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nema

Land Based Steam Turbine Generator Sets 0 to 33,000 KW

NEMA

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION ■ 2101 L STREET, N.W., WASHINGTON, D.C. 20037

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Foreword

This Standards Publication has been developed by the Steam Turbine Section of NEMA. In its preparation consideration has been given to the work of other organizations, such as the American National Standards Institute, the American Society of Mechanical Engineers, and the American Gear Manufacturers Association, striving toward the development of standards, and credit is hereby given to all whose standards may have been helpful in the preparation of this publication.

The purpose of this Standards Publication is to facilitate the application of turbine-generator sets by engineers, users, and contractors, to promote the economies of steam power generation equipment, and to assist in the proper selection and application of the differing designs of steam turbine-generator sets.

Users needs have been considered throughout the development of these standards. Comments or recommended revisions are welcome and should be submitted to:

Manager, Engineering Department
National Electrical Manufacturers Association
2101 L Street, N.W.
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Scope

This Standards Publication covers single-stage and multistage steam turbines, reduction gears, air-cooled electric generators, switchgear, and auxiliary systems. These standards are also applicable to turbines expanding various gases or compressed air.

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LAND BASED STEAM TURBINE GENERATOR SETS

Section 1

REFERENCED STANDARDS AND DEFINITIONS

1.1 REFERENCED STANDARDS

In this publication, reference is made to the standards listed below. Copies are available from the indicated sources:

American Boiler Manufacturers Association
1500 Wilson Boulevard
Arlington, VA 22209

Boiler Water Quality and Steam Purity Rates for Water Tube Boilers (1982)

American Gear Manufacturers Association
1901 North Fort Myer Drive
Arlington, VA 22209

421.06 *Practices for High-Speed Helical and Herringbone Generator Units*

American National Standards Institute
1430 Broadway
New York, NY 10018

B1.20.1-1983 *General Purpose Pipe Threads (Inch)*
B16.1-1980 *Cast Iron Pipe Flanges and Flanged Fittings Class 25, 125, 250, and 800*
B16.5-1981 *Fittings, Flanges, and Valves*
B31.3-1984 *Chemical Plant and Petroleum Refinery Piping*
S1.4-1983 *Specification for Sound Level Meters*
S5.1-1971 *Test Code for the Measurement of Sound from Pneumatic Equipment*
C37.06-1979 *Standard for High Voltage Circuit Breakers*
C37.13-1981 *Standard for Low Voltage AC Power Circuit Breakers Used in Enclosures*
ANSI/IEEE 100-1984 *Dictionary of Electrical and Electronic Terms*

Expansion Joint Manufacturers Association
25 North Broadway
Tarrytown, NY 10591

The Standard of the Expansion Joint Manufacturers Association (1980)

Institute of Electrical & Electronic Engineers
345 East 47th Street
New York, NY 10017

IEEE Standard 1-1969 *General Principles for Temperature Limits in the Rating of Electrical Equipment*
ANSI/IEEE 100-1984 *Dictionary of Electrical and Electronics Terms*
IEEE Standard 112-1984 *Test Procedures for Polyphase Induction Motors and Generators*
IEEE Standard 115-1983 *Test Procedures for Synchronous Machines*
IEEE Standard 200-1975 *Design Electrical & Electronic Parts & Equipment (Device Numbers and Functions)*

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MG 1-1978 (R 1981)	*Motors and Generators*
SM 23-1979	*Steam Turbines for Mechanical Drive Service*
AB 1-1975 (R 1981)	*Molded Case Circuit Breakers*
250-1985	*Enclosures for Electrical Equipment (1000 Volts Maximum)*

1.2 DEFINITIONS

The terms in Section 1.2 are defined as they apply to land based steam turbine generator sets covered in this Standards Publication. Definitions marked with an asterisk (*) are in accordance with ANSI/IEEE Std. 100-1984, *IEEE Standards Dictionary of Electrical and Electronic Terms*

AC POWER—Power used in an alternating current electrical circuit. (See Appendix.)

ALTERNATING CURRENT (ac)—Current which varies from zero to a positive maximum to zero to a negative maximum to zero, a number of times per second, the number being expressed in cycles per second or Hertz (Hz).

ALTERNATOR—A generator which produces alternating current.

AMBIENT TEMPERATURE—The temperature of the surrounding air in which the generating system operates.

***AMMETER**—An instrument for measuring the magnitude of an electric current.

AMORTISSEUR—A short-circuited winding consisting of conductors embedded in the pole faces of the rotor of a synchronous generator.

AMPERE—The unit of electric current flow. One ampere will flow when one volt is applied across a resistance of one ohm.

APPARENT POWER—The vectoral sum of real power and reactive power. (See Appendix.)

AUTOMATIC TRANSFER SWITCH—An automatic device for transferring an electrical load from one power source to another.

***BRUSHLESS EXCITER**—An ac (rotating armature type) exciter whose output is rectified by a semiconductor device to provide excitation to an electric machine. The semiconductor device would be mounted on and rotate with the ac exciter armature.

***CAPACITANCE**—The property of a system of conductors and dielectrics that permits the storage of electrically separated chargers when potential differences exist between the conductors.

***CAPACITOR**—A device, the primary purpose of which is to introduce capacitance into an electric circuit.

***CIRCUIT BREAKER**—A mechanical switching device capable of making, carrying, and breaking circuit conditions and also, making, carrying for a specified time, and breaking currents under specified abnormal circuit conditions, such as short circuit.

CONTINUOUS RATING—The load rating of an electrical generating system which it is capable of supplying without exceeding its specified maximum temperature rise limits for continuous operation.

***CORE**—An element made of magnetic material, serving as a part of a path for magnetic flux.

CRITICAL SPEED—A speed at which the amplitude of the vibration of a rotor due to shaft transverse vibration reaches a maximum value.

CROSS-CURRENT COMPENSATION—One of two systems which permits generators in parallel, to share the reactive component of the power in proportion to their rating while maintaining constant output voltage. See Droop Compensation.

