STD.NEMA C93.3-ENGL 1995 ■ 6470247 0514720 652 ■

American National Standard

ANSI C93.3-1995

American National Standard—

Requirements for Power-Line Carrier Line Traps

National Electrical Manufacturers Association
1300 North 17th Street
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Rosslyn, Virginia 22209
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American National Standard

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ANSI® C93.3-1995

American National Standard—

Requirements for Power-Line Carrier Line Traps

Secretariat

National Electrical Manufacturers Association
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Published by

National Electrical Manufacturers Association
1300 N. 17th Street, Rosslyn, Virginia 22209

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Foreword (This Foreword is not part of American National Standard C93.3-1995)

This document was developed by Standards Committee C93, on Power-Line Carrier Equipment and Coupling Capacitor Voltage Transformers. During its development the standard received the benefits of a consensus of input from a balanced group representing the consumer, producer, and general-interest viewpoints. These inputs were harmonized and integrated into the standard in its present approved form.

Standards Committee C93 was established to coordinate, review, and update the existing documents into an effective group of American National Standards, including this standard for line traps. A Separate standard will be developed to cover each type of equipment described in the Committee's scope.

This standard includes technical definitions, performance ratings, testing methods and manufacturing requirements for line traps. It is related to ANSI C93.1-1990, ANSI C93.4-1990.

Suggestions for improvement of this standard are welcome. They should be sent to:

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This standard was processed and approved for submission to ANSI by Accredited Standards Committee C93 on Power-Line Carrier Equipment and Coupling Capacitor Voltage Transformers. Committee approval of this standard does not necessarily imply that all committee members voted for its approval. At the time it approved this standard, the C93 Committee had the following members:

W. Seamon, Chairman
M. Holsinger, Secretary

Organization Represented	*Name of Representative*
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Requirements for Power-Line Carrier Line Traps

1 Scope

This standard applies to a line trap inserted into a power circuit to minimize carrier-frequency signal losses. The standard covers line traps in which the main coil is designed as a single phase, air-cooled inductor of the dry type.

2 Normative references

When the following standards referred to in this document are superseded the revision shall apply:

ANSI C29.8-1985, *American National Standard for Wet-Process Porcelain Insulators (Apparatus, Cap and Pin Type)*

ANSI C84.1-1992, *American National Standard for Voltage Ratings for Electrical Systems and Equipment (60 Hz)*

ANSI C92.2-1981, *American National Standard for Preferred Voltage Ratings for Alternating-Current Electric Systems and Equipment Operating at Voltages above 230 Kilovolts Normal*

ANSI C93.1-1990, *American National Standards Requirements for Power Line Carrier Coupling Capacitors & Coupling Capacitor Voltage Transformers*

ANSI/IEEE 4-1978, *American National Standard for Techniques for Dielectric Tests*

ANSI/IEEE C62.11-1987, *American National Standard for Metal-Oxide Surge Arresters for AC Power Circuits*

ANSI/IEEE 100-1988, *American National Standard for Dictionary of Electrical and Electronics Terms*

ANSI/IEEE C57.21-1990, *IEEE Standard Requirements, Terminology, and Test Code for Shunt Reactors Rated Over 500kVA*

NEMA Standards Publication 107, *Methods of Measuring Radio Noise*

NEMA Standards Publication CC 1, *Electrical Power Connectors for Substations*

3 Definitions

All definitions, except as specifically covered in this standard, shall be in accordance with ANSI/IEEE 100 and ANSI C93.1.

3.1 Auxiliary protective device: A device associated with the tuning device to protect individual components by limiting transient overvoltages.

3.2 Bandwidth: The frequency range within which the blocking impedance is not less than a specified amount.

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3.3 Blocking impedance: The complex impedance of the complete line trap within a specified carrier-frequency range.

3.4 Emergency overload current: A value of power frequency current, greater than the rated continuous current, which the line traps may be required to carry for some limited period of time.

3.5 Geometric mean frequency (GMF): The geometric mean of the bandwidth limit frequencies, which is the square root of their product.

3.6 Inductance

3.6.1 Apparent power-frequency inductance (L_p): The reactance of the main coil divided by the angular frequency at which the reactance is determined, uncompensated for the effects of self-capacitance.

3.6.2 Rated inductance (L_{tN}): The minimum value of true inductance determined at 100 kHz.

3.6.3 True inductance (L_t): The self-inductance of the main coil at a specified frequency, compensated for the effects of the self-capacitance.

3.7 Line trap: A main coil with a protective device, with or without tuning device(s), series connected in a power circuit to provide a high impedance at carrier frequencies, and negligible impedance at the power frequency.

3.8 Main coil: An inductor which carries the power frequency current.

3.9 Protective device: A device that protects the line trap by limiting transient overvoltages. It is shunt-connected to the tuning device and the main coil.

3.10 Rated blocking impedance (Z_b): The minimum value of blocking impedance over the bandwidth.

3.11 Rated continuous current (I_N): The rms power frequency current which the line trap can carry continuously without exceeding the maximum temperature rise for its insulation temperature index.

3.12 Rated short-time current (I_{kN}): The rms symmetrical value of current which a line trap is capable of carrying for two seconds without exceeding a specified temperature.

3.13 Resistive bandwidth: The frequency range within which the resistive blocking impedance is not less than a specified amount.

3.14 Resistive blocking impedance (R_b): The resistive component of the blocking impedance.

3.15 Resonant frequency: The frequency or frequencies to which the line trap is tuned.

3.16 Self-capacitance (C_r): The capacitance resulting from the turn-to-turn, layer-to-layer and terminal-to-terminal configuration of the main coil.

3.17 Self-resonant frequency: The frequency at which the combination of true inductance and self-capacitance becomes resonant.

