The load of a transformer is the power—in kva or volt-amperes—supplied by the transformer.

Load Losses – Load losses are those losses in a transformer which are incident to load carrying. Load losses include I²R loss in the windings due to load current, stray loss due to stray fluxes in the winding, core clamps, etc., and to circulating currents (if any), in parallel windings.

Mid-tap – A reduced-capacity tap midway in a winding—usually the secondary.

Moisture-resistant – Moisture-resistant apparatus is one which is constructed or treated so that it will not be harmed readily by exposure to a moist atmosphere.

Multiple Winding – (See Parallel and Series/Multiple).

Natural-draft or Natural-draft Ventilated – An open transformer cooled by the draft created by the chimney effect in heating the air in its enclosure.

NEMA Standard – NEMA Standards for dry-type general purpose transformers: NEMA ST-1 applies to transformers 600v and below; NEMA TR 27-1965 applies to transformers above 600v to 15 KV.

Noise Level – The relative intensity of sound, measured in db.

No-load Losses (Excitation Losses) – Loss in a transformer which is excited at rated voltage and frequency but which is not supplying load. No-load losses include core loss, dielectric loss, and copper loss in the winding due to exciting current.

Parallel Operation – Single- and three-phase transformers having appropriate terminals may be operated in parallel by connecting similarly-marked terminals, provided their ratios, voltages, resistances, reactances, and ground connections are designed to permit parallel operation and provided their angular displacements are the same in the case of three-phase transformers.

Per Cent IR – (Per cent resistance) – Voltage drop due to resistance at rated current in per cent of rated voltage.

Per Cent IX – (Per cent reactance) – Voltage drop due to reactance at rated current in per cent of rated voltage.

Per Cent IZ – (Per cent impedance) – Voltage drop due to impedance at rated current in per cent of rated voltage.

Phase – Type of ac electrical circuit, usually single-phase, 2-wire or 3-wire, or three-phase, 3- or 4-wire.

Polarity Tests – A standard test on transformers to determine instantaneous direction of the voltages in the primary compared to the secondary, (see Transformer Tests).

Potential (Voltage) Transformer – A transformer generally used in instrumentation circuits for measuring or controlling voltage.

Power Factor – The relation of watts to volt amps in a circuit.

Primary Taps – Taps added in the primary winding, (see Tap).

Primary Voltage Rating – Designates the input circuit voltage for which the primary winding is designed.

Primary Winding – The primary winding is the winding on the energy input (supply) side.

Ratio Test – A standard test of transformers to determine the ratio of the primary to the secondary voltage, (see Transformer Tests).

Reactance – The effect of inductive and capacitive components of the circuit producing other than unity power factor.

Reactor – A device for introducing inductive reactance into a circuit for motor starting, operating transformers in parallel, and controlling current.

Reduced Capacity Taps – Taps which will carry full-rated winding current only, thus reducing available power because of lower output voltage.

Regulation – Usually expressed as the percent change in output voltage when the load goes from full load to no load.

Scott Connection – Connection for polyphase transformers. Usually used to change from two-phase to three-phase or three-phase to two-phase.

Secondary Voltage Rating – Designates the load-circuit voltage for which the secondary winding (winding on the output side) is designed.

T-Connection – Use of Scott connection for three-phase operation.

Tap – A tap is a connection brought out of a winding at some point between its extremities, usually to permit changing the voltage or current ratio.

Temperature Rise – The increase over ambient temperature of the winding due to energizing and loading the transformer.

Transformer – A transformer is an electrical device, without continuously moving parts, which by electro-magnetic induction, transforms energy at one voltage or current to another voltage or current at the same frequency.

Wye Connection (Y) – A standard 3-wire transformer connection with similar ends of the single-phase coils connected. This common point forms the electrical neutral point and may be grounded.

Zig-Zag Connection – Special transformer connection commonly used in grounding transformers.

Further Information

Prices: Price List 46-920

Price List 46-921 (Totally-Enclosed, Non-Ventilated)

Price List 46-922 (Grounding Transformers, Zig-zag Auto-connected)

Price List 46-923 (Motor Starting Autotransformers)

Price List 46-926 (Marine Type)

Price List 46-927 (Saturable Core Reactors)

Description: Descriptive Bulletin 46-950
Descriptive Bulletin 46-951
(Totally-Enclosed, Non-Ventilated)
Descriptive Bulletin 46-956
(Marine Type)
Descriptive Bulletin 46-957
(Saturable Core Reactors)