CROSS-CURRENT COMPENSATION TRANSFORMER (CCCT)—A current transformer which controls the division of reactive KVA in proportion to the rating of generators operating in parallel.

CURRENT TRANSFORMER (CT)—An instrument

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transformer used in conjunction with ammeters and control circuits that produces an output proportional to primary current.

CYCLE—One complete reversal of an alternating current or voltage, from zero to a positive maximum to zero to a negative maximum back to zero. The number of cycles per second is the frequency, expressed in Hertz (Hz).

DC FIELD—The field poles and their winding which, when energized, produce the magnetic flux in a generator.

DELTA CONNECTION—A three phase connection in which the start of each phase is connected to the end of the next phase, forming the Greek letter Delta (Δ).

***DEVIATION FACTOR**—The deviation factor of a voltage wave is the ratio of the maximum difference between corresponding ordinates of the wave and of a sine wave of the same root-mean-square value and time base to the peak value of this sine wave when this sine wave is superimposed in such a way as to make this difference as small as possible.

DIODE—Solid state semiconductor which allows current to pass in one direction only.

DROOP—The change in speed when the power output is gradually changed from zero power to rated power output. See Speed Regulation.

DROOP COMPENSATION—A system which permits generators in parallel to share the reactive component of the power in proportion to their rating. See also Cross Current Compensation.

EFFICIENCY—The efficiency of a turbine generator set is the ratio (expressed as a percentage) of its useful power output to its net available energy input.

EXCITATION—The input of dc power into the rotating field coils of a synchronous generator or the input of ac power into the stator coils of an induction generator.

EXCITER—A rotating or static device for supplying excitation to the field of a synchronous generator.

FIELD—A region of space under magnetic influence resulting in a distribution of magnetic lines of flux in that space.

***FIELD COIL**—A suitably insulated winding to be mounted on a field pole to magnetize it.

***FIELD POLE**—A structure of magnetic material on which a field coil may be mounted.

FREQUENCY—The number of complete cycles of an alternating voltage or current per unit of time, usually per second, expressed in Hertz (Hz).

FREQUENCY DROOP—The change in frequency expressed in Hertz (Hz) between steady state no load and steady state full load.

FREQUENCY REGULATION—The percentage change in frequency from steady state full load to steady state no load.

FREQUENCY RECOVERY TIME—The interval of time required for the frequency to return to and remain with a prescribed frequency band following an instantaneous load change.

FREQUENCY TRANSIENT—The maximum frequency deviation as a result of a sudden change in load.

FULL LOAD CURRENT—The full load current of a generator is the value of current in root mean square (rms) or dc amperes which it carries when delivering rated output under rated conditions.

***GENERATOR**—A machine that converts mechnical power into electric power.

***GROUND**—A conducting connection, whether intentional or accidental, by which an electric circuit or equipment is connected to the earth, or to some conducting body of relative large extent that serves in place of the earth.

GROUNDED NEUTRAL—A point of an electrical system which is intentionally connected to ground.

***HERTZ (Hz)**—The unit of frequency, one cycle per second.

HUNTING—The oscillation of voltage or frequency above and below the mean value. An unstable condition.

IMPEDANCE—The total opposition offered by a circuit to the flow of alternating current. It is composed of resistance and reactance (inductive or capacitive, or both), and its symbol "Z" is expressed in ohms.

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***INDUCTANCE**—The property of an electric circuit by which a varying current induces an electromotive force in that circuit or in a neighboring circuit.

INDUCTION GENERATOR—An induction machine driven above synchronous speed by an external source of mechanical power for use as a generator.

IN-PHASE—A condition in which the ac voltage waves of two generating systems coincide.

INRUSH CURRENT—The inrush current of a machine or apparatus is the maximum value of rms or dc amperes which it carries after being suddenly and fully energized and prior to reaching a stable operating condition.

***INSULATION**—Material or a combination of suitable nonconducting materials that provide electric isolation of two parts at different voltages.

KILOVOLT AMPERE—One thousand volt amperes (apparent power), equal to kilowatt divided by the power factor, also equal to (root-mean-square current) times (root-mean-square volts in kilovolts). (See Appendix.)

KILOVOLT AMPERE REACTIVE—One thousand volts ampere reactive—reactance power.

KILOWATT—One thousand watts (real power). Equal to kilovolt amperes times power factor. (See Appendix.)

KILOWATT HOUR (kwh)—One thousand watts times one hour, unit of electric energy or work.

***LATERAL CRITICAL SPEEDS**—The speeds at which the amplitude of the lateral vibration of a machine rotor due to shaft rotation reach their maximum value.

LINE-TO-LINE VOLTAGE—The voltage existing between any two conductors in polyphase circuits. Also, the voltage between the phase conductors.

LINE-TO-NEUTRAL VOLTAGE—The voltage existing between any phase conductor and the neutral conductor.

MANUAL TRANSFER SWITCH—A manually operated device for transferring an electrical load from one power source to another.

MAXIMUM POWER—Maximum power is the output power at the generator terminals in kilowatts when operating with maximum inlet conditions, minimum exhaust conditions, specified power factor, minimum extraction, and maximum induction steam flow, when applicable.

NEUTRAL—The point common to all phases of a polyphase circuit—it is the point along an insulated winding where the voltage is the instantaneous average of the line terminal voltage during normal operation.

NON-SALIENT POLE—A pole structure with its electrical coils wedged in axial slots in a cylindrical body.

NORMAL POWER—Normal power is the power which the turbine generator set will produce when operating at specified normal conditions.

OHM—Unit of electrical resistance. One volt will cause a current of one ampere to flow through a resistance of one ohm.

OVERLOAD POWER—Overload power is that load in excess of rated load which the turbine generator unit is capable of delivering for a specified period of time. The voltage, frequency, and operating temperature may differ from normal rated values.

OUT-OF-PHASE—A condition in which the ac voltage waves of two generating systems do not coincide.

PARALLEL OPERATION—Two or more generators of the same phase, voltage, and frequency characteristics supplying power to the same load.

PARALLELING—The procedure used to connect two or more generators to a common load.

PERMANENT MAGNET GENERATOR (PILOT EXCITER)—A generator in which the open-circuit magnetic flux field is provided by one or more permanent magnets.