3.18 Self-tuned trap: A line trap without a tuning device and for wide-band operation designed such that the self-resonant frequency is in the carrier band.

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3.19 Single-frequency line trap: A line trap which is adjustably tuned for parallel resonance at one selected carrier frequency.

3.20 Tapping loss (A_t): A loss A_t sustained by a carrier-frequency signal due to the finite blocking ability of the line trap. It is defined in terms of the ratio of the signal voltages across an impedance equal to the characteristic impedance of the transmission line with and without the shunt connection of the line trap and is expressed in decibels.

3.21 Tapping loss based on blocking impedance (A_{tz}): The loss A_{tz}, expressed in decibels, sustained by a carrier-frequency signal due to the shunt connection of the line trap impedance.

3.22 Tuning device: A passive network which, when shunt-connected to the main coil, produces a relatively high line trap impedance for one or more frequencies or frequency bands. It consists of capacitors and may include inductors, resistors and auxiliary protective devices.

3.23 Tuning range: The portion of the carrier frequency band through which the geometric mean frequency or resonant frequency may be adjusted.

3.24 Two-frequency line trap: A line trap which is adjustably tuned for parallel resonance at two selected carrier frequencies.

3.25 Wideband line trap: A line trap which provides a greater bandwidth than a single-frequency line trap for the same main coil inductance, resonant (or geometric mean) frequency, and impedance level.

4 Service conditions

4.1 Usual service conditions

1) Outdoor service
2) Ambient temperature range: -40°C to +45°C. With regard to temperature range, table 1 defines the upper ambient temperature limit conditions.
3) Maximum altitude: 3300 feet (1000 meters) above sea level.
4) Power frequency: 50Hz or 60Hz.
5) Atmosphere free of damaging fumes or excessive or abrasive dust, explosive mixtures of dust or gases, steam, and salt spray.
6) Carrier frequency range 30–500 kHz.

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4.2 Unusual service conditions

4.2.1 Ambient temperature

When a line trap is applied in ambient temperatures that exceed the limits specified in table 1, the allowable temperature rise shall be reduced by the same number of degrees the ambient temperature exceeds the upper temperature limit.

Table 1 – Upper ambient temperature limit conditions

Maximum Ambient Temperature Limit Conditions (Degrees Celsius)		
Mean Over 1 Hour	Mean Over 24 Hours	Mean Over 1 Year
45	40	30

4.2.2 Altitude

4.2.2.1 Temperature rise

Line traps may be used at altitudes greater than 3300 feet (1000 meters) provided that the current correction factors in table 2 are applied and the temperature of the cooling air does not exceed the mean values given in table 3.

Table 2 – Current correction factors

Altitude (Above Sea Level)	Correction Factor
3,300 feet (1,000 meters)	1.00
5,000 feet (1,500 meters)	.99
10,000 feet (3,000 meters)	.96

Table 3 – Altitude versus temperature

Maximum Mean Temperature of Cooling Air Over 24 Hours	
Altitude (Above Sea Level)	Air (Degree Celsius)
3,300 feet (1,000 meters)	40
5,000 feet (1,500 meters)	37
10,000 feet (3,000 meters)	30

4.2.2.2 Dielectric strength

When a line trap is applied at altitudes greater than 3,300 feet (1,000 meters), the dielectric strength correction factors for air-insulated components as given in table 4 shall apply.

Table 4 – Dielectric strength correction factors

Altitude (Above Sea Level)	Correction Factor
3,300 feet (1,000 meters)	1.00
5,000 feet (1,500 meters)	.95
10,000 feet (3,000 meters)	.80

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4.2.3 Other unusual service conditions

1) Direct-current applications
2) Seismic conditions

5 Ratings

5.1 General ratings

5.1.1 Main coil orientation classes

The ratings of this standard shall apply to the following classes:

— Class 1: Main Coil Axis orientation interchangeable, vertical or horizontal

— Class 2A: Main Coil Axis orientation vertical only

— Class 2B: Main Coil Axis orientation horizontal only

5.1.2 Current

The continuous and corresponding short-time current ratings shall be in accordance with table 5. Other current ratings (continuous and short-time current) may be specified, based on agreement between manufacturer and purchaser.

Table 5 – Current ratings

Continuous (amperes)	Short-time (kilo-amperes)
400	15
800	20
1200	36
1600	44
2000	63
3000	63
4000	80

5.1.3 Power losses

There is no standard for power losses; for further information refer to Appendix A2.

5.1.4 Main coil inductance

The rated inductance of the main coil in mH shall be one of the following: 0.265, 0.53, 1.06, 1.59, 2.12, 2.65. Other ratings of inductance may be specified based on agreement between manufacturer and purchaser.

Note—For reference, the following nominal 60-Hz reactance values, in ohms, are given corresponding to the above rated inductances as 0.1, 0.2, 0.4, 0.6, 0.8, 1.0, respectively.

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5.1.5 Temperature rise at rated continuous current

Since a line trap is usually not fully loaded during all its working life, the values given in table 6 are higher than those given in dry-type reactor publications. For special and non-conventional installations, appropriate units must be requested.

The maximum temperature rise above the 40°C 24-hour mean ambient temperature at rated continuous current shall not exceed those values in table 6.

Table 6 – Maximum temperature rise at rated continuous current

Insulation Temperature Index	Maximum Temperature Rise (Degrees Celsius)	
	Hottest Spot (by Thermocouple)	Average Winding (by Resistance)
105	85	65
130	110	90
155	135	115
180	160	140

5.1.6 Limiting temperature for rated short time current

The line trap shall withstand the heating effects of the rated short-time current for two seconds without exceeding the temperature given in table 7, and as determined in accordance with 6.2.3. Other short-time current durations may be specified based on agreement between manufacturer and purchaser.

Table 7 – Limiting temperature for rated short-time current

Insulation Temperature Index	Actual Limiting Temperature (Degrees Celsius)
105	205
130	285
155	315
180	350

5.1.7 Mechanical strength for rated short-time current

The line trap shall be capable of withstanding the mechanical forces produced by an offset current having a single peak with a value of 2.55 times the rated short-time current. The term "capable of withstanding" shall be interpreted to mean that if subjected to this duty the line trap shall show no damage and shall be capable of meeting all other requirements of this standard.

5.1.8 Protective device voltage rating

The voltage rating of the protective device shall be no less than "E," the voltage developed across the line trap with rated short-time current, determined as follows:

$$E = 1.1 \times 2\pi f L_p I_{KN}$$

Where:

f = power frequency (hertz)
L_p = apparent power-frequency inductance (henries) of the main coil
I_{KN} = rated short-time current (amperes)

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The protective device shall meet the requirements of ANSI/IEEE C62.11 for its classification and voltage rating.

5.1.9 Main coil insulation level

The insulation level for the main coil shall be at least 30% above the value of the maximum 200kV/microsecond front-of-wave protective voltage or of the 20 kA discharge voltage of the protective device, whichever is higher.

5.1.10 Radio influence voltage (RIV)

The radio influence voltage of a line trap shall not exceed the value stated in table 8, when the line trap is applied at the stated maximum system voltage.

Table 8 – Radio influence voltage

System Voltage (kV)*		Radio-Influence Test Voltage (kV)**	Maximum Radio-Influence Voltage (uV)†
Maximum	Nominal		
36.2	34.5	21	125
48.3	46	28	125
72.5	69	42	125
121	115	70	250
145	138	84	250
169	161	98	250
242	230	140	250
362	345	209	250
550	500	317	500
800	765	462	750

* The maximum and nominal system voltages are from American National Standards C84.1 and C92.2.

** The radio-influence test voltage is the line-to-ground value of the maximum system voltage.

† The maximum permissible background voltage level will be 1/2 of the radio-influence voltage rating. Correction for background voltage level shall be by the rms method. These maximum radio-influence voltages, as conducted radio noise, will add a negligible amount to the radio noise normally radiated from the line, even at short distances from the line trap.

5.1.11 Tensile strength

A line trap intended for vertical suspension mounting shall be capable of withstanding, without yielding, a tensile force of not less than 3,000 pounds (13,300 N), in addition to the weight of the line trap.

5.1.12 Self-resonant frequency

This frequency shall always be higher than 500 kHz except for line traps where it may not be possible to achieve such a high frequency because of the physical size and construction of the main coil. For these special cases the self-resonant frequency must be greater than the GMF of the operating bandwidth.

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5.2 Ratings for tuned type line traps

5.2.1 Types of tuning

The types of tuning shall be as follows:

1) Single-frequency (Field-adjustable or factory-fixed)
2) Two-frequency (Field-adjustable or factory-fixed)
3) Wide-band (Field-adjustable or factory-fixed)
4) Self-tuned wide-band

5.2.2 Tuning

5.2.2.1 Tuning ranges for field adjustable line traps

Tuning ranges for a line trap that is adjustable in the field are given in table 9, and are the ranges through which the resonant frequencies (for single- and two-frequency line traps) or geometric mean frequencies (for wide-band line traps) may be tuned.

Note—The indicated tuning ranges in table 9 do not preclude the use of frequency combinations from two tuning ranges in a two-frequency line trap. A line trap having an inductance greater than 0.265 mH is generally not field-adjustable. This is because high inductance line traps are normally used for factory-fixed wide-band or self-tuned wide-band operation.

Table 9 – Tuning ranges for 0.265 mH field adjustable line trap

Type of Tuning	Tuning Ranges (kHz)
Single-frequency	30–90 70–200 100–300
Two-frequency	30–90 70–200 100–300
Wide-band	50–200 100–300

5.2.2.2 Tuning range for factory-fixed wide-band line traps

A factory-fixed wide-band line trap shall have a bandwidth within the 30 to 500 kHz range, which is not adjustable in the field.

5.2.2.3 Frequency separation of a two-frequency line trap

For a two-frequency line trap, the frequencies shall be separated by at least 25 kHz or 25 percent of the higher frequency, whichever is greater.

5.2.2.4 Precision of tuning

A single- or two-frequency line trap shall be capable of being tuned to a selected frequency or frequencies within the specified range with an accuracy of ± 0.5 percent.

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5.2.3 Rated blocking impedance

For a single- or two-frequency line trap the rated blocking impedance shall be 400 ohms.

For a field adjustable wide-band line trap, the rated blocking impedance shall be 400 ohms or 600 ohms or 1,000 ohms or configured for any of these impedances as agreed between the manufacturer and purchaser.

For a factory fixed wide-band line trap, the rated blocking impedance shall be 400 ohms or 600 ohms or 1,000 ohms.

5.2.4 Variation of blocking characteristic with change in ambient temperature and change in continuous current

5.2.4.1 Single- and two frequency tuning

The resonant frequency shall not vary more than a total of two percent for changes in both the ambient temperature and the continuous current within the temperature range of -40°C to +45°C, and from zero to rated continuous current.

5.2.4.2 Wide band tuning

For the field-adjustable type, the geometric mean frequency shall not vary more than a total of two percent for changes in both the ambient temperature and the continuous current within the temperature range of -40°C to +45°C, and from zero to rated continuous current.

For the factory-fixed type, the minimum blocking impedance over the bandwidth shall be maintained for changes in both the ambient temperature and the continuous current within the temperature range of -40°C to +45°C, and from zero to rated continuous current.