PHASE—The number of complete voltage or current sine waves, or both, generated per 360 electrical degrees.

PHASE ANGLE—The amount by which the zero point of the voltage wave differs from the zero point of the current wave in an ac circuit. (See Appendix.)

PHASE ROTATION—The sequence in which the phases of a generator or network pass through the positive maximum points of their waves. The same sequence must exist

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when units are paralleled.

PHASE SEQUENCE—The order in which the voltages successively reach their positive maximum values between terminals.

POLE—A machine structure which generates and directs lines of magnetic energy.

POTENTIAL TRANSFORMER (VOLTAGE TRANSFORMER)—An instrument transformer that is intended to have its primary winding connected in shunt with a power-supply circuit, the voltage of which is to be measured or controlled.

POWER FACTOR—The ratio of real power divided by apparent power. (See Appendix.)

RATED CURRENT—The rated current of a generator is the value of current in rms or dc amperes which is obtainable from a turbine generator set when it is functioning at rated conditions. See Full Load Current.

REACTANCE—The out-of-phase component of impedance that occurs in circuits containing inductance or capacitance, or both.

REACTIVE KVA (KVAR)—The reactive component of ac power. (See Appendix.)

REAL POWER—The real component of ac power. (See Appendix.)

REDUCTION GEAR—A mechanical device used to reduce the turbine speed to the generator speed.

RELAY—A device which initiates an output change as a response to a specified input change.

RESISTANCE TEMPERATURE DETECTOR (RTD)—A device for measuring temperature in which the electrical resistance of the device changes with temperature.

RESPONSE TIME—The time required to recover to the steady state operating value after a sudden change in load.

ROOT MEAN SQUARE (rms)—A measurement of alternating current and voltage and representing a proportional value of the true sine wave.

ROTOR—A pole structure and its electrical coils which project from a hub or yoke.

SERVICE FACTOR—The factor by which the maximum power capability of a device exceeds its rated power.

***SHORT CIRCUIT RATIO**—The ratio of the field current for rated open-circuit armature voltage and rated frequency to the field current for rated armature current on sustained symmetrical short-circuit at rated frequency.

SHORT TERM RATING—The load rating of an electrical generating system which it is capable of carrying for a short specified period of time.

SILICON-CONTROLLED RECTIFIER (SCR)—Solid state device which permits current to flow in one direction only when triggered by a suitable potential applied to the control lead or terminal.

SPECIFIED CONDITIONS—Specified conditions are the specified power, steam conditions, voltage, frequency, and power factor at which the steam rate is guaranteed.

STATIC EXCITER—A non-rotating device which furnishes direct current to the generator field.

STATOR—A stationary part of a generator which includes the magnetic circuit and associated winding and leads.

***STATOR WINDING**—A winding on the stator of a machine.

STEADY STATE—The operating point under constant load when no transients are present.

STEAM TURBINE—A prime mover which converts the thermal energy of steam directly into mechanical energy of rotation.

***SWITCHGEAR**—A general term covering switching and interrupting devices and their combination with associated control, instrumentation, metering, protective and regulating devices. It also includes assemblies of these devices, associated interconnections, accessories, and supporting structures used primarily in connection with the generation, transmission, distribution, and conversion of electric power.

SYNCHRONOUS GENERATOR—A synchronous alternating current machine which transforms mechanical

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power into electrical power and operates at synchronous speed at any load. Excitation is supplied by a generator exciter.

SYNCHRONOUS SPEED—The generator speed which is directly proportional to the frequency of the system to which the generator is connected. This is expressed by the following equation:

$$N = \frac{120F}{P}$$

where:
N = speed in rpm
F = frequency in Hz.
P = number of poles

SYNCHRONIZING—The process whereby a synchronous machine, with its voltage and phase suitably adjusted, is paralleled with another synchronous machine or system.

TELEPHONE INFLUENCE FACTOR (TIF)—The telephone influence factor of a synchronous generator is a measure of the possible effect of harmonics in the generator voltage wave on telephone circuits.

THERMOCOUPLE—A device for sensing temperature in which a pair of dissimilar conductors are joined at two points so that an electromotive force is developed by thermoelectric effects when the junctions are at different temperatures.

***TORSIONAL CRITICAL SPEED**—The speed at which the amplitudes of the angular vibrations of a machine rotor due to shaft torsional vibration reach a maximum.

TRANSFORMER—A static electric device that introduces mutual coupling between electric circuits.

VOLT—The unit of electromotive force. One volt will cause a current of one ampere to flow through a resistance of one ohm.

VOLTAGE DIP—The maximum reduction in voltage resulting from an increase in load.

VOLTAGE RANGE—The voltage range of a generator is the band width of voltage through which the generator is capable of adjustment and operation from no load through full load at specified conditions.

VOLTAGE REGULATION—The voltage regulation of a generator is the difference between the regulated no load and the regulated full load output voltage expressed as a percentage of the regulated full load voltage.

VOLTAGE REGULATOR—A device which maintains the voltage output of a generator.

VOLTMETER—An instrument for measuring the voltage magnitude.

WYE CONNECTION—A method of interconnecting the phases of a three phase system to form a configuration resembling the letter "Y". A fourth or neutral wire can be connected to the center point.

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Section 2

CONSTRUCTION

2.1 GENERAL

2.1.1 Introduction

A steam turbine generator set includes a steam turbine, reduction gear (when applicable), and a generator.

The steam pressure converts energy from the available heat drop between two or more steam pressure levels into shaft power. The reduction gear, when applicable, allows the turbine to operate at an efficient speed and matches the output speed to the generator speed.

The generator converts the shaft power into electrical output at the generator terminals.

The turbine generator controls regulate the steam flow and generator excitation to produce stable operation.

Authorized Engineering Information 6-12-1985.

2.1.1.1 BASIS OF RATING

The basis of rating of the turbine generator set shall be the power output in kilowatts at the generator terminals when operating at the steam conditions, voltage, and power factor specified by the user (purchaser). The steam conditions as specified by the user shall be in accordance with the following:

Maximum Steam Conditions

Maximum steam conditions are the highest steam pressures and temperatures to which the turbine is subjected in usual operation.