5.2.5 Auxiliary protective device rating

Auxiliary protective gaps shall neither spark over nor continue to spark over following transient voltage actuation, with the power frequency voltage, "E," as determined in 5.1.8, across the main coil.

5.2.6 Tuning device insulation level

The insulation level for the tuning device shall be at least 30 percent above the value of the maximum 200kV/microsecond front-of-wave protective voltage or of the 20 kA discharge voltage of the protective device, whichever is higher.

The insulation level for the tuning device components protected by an auxiliary protective device shall be at least 30% above the impulse sparkover voltage determined in 6.2.13(1).

6 Testing

6.1 General

6.1.1 Test conditions

1) The ambient temperature range shall be from +10°C through +50°C.

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2) The line trap for application at an unusual altitude service condition may be tested at any altitude less than 3300 feet (1000 meters) if appropriate altitude corrections from tables 2, 3 and 4 are applied.
3) The line trap for application at a usual altitude service condition may be tested at any altitude higher than 3300 feet (1000 meters) if appropriate altitude corrections from tables 2, 3, and 4 are applied.
4) The test units shall be new and in clean, dry condition.
5) The sequence of testing shall be optional, except where otherwise noted.

6.1.2 Design tests

6.1.2.1 General

The following design tests shall be performed by the manufacturer on one line trap of each current and inductance rating to ensure that its characteristics and performance meet the requirements of this standard:

1) Measurement of main coil inductance (see 6.2.1)
2) Temperature rise at rated continuous current (see 6.2.2)
3) Calculation of time to reach limiting temperature for rated short-time current (see 6.2.3)
4) Tensile strength test for suspension mounted line traps (see 6.2.4)
5) Mechanical strength for rated short-time current (see 6.2.5)
6) Turn-to-turn insulation test of the main coil (see 6.2.6)
7) Protective device tests (see 6.2.7)
8) Radio-influence voltage test (see 6.2.8)
9) Self-resonant frequency test (see 6.2.9)

6.1.2.2 Tuned type

The following additional design tests shall be performed by the manufacturer on one tuned-type line trap of each current and inductance rating to ensure that its tuning characteristics and performance meet the requirements of this standard:

1) Bandwidth test (see 6.2.10)
2) Variation of blocking characteristics with change in ambient temperature and change in continuous current (see 6.2.11)
3) Power Frequency Test of protective device and auxiliary protective device(s) (see 6.2.12)
4) Insulation tests of the tuning device components protected by auxiliary protective device(s) (see 6.2.13)
5) Insulation test of an assembled tuned-type line trap (see 6.2.14)

6.1.3 Production (routine) tests

6.1.3.1 General

The following production tests shall be performed by the manufacturer on each line trap:

1) Measurement of main coil true inductance (see 6.3.1)
2) Measurement of main coil apparent power-frequency inductance (see 6.3.2)
3) Power-frequency test of protective device and auxiliary protective device(s) (see 6.3.3)
4) Turn-to-turn insulation test of the main coil (see 6.3.7)

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Measurement of main coil power frequency losses is optional per agreement between manufacturer and purchaser (see Appendix A2)

6.1.3.2 Tuned-type

The following additional production tests shall be performed by the manufacturer on each tuned-type line trap:

1) Measurement of blocking impedance (see 6.3.4)
2) Measurement of tuning device component values (see 6.3.5)
3) Power-frequency dielectric withstand test on tuning device (see 6.3.6)
4) Power-frequency test of auxiliary protective device(s) (see 6.3.3)

6.2 Design test procedures

6.2.1 Measurement of main coil inductance

Measurements of the main coil inductance shall be performed as follows:

1) The true inductance (L_t), shall be determined, and shall be not less than the rated value in accordance with 5.1.4.

   The main coil shall be parallel or series resonated at two frequencies, F_1 and F_2 with capacitors which will have values of C_1 and C_2 respectively. The true inductance is then given in henries as:

$$L_t = \frac{(\frac{F_1}{F_2})^2 - 1}{(2\pi F_1)^2 \times (C_2 - C_1)}$$

   Where:
   F_1, F_2 = Frequency (Hertz)

   C_1, C_2 = Capacitance (Farads)

   Note—To minimize computational errors, F_1 should be considerably larger than F_2. Also, the GMF of F_1 and F_2 should be approximately 100 kHz; therefore, test frequencies of 140 kHz and 70 kHz are recommended.

2) The apparent power-frequency inductance shall be measured to permit calculation of the voltage "E" as required in 5.1.8.

3) When 6.3.1(2) is used as the production test for the main coil true inductance, the apparent power-frequency inductance of the main coil shall be calculated by dividing the reactance by the angular power frequency.

The ratio of the true inductance (determined in 1) above) to the apparent power-frequency inductance (determined in 3) above) is the ratio used in 6.3.1(2).

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6.2.2 Temperature rise at rated continuous current

6.2.2.1 General conditions

All temperature rise tests shall be performed in an indoor area as free from drafts as practicable. The area shall be sufficiently large so that the ambient temperature is not appreciably increased by heating effects of the line trap under test. The line trap shall be fully assembled and shall be tested in each of the positions in which it is intended to operate.

There shall be sufficient clearance from the line trap to floors, walls, ceilings, and other objects in the test area so that there will be no hindrance to free natural convection or to normal radiation cooling.

Temperature rise tests shall be performed at rated continuous current and power frequency. It is permissible to shorten the time required for the test by the use of initial overloads or other suitable methods.

6.2.2.2 Ambient or cooling air temperature

The temperature of the cooling air shall be determined from the average of the readings of at least three thermometers or thermocouples placed uniformly around the line trap at the same level as the bottom of the coil at a horizontal distance of one to two coil diameters from the edge of the coil. To reduce to a minimum the errors due to time lag between the temperature of the line trap and the variations in the ambient temperature, the thermocouples or thermometers shall be placed in suitable containers. The container shall have such proportions as will require not less than two hours for the indicated temperature within to change 6.3°C if suddenly placed in air which has a temperature 10°C higher, or lower, than the previous steady-state indicated temperature within the container.

For measurements of increasing resistance of the coil, when the ambient temperature is other than 40°C, the winding losses will not be the same as the values that would have been obtained at 40°C ambient conditions. the correction factor is then as follows:

$$K = \frac{T + 40^{\circ}C}{T + \theta_a{}^{\circ}C}$$

Where:

K = correction factor
T = 234.5°C for copper or 225°C for aluminum
θ_a = ambient air temperature in degrees Celsius at the termination of the temperature rise test

To obtain the corrected temperature rise, the measured temperature rise shall be multiplied by the correction factor K.

6.2.2.3 Temperature rise measurement

The average temperature rise of the main coil winding shall be measured by the increase in resistance method, and shall not include contact resistance. This may be accomplished by using the double bridge method.

The maximum measurable hot spot temperature rise of the main coil winding conductor insulation, line terminals, tuning devices, and protective devices shall be measured by thermocouples or thermometers.

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The use of thermocouples is the preferred method of measuring hot spots and surface temperatures. The thermocouples should be placed and held firmly and snugly against the conductor surface, and thermally insulated from the surrounding cooling medium.

The temperature rise shall be considered constant when all temperatures, which can be measured at intervals of not less than 30 minutes, show that three consecutive readings are within ±2 percent of the previous three readings. During this period the test current shall be the rated continuous current and shall vary no more than ±2 percent.

6.2.2.4 Determination of winding resistance (R_T) at time of shutdown (cooling curve method)

A correction shall be made for the cooling that occurs from the time when the power is shut off to the time when the hot resistance is measured. The recommended method of determining the temperature of the winding at the time of shutdown is by measuring the resistance of the winding as the line trap cools immediately after shutdown and extrapolating to the time of shutdown. At least four measurements shall be made at intervals of no more than three minutes.

> **Note**—If the main coil winding employs aluminum conductor, then the leads and connections for the bridge used to measure the DC resistance shall also be of aluminum to avoid thermocouple effects, which can result in erroneous resistance measurements.

6.2.2.5 Determination of average winding temperature by the resistance method

The average temperature of the winding shall be determined by either of the following equations:

$$\theta_t = \frac{R_t}{R_o} \times (T + \theta_o) - T$$

or

$$\theta_t = \left[\frac{R_t - R_o}{R_o}\right] \times (T + \theta_o) + \theta_o$$

Where:

T = 234.5°C for copper or 225°C for aluminum
θ_t = temperature in degrees Celsius corresponding to the resistance of the winding at time of shutdown
θ_o = temperature in degrees Celsius corresponding to the reference resistance of the winding
R_t = resistance of the winding at time of shutdown
R_o = reference resistance of the winding

6.2.2.6 Determination of temperature rise

6.2.2.6.1 Average winding temperature rise

The average temperature rise is the difference between the final temperature established in 6.2.2.5 and the ambient temperature at the completion of the test in 6.2.2.2. The corrected average temperature rise is the product of the average temperature rise and the correction factor K (See 6.2.2.2).

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6.2.2.6.2 Maximum measurable hot spot temperature rise

The maximum measurable hot spot temperature rise is the difference between the hottest thermocouple or thermometer reading and the measured ambient temperature at the completion of the test.

The corrected maximum measurable hot spot temperature rise is the product of the hottest observable spot temperature rise and the correction factor K (See 6.2.2.2).

In accordance with 6.2.11, the maximum measurable temperature rise of the tuning device capacitor should be measured at this time.

6.2.2.7 Correction of temperature rise for variation in altitude

If the tests are made at an altitude exceeding 3,300 feet (1,000 meters) above sea level, the temperature rise shall be corrected by the following method:

$$\text{(U.S.)}\quad \theta_r = \theta_m \left[1 - 0.005\left(\frac{h-3300}{330}\right)\right]$$

or

$$\text{(metric)}\quad \theta_r = \theta_m \left[1 - 0.005\left(\frac{h-1000}{100}\right)\right]$$

Where:

θ_r = corrected temperature rise for altitude above 3300 feet (1000 meters)

θ_m = measured temperature rise corrected to 40°C conditions

h = altitude above sea level in feet (meters)

6.2.3 Calculation of time to reach limiting temperature for rated short-time current

The ability of the line trap to withstand the heating effects of the rated short-time current for two seconds shall be verified by calculation of the time to reach limiting temperature based on the assumption that all the heat is stored in the conductor.

The time required to reach a specified limiting temperature may be calculated by the following formula:

$$t = \frac{(T+\theta_s)C}{W_s} \ln\left(1+\frac{\theta}{T+\theta_s}\right)$$

Where:

t = time in seconds for a temperature rise θ from a starting temperature of θ_s

θ = temperature rise in degrees Celsius (limiting temperature from 5.1.6 minus the starting temperature)

θ_s = starting temperature in degrees Celsius (45°C plus average temperature rise at rated continuous current)

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C = heat capacity of conductor, joules per pound (kilogram) per degree Celsius

T = inferred absolute temperature for conductor, degrees Celsius

W_s = heat input per unit time in watts per pound (kilogram) at starting temperature

Note— For Copper: C = 180 for pounds, (397 for kilograms), T = 234.5°C
For Aluminum: C = 429 for pounds, (946 for kilograms), T = 225°C

6.2.4 Tensile strength test for suspension mounted line traps

The tensile strength test shall be performed prior to the mechanical strength for rated short-time current test (see 6.2.5).