Normal Steam Conditions

Normal steam conditions are the pressures and temperatures to which the turbine is subjected during specified normal operation.

Minimum Steam Conditions

Minimum steam conditions are the lowest steam pressures and temperatures to which the turbine is subjected in usual operation.

The steam conditions used for rating the turbine generator set shall be the normal steam conditions unless otherwise specified by the user (purchaser).

For the purpose of this standard, normal and rated are synonomous.

NEMA Standard 6-12-1985.

2.1.1.2 GUARANTEED STEAM RATE OR HEAT RATE

The turbine generator set guaranteed steam rate or heat rate is the rate which will not be exceeded when the turbine generator set is operating at specified conditions. The steam rate shall be stated in pounds per kilowatthour, or BTU per kilowatthour for heat rate, based on kilowatt output measured at the generator terminals. For separate exciters, the exciter losses shall be deducted from the output kilowatts.

NEMA Standard 6-12-1985.

2.1.2 Bearings and Bearing Housings

Radial bearings shall be supplied as needed to support the rotating elements of the turbine generator set. These shall be of the sleeve, tilting-pad, or antifriction type. Sleeve bearings and tilting-pad bearings shall be split to facilitate inspection and replacement without removal of the rotor.

Thrust bearings shall be supplied as needed to transmit axial thrust from rotating elements to the bearing housings and maintain proper axial clearances between stationary and rotating parts. These shall be of the antifriction, land, or segmented tilting-pad type.

Bearing housings shall be supplied to contain and support the bearings in the turbine generator set. The bearing housings shall be equipped with seals to prevent leakage of lubricant and to prevent the entrance of moisture, dust, and foreign materials.

NEMA Standard 6-12-1985.

2.1.3 Lubrication

2.1.3.1 NONPRESSURE-TYPE OIL LUBRICANT

Sleeve Bearings

Lubrication should be provided by oil rings or other means.

Bearing housings should be large enough to permit solids or water to settle to the bottom and should have a drain connection at the lowest point, oil-fill fittings, and an oil-level indicator.

Facilities for cooling should be provided when necessary to ensure the proper oil temperature. The cooling eater should be supplied at a temperature not exceeding 90°F (34°C).

Antifriction Bearings

Bearings should be oil- or grease-lubricated.

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Means should be provided for venting the grease-lubricated bearings to prevent the buildup of pressure within the housing.

Facilities for cooling should be provided when necessary to ensure the proper lubricant temperature. The cooling water should be supplied at a temperature not exceeding 90 °F (34 °C).

Grease-lubricated antifriction bearings should be regreasable in the field. Grease fittings should extend to the outside of the machine to permit regreasing during operation.

Authorized Engineering Information 6-12-1985.

2.1.3.2 Pressure-Type Oil Lubrication

It is recognized that there is a wide variation of turbine generator sizes and applications which makes it impractical to have one recommended lubrication system design. However, the following should serve as a general design guide to the user for specifying his requirements:

A main shaft driven oil pump or a separately driven pump to provide oil for lubrication and governing.

An auxiliary oil pump for use during the start-up or shut-down period should be furnished when required by the design or when specified. This pump should be powered by a different source of energy than the main oil pump. A pressure sensing device should be provided for automatically starting the auxiliary oil pump when the oil pressure in the main system drops below a predetermined value.

For a turbine driven auxiliary oil pump, the turbine should conform to all of the applicable provisions of NEMA Standards Publication SM 23-1979, *Steam Turbines for Mechanical Drive Service*.

Oil Reservoir

An oil reservoir should have:

1. Sufficient capacity to provide for the defoaming and settling of foreign material and for the contents of the system when drained.
2. Interiors cleaned.
3. Fill connection, level indicator, and breather suitable for outdoor use.
4. Sloped bottom and connection for complete drainage when the design permits.
5. Clean-out opening large enough to permit inspection and cleaning.
6. Reservoir and fittings applicable for the intended ambient conditions.

Oil Cooler

The oil cooler should be capable of maintaining the temperature of the oil supplied to the bearings at a maximum of 120 °F (49 °C), with a maximum cooling water temperature not exceeding 90 °F (32 °C). It should have a fouling factor of 0.001 on the water side and be suitable for a working pressure of not less then 75 psig.

Single or twin shell-and-tube type coolers may be used. Twin coolers should be piped in parallel with a continuous flow transfer valve to permit the transfer of oil from one cooler to the other without interrupting the oil flow. Each cooler should be sized for the total cooling load, and should be arranged for cleaning either tube bundle with the turbine in operation. Each cooler should be capable of operating at a pressure equal to or greater than the relief valve setting of positive displacement oil pumps, or of the maximum discharge pressure of centrifugal oil pumps.

Oil Filter

Single or twin full-flow oil filters may be used. A filter(s) should be capable of removing particles larger than 25 microns. When the filter is clean the pressure drop should not exceed 5 psi at design temperature and flow. Twin filters should be piped in parallel with a continuous-flow transfer valve to permit the transfer of oil from one filter to the other without interrupting the oil flow. A common transfer valve may be used for the oil filter and coolers. The filter cartridge should be corrosion-resistant. Filter cases should be suitable for operation at a pressure not less than the relief value setting of the positive-displacement oil pumps, or at the maximum discharge pressure of centrifugal oil pumps.

Pressure gauges should be provided for each pressure level (for example, oil header to bearings, discharge from oil pumps, before and after filter(s) and control oil).

Thermometers when specified, should be provided for the oil outlet from each bearing housing and before and after oil cooler(s). Thermometers should be either mercury filled or of the corrosion-resistant bimetallic type.

An oil sight flow indicator when specified should be provided in the oil return from each bearing housing where the design permits.

A pressure regulator or relief valve should be provided to maintain the oil pressure levels.

After fabrication, piping should be cleaned by either mechanical or chemical means.

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2.1.3.3. A turbine generator set may combine a turbine, reduction gear, and generator using any combination of the lubrication systems described in 2.1.3.