The line trap shall be vertically suspended using the suspension members and hardware normally supplied for this purpose. An additional tensile force of 3000 pounds (13,300N) shall be applied axially to the line trap and maintained for a period of one hour.

Successful completion shall be determined by the absence of permanent deformation of any part of the line trap.

6.2.5 Mechanical strength for rated short-time current test

The mechanical strength for rated short-time current test shall be performed subsequent to the following tests: insulation test of the main coil (see 6.2.6) and the tensile strength test (see 6.2.4) when applicable.

The ability of a line trap to withstand the mechanical forces produced by the rated short-time current shall be verified by an offset current having a single peak with a value of 2.55 times the rated short-time current. Successful completion of the test shall be determined by the absence of visible damage and conformance to the ratings in accordance with the production tests in 6.3.

6.2.6 Turn-to-turn insulation test of the main coil

The insulation test for the main coil shall be performed prior to and following the mechanical strength for rated short-time current.

The insulation test procedures for the main coil shall be performed according to IEEE C57.21 (see 10.3.3.2). The insulation test level shall not be less than that required in 5.1.9.

6.2.7 Protective device tests

The following tests shall be performed on the protective devices according to ANSI/IEEE C62.11:

1) Protective device voltage rating, determined in 5.1.8 of this document.
2) Establish protective device characteristics, required in 5.1.9 and 5.2.6 of this document.
3) Protective device power frequency voltage test required in 6.3.3 of this document.
4) Protective device fault-current withstand capability shall be tested in accordance with ANSI/IEEE C62.11.

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6.2.8 Radio influence voltage test

The radio influence voltage test shall be performed with the line trap suitably supported in order to determine the radio influence voltage produced by the line trap itself. The equipment and general method used in determining the radio influence voltage shall be in accordance with the NEMA Standards Publication No. 107. The radio influence voltage shall not exceed the value in accordance with 5.1.10.

6.2.9 Self-resonant frequency test

The self-resonance of the main coil shall be determined by measuring the voltage across the coil and the current through the coil using a suitable method (e.g., volt-ammeter, bridge, etc.). The signal shall be applied across the main coil with the voltage held constant. The frequency shall be varied until the self-resonant point is determined (minimum current through the coil).

The self-resonant frequency shall be in accordance with 5.1.12.

6.2.10 Bandwidth test

The bandwidth test for a line trap shall be performed by measuring the blocking impedance of the line trap. The measurement shall determine the lowest and highest frequencies at which the rated blocking impedance in accordance with 5.2.3, is obtained. Sufficient data shall be taken to characterize the impedance variation between these two extremes.

6.2.10.1 Single-frequency line trap

The test shall be performed at the upper, middle, and lower frequency of each rated tuning range (see table 9).

6.2.10.2 Two-frequency line trap

The test shall be performed at the extremes of each rated tuning range. A test shall be performed at the lowest frequency of the range with the second frequency being spaced so that the lowest frequency is 25 percent or 25 kHz (whichever is greater) lower than the upper frequency. Another test shall be performed at the highest frequency of the range with the second frequency being spaced so that the lower frequency is 25 percent or 25 kHz (whichever is greater) lower than the upper frequency (see table 9).

6.2.10.3 Field adjustable wide-band line traps

The test shall be performed at the upper, middle, and lower frequency of each rated tuning range and for each rated blocking impedance. The resistive blocking impedance shall also be measured (see table 9).

6.2.10.4 Factory fixed wide-band line traps

The test shall be performed for the specified bandwidth and blocking impedance. The resistive blocking impedance shall also be measured.

6.2.11 Variation of blocking characteristics with change in ambient temperature and change in continuous current

The variation in the resonant frequency(ies) of a single-frequency, or two-frequency line trap and the GMF of a field-adjustable wide-band line trap caused by variation of the ambient temperature from -40°C to +45°C, and concurrent variations of the continuous current from zero to rated continuous current shall be

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determined by measuring the capacitance, at 100 kHz, of the tuning device(s) over its operating temperature range. The resulting variation in the resonant frequency or GMF shall be in accordance with 5.2.4.1 or 5.2.4.2 (whichever is applicable) and shall be calculated as follows:

$$V\% = \frac{f_h - f_l}{\frac{(f_h + f_l)}{2}} \times 100$$

Where:

f_h = highest frequency calculated from capacitor measurements

f_l = lowest frequency calculated from capacitor measurements

The variation in blocking impedance of a factory fixed wide-band line trap caused by a change in ambient temperature from -40°C to +45°C, and concurrent variations of the continuous current from zero to rated continuous current, shall be determined by blocking impedance measurements over the operating temperature range of the tuning device(s). The minimum blocking impedance over the bandwidth shall be in accordance with 5.2.4.2.

The lower limit of the operating temperature range of the capacitor is -40°C with zero current. The upper limit is +45°C, plus the temperature rise of the tuning device(s) measured in 6.2.2.6.

Since the inductance of the line trap basically does not change with variations in temperature or current, it is sufficient to subject only the tuning devices to the temperature cycles.

6.2.12 Auxiliary protective device tests

For these tests the tuning device shall not be connected to the main coil.

The requirements for the auxiliary protective device in accordance with 5.2.5, shall be verified by the following tests:

1) A power frequency voltage, "E," in accordance with 5.1.8 shall be applied across the terminals of the tuning device for a minimum of two seconds during which time the auxiliary protective device shall not spark over.

2) With the voltage, "E," applied across the terminals of the tuning device as in (1), a 1.2-5.0 x 40–60 microsecond impulse voltage with sufficient magnitude to cause sparkover of the auxiliary protective device shall be applied. At the first power frequency current zero after the impulse the auxiliary protective device shall not continue to spark over.