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2.1.4 Weather Protection

Steam turbine generator sets should preferably be installed in enclosed areas. The effects of unusual service conditions may be mitigated by the use of one or more of the measures described in 2.1.4.1 and 2.1.4.2.

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2.1.4.1 EXPOSURE TO NATURAL ELEMENTS

In general, all exposed machined surfaces should be protected against rusting by a protective coating or paint after installation of the unit. Exposed working parts which affect operation of the unit, such as governor, governor linkage, fulcrum points, valve stems, and similar elements should be protected against rusting by the use of corrosion-resistant materials.

Generators should incorporate weatherproof construction or a weatherproof enclosure and space heater(s).

Equipment having nonpressure lubricated bearings should be designed to prevent the entrance of moisture, dust, and foreign materials to the governing systems and bearing housings.

Equipment having pressure lubrication or hydraulic governing systems, or both, should be protected as follows:

1. The lubrication system or governor system, or both, should be protected against the entrance of water or foreign materials by proper sealing devices. The points to be protected include all connections or openings to the oil reservoir, governor, servomotor, bearing housings, and similar elements. The reservoir should be provided with a vent with an air filter and connections to facilitate removal of water.
2. In addition to the foregoing protective measures, the following should be included when ambient temperatures will be less than 40°F (4.4°C).
   a. For use during down times, drains should be provided where water can collect for all steam, oil, and water lines, the turbine casing and steam chest, and the oil and water side of the oil cooler. Pneumatic "blow down" may be necessary in some instances.
   b. A heater for the oil reservoir. If an electric heater is specified, it must be of a sufficiently low watt density to prevent coking of the oil. An auxiliary pump may be required to ensure oil circulation for uniform heating.
   c. An enclosure or hood with venting to cover the governing system may be provided, and heating should be supplied to prevent icing. The amount and type of enclosure and heating will be governed by local conditions.
   d. Protection against freezing for instruments and small piping.

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2.1.4.2 EXPOSURE TO ABNORMAL ATMOSPHERIC CONDITIONS

If possible, the turbine generator set should be located away from damaging fumes and vapors, or abrasive, magnetic or metallic dust. If this is not practical, the atmospheric conditions should be called to the attention of the manufacturer. Suitable materials or protective coatings may be required to offset the corrosive effects of the fumes. When necessary, purge air connections on bearing housings, gland cases, and governors should be provided.

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2.1.5 Output Shaft Extensions

Output shaft extensions shall be suitable for a cylindrical or tapered coupling bore and provided with a keyway(s), tapered for hydraulic fit or flanged.

When a tapered shaft extension with keyway(s) is specified, the taper, coupling hub, and coupling nut shall be in accordance with NEMA Standards Publication SM 23-1979.

NEMA Standard 6-12-1985.

If cylindrical shaft extension is specified, it is recommended that the coupling-to-shaft fit be an interference fit.

When a hydraulic fit coupling is specified, the mounting method should be reviewed with the turbine, gear, and generator manufacturers.

Recommended use of one and two keys is as shown in Table 2-1.

Table 2-1
KEYWAYS

Nominal Shaft Diameter Inches	Nominal Shaft Diameter Millimeters	Maximum Speed Per One Key, R/Min
1.50 up to and including	40	16,000
2	50	14,000
2.50	65	12,000
3	75	11,500
3.50	90	10,500
4	100	10,500
4.50	115	9,500
5	125	9,500
5.50	140	8,500
6	150	8,500
6.50	165	7,500
7	180	7,500
7.50	190	7,000
8	200	7,000
9	230	6,500
10	250	5,000

Two keys may be used in any case.

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2.1.6. Coupling and Coupling Guard

For direct-connected turbine generator sets, a coupling shall be supplied between the turbine and the generator.

For geared turbine generator sets, a coupling shall be supplied between the turbine and the gear input shaft, and between the gear output shaft and the generator.

Flexible type couplings shall accommodate the maximum possible relative axial movement of the connected shafts without exceeding the thrust bearing capacities of the connected machines.

A limited-end-float flexible coupling shall be used to transmit power to a generator which has sleeve bearings. When the generator is energized, its rotor shall be free to position itself at the magnetic center of the generator. When the generator is not energized, the coupling shall limit relative axial motion between the generator rotor and the shaft of the machine which drives the generator.

Flexible coupling parts shall be machined to a tolerance of not more than 0.001 inch (0.025 mm) on the diameter and the face-to-face. The bore shall be concentric within 0.001 inch (0.025 mm) with the surface used for dial indicating. Where required by coupling size and speed, coupling parts, including bolts, shall be matchmarked and each hub shall be dynamically balanced. The assembled coupling shall be balanced to a tolerance which will permit satisfactory performance at speeds up to 110 percent of maximum continuous speed of the turbine and without damage at 110 percent of the tripping speed.

Non-flexible type couplings shall be installed in accordance with the manufacturer's instructions.

Couplings shall be mounted on the shaft with either a taper or a cylindrical fit.

An easily removable coupling guard shall be placed over all exposed couplings. The coupling guard shall be of sufficiently rigid design to withstand deflection and consequent rubbing as a result of bodily contact and shall extend to within ½ inch (12.7 mm) of a stationary housing.

NEMA Standard 6-12-1985.

2.1.7 Mounting Arrangement

The turbine generator set shall be mounted on a baseplate(s), soleplates, or a combination of both.

Baseplate—A fabricated steel structure having machined pads for mounting of the equipment and for grouting to the foundation.

Soleplate—Machined flat steel plates for mounting of the equipment supports and for grouting to the foundation.

NEMA Standard 6-12-1985.

2.1.8 Critical Speeds

The turbine generator set shall be designed so that its critical speeds, including the effect of couplings, shall not be detrimental to its satisfactory operation.

The calculated first lateral critical speed of a stiff shaft rotor shall be a minimum of 10 percent over the trip speed.

Torsional critical speed shall not occur at the operating speed of the turbine generator set.

The actual first lateral critical speed of a flexible shaft rotor shall be determined during the no-load running test when practical and shall be stamped on the nameplate followed by the word "test." When it is not practical to determine critical speeds during the running test, the calculated critical speed shall be stamped on the nameplate followed by the abbreviation "approx."

The calculated first lateral critical speed of a flexible shaft rotor(s) shall be not more than 80 percent of the rated speed, and the calculated second lateral critical speed shall be a minimum of 10 percent over the trip speed.

NEMA Standard 6-12-1985.

2.1.9 Vibration

The vibration (double amplitude) of the rotating elements when operated within the specified operating speed range at no-load, as measured on the surface of the shaft adjacent to the radial bearings shall be in accordance with Figure 2-1.

Shaft mechanical and electrical runout shall be determined by slowly rolling the rotor in vee blocks or its bearings when measuring the runout with a proximity probe. If it can be demonstrated that mechanical and electrical runout is present, this shall be added to the allowable vibration level up to a maximum 25 percent of the allowed double vibration amplitude of 0.25 mils, whichever is greater.

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Vibration of the installed turbine generator set may be adversely affected by many factors, such as piping loads, alignment at operating conditions, supporting structures, handling during shipment, handling and assembly at the site, and abnormal electrical conditions.

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2.1.10 Trip Speed

The steam turbine generator set shall be designed to withstand momentary operation at trip speed.

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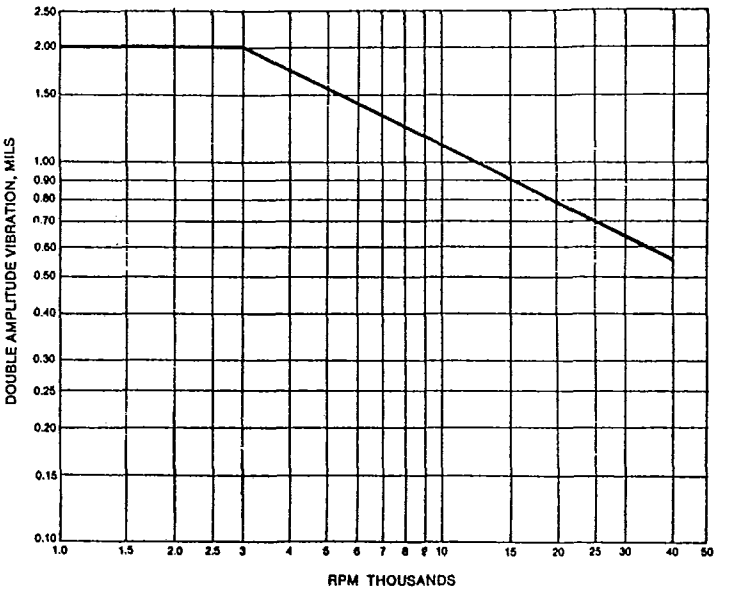


Figure 2-1
MAXIMUM PERMISSABLE SHAFT VIBRATION

2.1.11 Short Circuit Requirements

The turbine, gear, generator, and couplings of a turbine generator set shall be capable of withstanding, without injury, a 30 second 3-phase short circuit at the generator terminals when operating at rated kVA and power factor, at 5 percent overvoltage, with fixed excitation. The turbine, gear, generator, and couplings shall be capable of withstanding, without injury, any other short circuit at the generator terminals of 30 seconds or less provided:

1. The generator phase currents under fault conditions are such that the negative phase sequence current, (I_2) expressed in per unit of stator current at rated kVA, and the duration of the fault in seconds, t, are limited to values which give an integrated product, $(I_2)^2t$, equal to or less than 40, and
2. The maximum phase current is limited by external means to a value which does not exceed the maximum phase current obtained from the 3-phase fault.

NEMA Standard 6-12-1985.

2.2 TURBINE CONSTRUCTION

2.2.1 Types

2.2.1.1 NONCONDENSING TURBINE

A noncondensing turbine is a steam turbine designed to operate with an exhaust steam pressure equal to or greater than atmospheric pressure.

NEMA Standard 6-12-1985.

2.2.1.2 CONDENSING TURBINE

A condensing turbine is a steam turbine designed to operate with an exhaust steam pressure below atmospheric pressure.

NEMA Standard 6-12-1985.

2.2.1.3 SINGLE-VALVE SINGLE-STAGE TURBINE

A single-valve single-stage turbine is a steam turbine which has one governor-controlled valve and one stage.

NEMA Standard 6-12-1985.

2.2.1.4 SINGLE-VALVE MULTISTAGE TURBINE

A single-valve multistage turbine is a steam turbine which has one governor-controlled valve and two or more stages.

NEMA Standard 6-12-1985.

2.2.1.5 MULTIVALVE SINGLE-STAGE TURBINE

A multivalve single-stage turbine is a steam turbine which has two or more governor-controlled valves and one stage.

NEMA Standard 6-12-1985.

2.2.1.6 MULTIVALVE MULTISTAGE TURBINE

A multivalve multistage turbine is a steam turbine which has two or more governor-controlled valves and two or more stages. NEMA Standard 6-12-1985.

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2.2.1.7 CONTROLLED (AUTOMATIC) EXTRACTION TURBINE

A controlled (automatic) extraction turbine is a steam turbine which has an opening(s) in the turbine casing for the extraction of steam and which is provided with means for directly regulating the flow of steam to the turbine stages following the extraction opening for the purpose of controlling extraction pressure.

NEMA Standard 6-12-1985.

2.2.1.8 NONCONTROLLED EXTRACTION TURBINE

A noncontrolled extraction turbine is a steam turbine which has an opening(s) in the turbine casing for the extraction of steam but which does not have means for controlling the pressure of the extracted steam.

NEMA Standard 6-12-1985.

2.2.1.9 CONTROLLED INDUCTION (MIXED-PRESSURE) TURBINE

A controlled induction (mixed-pressure) turbine is a steam turbine which is provided with separate inlets for steam at two pressures and has an automatic device for controlling the flow of steam to the turbine stages following the induction opening.

NEMA Standard 6-12-1985.

2.2.1.10 NONCONTROLLED INDUCTION TURBINE

A noncontrolled induction turbine is a steam turbine which has an opening(s) in the turbine casing for the induction of steam but does not have means for controlling the pressure of the inducted system.