6.2.13 Insulation tests of the tuning device components protected by auxiliary protective device(s)

To verify the requirements of 5.2.6, the following tests shall be performed:

1) The impulse sparkover voltage of the auxiliary protective device shall be determined by testing with a 1.2-5.0 x 40–60 microsecond waveform. The tests shall consist of five positive and five negative impulse voltage waves. The setting of the auxiliary protective device shall be the maximum production setting and shall not be less than that required in 6.2.12.

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2) An impulse voltage of 1.2-5.0 x 40–60 microseconds shall be applied to the tuning device. The auxiliary protective device shall be disconnected and the components shall be in the same physical relation and with the same electrical connections they will have in service. Components not protected by the auxiliary protective device shall be disconnected. The test shall consist of five positive and five negative impulse voltage waves. The peak value shall be 30% above the impulse sparkover voltage determined above.

6.2.14 Insulation test of the assembled tuned-type line trap

The insulation test shall be performed on an assembled tuned-type line trap. Tuning device components and wiring shall be connected in the operational setting which produces a condition of maximum voltage stress on the components and wiring, and between the live parts.

The insulation test of the assembled tuned-type line trap shall be performed by applying a 1.2-5.0 x 40–60 microsecond impulse voltage to the terminals of the line trap with the protective device disconnected and with the auxiliary protective device shorted. The magnitude of the voltage is determined from 5.1.9.

A series of 5 positive and 5 negative impulse voltage waves shall be applied to the line trap.

To verify successful completion of the test, oscillograph records shall show no disruption in the 1.2-5.0 x 40–60 microsecond positive and negative voltage waveforms, and the blocking impedance shall be measured before and after the test.

In general this test shall be performed in accordance with ANSI/IEEE 4.

6.3 Production test procedures

6.3.1 Measurement of main coil true inductance

The main coil true inductance shall be obtained by either of the following methods:

1) Measurement in accordance with 6.2.1(1).

2) Determination from the apparent power-frequency inductance of the main coil calculated by dividing this reactance by the angular power frequency. The product of this value and the ratio determined in 6.2.1, shall be not less than the rated inductance.

6.3.2 Measurement of main coil apparent power-frequency inductance

The voltage/current method shall be used to determine the power frequency reactance of the main coil. The apparent power frequency inductance of the main coil is calculated by dividing this reactance by the angular power frequency.

6.3.3 Power frequency test of protective device and auxiliary protective device(s)

The protective device shall be subjected to power-frequency voltage withstand tests, for metal-oxide surge arresters according to ANSI/IEEE C62.11. The auxiliary protective device(s) shall be given three consecutive power-frequency spark over tests, each of which shall be within the sparkover voltage range certified by the manufacturer.

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6.3.4 Measurement of blocking impedance

The blocking impedance of each line trap shall be measured using the voltmeter-ammeter method, the bridge method, or an equivalent method, and shall meet the requirements of 5.2.3.

For a field-adjustable line trap, the measurement shall be performed with the line trap tuned to the specified frequency or frequencies or, if not specified, to a frequency or frequencies which require(s) all tuning device components to be connected in the circuits.

6.3.5 Measurement of tuning device component values

The capacitance, inductance, and resistance of the tuning device capacitors, inductors, and resistors, respectively, shall be measured to verify the component design values.

6.3.6 Power-frequency dielectric withstand test on tuning device

For the purpose of this test the tuning device is disconnected from the main coil and a test voltage E_t = 1.3 "E" applied for 5 seconds. The voltage "E" is determined in accordance with 5.1.8.

6.3.7 Turn-to-turn insulation test of the main coil

The insulation test procedures for the main coil shall be performed according to ANSI/IEEE C57.21 (see 10.3.3.2). The insulation test level shall not be less than that required in 5.1.9.

7 Manufacturing Requirements

7.1 Mounting

Line traps for mounting on insulators shall be equipped with flanges to fit 5-inch (127 mm) or 7-inch (178 mm) bolt circles in accordance with ANSI C29.8.

> **Note**—In suspension mounting of line traps, care must be taken not to exceed the tensile strength requirements in accordance with 5.1.11.

7.2 Terminals

7.2.1 Location

The line-side and station-side terminals shall be located at opposite ends of the line trap.

7.2.2 Types

The terminals of the line traps for currents 1600 amps and below, shall be flat pads at least 3 inches (76 mm) by 3 inches (76 mm). The terminals of the line traps for currents 2000 amps and above, shall be flat pads at least 4 inches (102 mm) by 4 inches (102 mm). Four 9/16-inch-diameter (14 mm) holes shall be drilled symmetrically on 1-3/4-inch (45 mm) centers to allow connections both in line with, and at right angles to the coil axis.

Terminals which are an integral part of a structural member, such as a crossarm, shall conform to the above, except it shall be permissible to allow connections only in line with the coil axis.

It shall be possible to make connection to either or both sides of the terminals.

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Copper terminals shall be treated to allow the use of either aluminum or copper connectors.

> **Note**—Aluminum terminals are suitable for aluminum connectors. When copper connectors are used with aluminum terminals, the connectors should be treated to allow an aluminum-to-copper joint.

For additional information on connections, see NEMA Standards Publication No. CC 1, Section 5.12.

Alternate terminal locations can be found in Appendix A3.

7.3 Tuning and protective device location and mounting

Tuning and protective devices shall be located and mounted so that they can be adjusted or replaced without removing the line trap main coil from its installation.

7.4 Bird barriers

All line traps shall be provided with barriers. No entrance to the line trap shall admit a sphere having a diameter greater than 5/8 inch (16 mm).