NEMA Standard 6-12-1985.

2.2.1.11 INDUCTION/EXTRACTION TURBINE

An induction/extraction turbine is a steam turbine which combines the features of extraction (controlled or noncontrolled) with the features of induction.

NEMA Standard 6-12-1985.

2.2.2 Thermodynamic Terms

2.2.2.1 STEAM AND HEAT RATES

1. *Theoretical Steam Rate*

Theoretical steam rate is the quantity of steam per unit of power required by an ideal Rankine cycle heat engine. It is expressed in pounds of steam per kilowatthour or in kilograms of steam per kilowatthour.

$$\text{Theoretical steam rate in pounds/kwh} = \frac{3413}{h_1 - h_2}$$

$$\text{Theoretical steam rate in Kg/kwh with h in kilojoule per kilogram.} = \frac{3600}{h_1 - h_2}$$

Based on Keenan, Keyes, et. al. Steam Tables (International Edition—Metric Units) or other steam tables or Mollier Charts, which are in accordance with the International Skeleton Tables of 1963 of the International Conference on the Properties of Steam that are expressed in joules per gram or kilojoules per gram, or based on Keenan and Keyes Steam Tables published in 1969 expressed in BTU per pound, where:

h_1 = The enthalpy of steam at inlet steam pressure and temperature.

h_2 = The enthalpy of steam at exhaust steam pressure and initial entropy.

NEMA Standard 6-12-1985.

2. *Heat Rate*

Heat rate is the heat supplied in BTU/hr minus heat returned in BTU/hr divided by output in kilowatts.

NEMA Standard 6-12-1985.

2.2.2.2 INLET STEAM PRESSURE

Inlet steam pressure is the pressure of the steam supplied to the turbine. It is measured at the steam inlet connection.

NEMA Standard 6-12-1985.

2.2.2.3 EXHAUST STEAM PRESSURE

Exhaust steam pressure is the pressure of the steam system to which the turbine exhausts and is measured at the exhaust connection of the turbine.

NEMA Standard 6-12-1985.

2.2.2.4 EXTRACTION STEAM PRESSURE

Extraction steam pressure is the pressure of the steam extracted from the turbine and is measured at the extraction connection of the turbine.

NEMA Standard 6-12-1985.

2.2.2.5 INDUCTION STEAM PRESSURE

Induction steam pressure is the pressure of the secondary steam supplied to the turbine and measured at the induction connection of the turbine.

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2.2.2.6 STEAM TEMPERATURE

1. *Inlet Steam Temperature*

Inlet steam temperature is the total temperature of the steam supplied to the turbine. It is measured at the steam inlet connection of the turbine and is expressed in degrees Fahrenheit or in degrees Celsius.

NEMA Standard 6-12-1985.

2. *Exhaust Steam Temperature*

Exhaust steam temperature is the total temperature of the steam exhausted from the turbine. It is measured at the exhaust connection of the turbine and is expressed in degrees Fahrenheit or in degrees Celsius.

NEMA Standard 6-12-1985.

3. *Extraction Steam Temperature*

Extraction steam temperature is the total temperature of the steam exhausted from the turbine. It is measured at the induction connection of the turbine and is expressed in degrees Fahrenheit or in degrees Celsius.

NEMA Standard 6-12-1985.

4. *Induction Steam Temperature*

Induction steam temperature is the total temperature of the secondary steam supplied to the turbine. It is measured at the induction connection of the turbine and is expressed in degrees Fahrenheit or in degrees Celsius.

NEMA Standard 6-12-1985.

2.2.2.7 GENERAL PRESSURE AND TEMPERATURE RANGES

Steam turbines will operate successfully over a range of steam conditions. The purchaser will specify "normal" inlet temperature and pressure with corresponding exhaust pressure (or vacuum).

Any variations from the normal steam conditions should be specified by the user (purchaser) to ensure mechanical capability of the turbine design. Table 2-2 shows ranges for combinations of inlet temperatures and pressures, and the points where material or design changes may be required.

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2.2.2.8 VARIATIONS IN STEAM CONDITIONS

Steam turbines shall be capable of operating under the following variations of inlet pressure and temperature, but performance shall not necessarily be in accordance with the standards established for operating at maximum steam conditions. Continuous operation at other than maximum steam conditions shall be reviewed with the turbine manufacturer.

NEMA Standard 6-12-1985.

1. *Variations from Maximum Inlet Steam Pressure*

The turbine shall be capable of operating without damage at less then the guaranteed steam flow to the turbine with average inlet pressure of 105 percent of maximum inlet steam pressure. This permissible variation recognizes the increase in pressure with decrease in steam flow encountered in operation. (The last sentence is approved as Authorized Engineering Information.)

The inlet steam pressure shall average not more than maximum pressure over any 12-month operating period.

The inlet steam pressure shall not exceed 110 percent of maximum pressure in maintaining these averages, except during abnormal conditions.

During abnormal conditions, the steam pressure at the turbine inlet connection shall be permitted to exceed maximum pressure briefly by as much as 20 percent, but the

Table 2-2
GENERAL PRESSURE AND TEMPERATURE RANGES

Inlet Steam Pressure, psig/kPa	Inlet Steam Temperature, °F (°C)						
	500F—(260C) and less	501 to 600 F 261 to 315 C	601 to 750F 316 to 400C	751 to 825F 401 to 440C	826 to 900F 441 to 482C	901 to 950F 482 to 510C	951F and Above 511C and Above
up to 250 18.3 kPa							
251 to 600 13.3 to 42.4 kPa							
601 to 900 42.5 to 63.0 kPa							
901 to 1500 63.1 to 104.5 kPa							
1501 and Above/ 104.6 kPa and Above							

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aggregate duration of such swings beyond 105 percent of maximum pressure shall not exceed 12 hours per 12-month operating period.