7.5 Nameplate markings for the main coil

The following minimum information shall be on the nameplates of all line traps:

1) Manufacturer's name and year of manufacture
2) Manufacturer's type or model designation
3) Manufacturer's serial number
4) Manufacturer's instruction book or data sheet number
5) Rated inductance (mh)
6) Rated continuous current (A)
7) Type of tuning
8) Frequency band(s) or center frequency(ies)
9) Weight (lbs. Or kg)
10) Tensile strength rating for suspension only
11) Main coil orientation class
12) Rated short-time current (ka) and duration(s)
13) Rated power frequency (Hz)

7.6 Nameplate markings for the tuning device

1) Manufacturer's name and year of manufacture
2) Manufacturer's type or model designation
3) Serial number
4) Frequency band(s) (kHz)
5) Blocking impedance (minimum value) (omega)
6) Rated impulse protective level (kV)

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Annex A
(Informative)
Guide for emergency overload current capability of line traps

Line traps are designed within temperature-rise limitations to ensure normal life expectancy. Any values of currents in excess of the rated current in this standard may cause the designed temperature rise to be exceeded and may shorten the life expectancy of the line trap.

Table A1 shows percentages of rated continuous current that have been selected to minimize the reduction in operating life and should be applied with great care.

The guidelines in table A1 may be applied to all line traps covered in this standard.

To avoid loss of life expectancy for the line trap it is recommended that purchaser clearly specify his emergency overload requirements at time of purchase.

Table A1 – Emergency overload current as a percentage of rated continuous current

Ambient Temperature (Degrees Celsius)	Emergency Period			
	15 Minutes	30 Minutes	1 Hour	2 Hours
45	138	128	118	108
40	140	130	120	110
20	145	135	125	115
0	150	140	130	120
-20	155	145	135	125
-40	160	150	140	130

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Annex B
(Informative)
Measurement of losses at power frequency

Since line traps operate at extremely low power factors, small variations in frequency, deviations from the true sine wave in applied voltage, errors in measuring components, and electromagnetic interference may introduce significant errors in loss measurements. Proper test conditions and precision components, specifically designed for low power factor measurements, are essential for an accurate determination of line trap losses.

Impedance bridges and current comparator bridges are frequently used to measure losses. They are generally more accurate than wattmeter measurements. While many configurations of impedance bridge networks are possible, the choice of a particular network shall be determined by the measurement problem at hand and the testing facilities available.

If the purchaser requires the losses to be determined, this should be done by agreement with the manufacturer. A requirement for lower power losses can influence the overall expenditure for the line trap.

Since line traps vary widely in design and construction, it is recommended, for comparison purposes, that the losses be corrected for a temperature of 75°C.

Measurements should be in accordance with IEEE C57.21.

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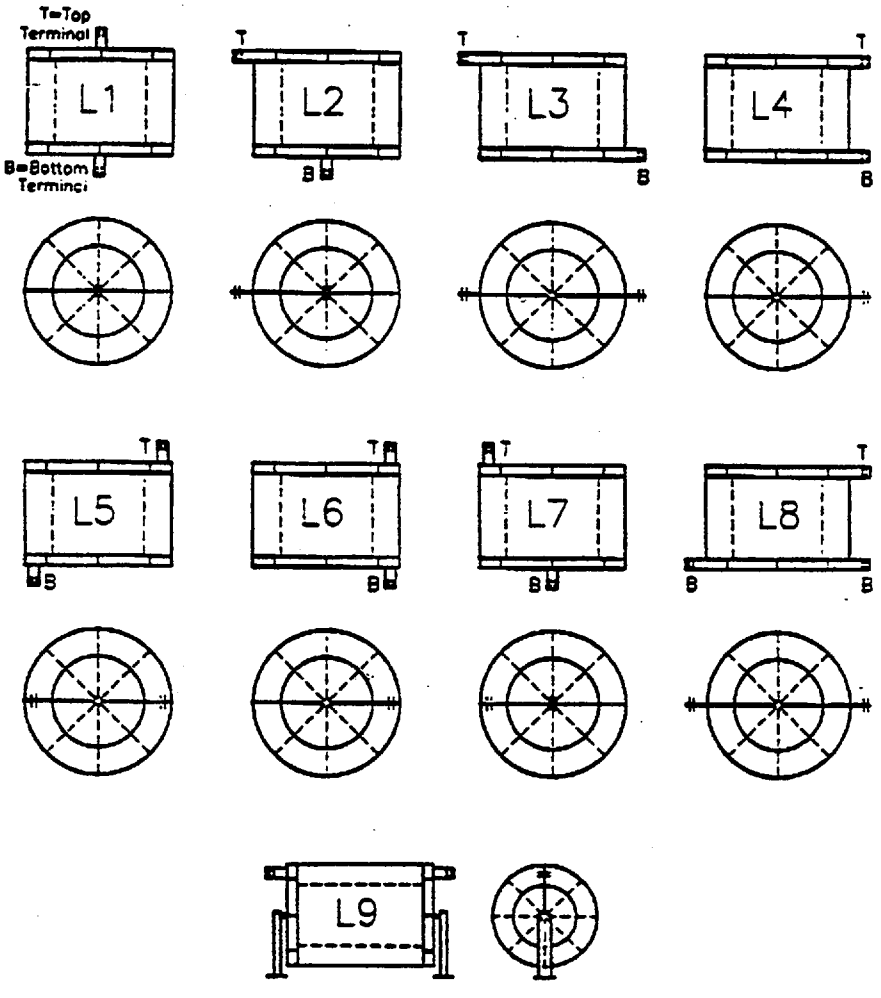
Annex C
(Informative)
Terminal orientation

The following are the most common terminal orientations in use. However, other arrangements are also possible; hence, it is recommended that purchaser clearly specify one of the following arrangements or any other peculiar orientation at time of purchase.



Note—Horizontal orientation may not be practical for all ratings.

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