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2. *Variations from Maximum Inlet Steam Temperature*

The inlet steam temperature shall average not more than maximum temperature over any 12-month operating period. In maintaining this average, the temperature shall not exceed maximum temperature by more than 15 °F (8 °C) except during abnormal conditions. During abnormal conditions, the temperature shall not exceed maximum temperature by more than 25 °F (14 °C) for operating periods of not more then 400 hours per 12-month operating period nor by more than 50 °F (28 °C) for swings of 15 minutes duration or less, aggregating not more than 80 hours per 12-month operating period.

NEMA Standard 6-12-1985.

3. *Variations from Maximum Exhaust Steam Pressure on Noncondensing Turbines*

The exhaust pressure shall average not more then the maximum exhaust pressure over any 12-month operating period.

In maintaining this average, the exhaust pressure shall not exceed maximum pressure by more than 10 percent nor drop more then 20 percent below maximum exhaust pressure.

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4. *Variations in Exhaust Steam Pressure on Condensing Turbines*

Any anticipated variations in the exhaust steam pressure should be specified by the user so that it can be taken into consideration in the design of the turbine.

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2.2.2.9 Flow Limits for an Automatic-Extraction Turbine

An automatic-extraction turbine may be designed so that, when operating with extraction flow and with only cooling steam flowing to the exhaust, it will develop the rated horsepower of the turbine.

Good design practice dictates that the maximum extraction flow ratio should be held to 2.5 or less. (The extraction flow ratio is the ratio of the total extraction flow to the nonextracted rated load flow.)

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2.2.2.10 Flow Limits for an Induction Turbine

An induction turbine may be designed for a steam flow through the low-pressure stages equal to the flow of low-pressure steam alone that is required to produce the rated horsepower of the turbine.

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2.2.2.11 Noncondensing Turbine Operation of a Multistage Condensing Turbine

Noncondensing operation of a multistage condensing turbine is not recommended due to the possibility of high exhaust-casing temperature causing distortion and damage, and misalignment with driven machines. An increase in exhaust temperature and pressure may also affect piping forces. (See piping force calculations given in Section 9).

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2.2.2.12 Turbine Casing

The casing is the enclosure which surrounds the rotating element of the turbine and supports the stationary steam parts. Casings shall be axially split, radially split, or a combination thereof.

The turbine casing shall be divided into two or more sections as follows:

1. *Steam Inlet End Section*

That portion of the casing which contains the higher pressure steam.

2. *Exhaust End Section*

That portion of the casing which contains the exhaust connection and the steam at exhaust conditions. It shall also contain the low-pressure stage(s) of a multistage turbine.

3. *Intermediate Section (Multistage Turbines Only)*

That portion of the casing which is between the steam inlet end and the exhaust end sections and which contains the intermediate stage(s).

NEMA Standard 6-12-1985.

2.2.2.13 Steam Chest (Governor Valve Body)

A steam chest incorporates the inlet connection, houses the governor-controlled valve(s), and is bolted to or integral with the steam ring inlet section.

NEMA Standard 6-12-1985.

2.2.2.14 Steam Ring

A steam ring incorporates the passage(s) through which the steam flows from the governor valve(s) and steam chest to the first stage nozzles.

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2.2.2.15 NOZZLES

Nozzles are stationary machined or formed openings which expand the steam and direct it against the turbine blades or buckets.

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2.2.2.16 STATIONARY REVERSING BLADES (CHAMBERS)

Stationary reversing blades or chambers in a velocity-compounded stage direct the steam flow from one row of rotating blades or buckets to the following rotating blades or buckets.

NEMA Standard 6-12-1985.

2.2.2.17 DIAPHRAGM

A diaphragm is a stationary element of a stage containing nozzles to expand the steam and direct it against the rotating blades. It is normally used in a multistage turbine.

NEMA Standard 6-12-1985.

2.2.2.18 CASING SHAFT SEALS

Casing shaft seals minimize the leakage of steam out of the casing along shaft.

For condensing turbines, seals are arranged to prevent the entrance of air into the casing along the shaft. They are arranged for the admission of steam at constant low pressure and low temperature.

NEMA Standard 6-12-1985.

2.2.2.19 INTERSTAGE SHAFT SEALS

Interstage shaft seals minimize the leakage of steam along the shaft between stages in a multistage turbine.

NEMA Standard 6-12-1985.

2.2.2.20 ROTOR ASSEMBLY

The rotating element of the turbine which includes all parts attached to the shaft including the coupling if integral with the shaft.

NEMA Standard 6-12-1985.

2.2.2.21 WHEELS (DISCS)

Wheels are discs which are integral with, or fixed to, the turbine shaft and on which blades are mounted, or in which blades or buckets are machined.

NEMA Standard 6-12-1985.

2.2.2.22 BLADES (BUCKETS)

Blades or buckets are curved vane elements proportioned to convert kinetic energy of steam to mechanical energy.

NEMA Standard 6-12-1985.

2.2.2.23 SHROUD

A shroud is that part of the blade assembly which prevents steam from spilling out radially and increases rigidity of the blade group.

NEMA Standard 6-12-1985.

2.2.2.24 SENTINEL WARNING VALVE

A sentinel warning valve is an excessive exhaust pressure warning device which opens when the steam pressure in the exhaust casing rises to a predetermined level. The device shall discharge to the atmosphere and shall be located to be plainly visible.

For condensing turbines, it shall be set at 5 psig (135kPa). For noncondensing turbines, the minimum setting shall be either 10 percent or 10 psig (70 kPa) above maximum exhaust pressure, whichever is greater.

NEMA Standard 6-12-1985.

2.2.2.25 BASIC FEATURES

The steam turbine shall include at least the following basic features which are deemed necessary for proper functioning and safety of operation:

1. Steam strainer with removable corrosion-resistant element.
2. Speed governor.
3. Overspeed trip system.
4. Trip valve.
5. Lubrication.
6. Sentinel warning valve mounted on the turbine casing.
7. Exhaust casing gland sealing connection (for condensing turbines only).
8. Eyebolts or other provisions for lifting the upper half of the casing on an horizontally split turbine.
9. Bearings as required to support and axially position the rotor.

NEMA Standard 6-12-1985.

2.2.2.26 ACCESSORIES

The following are accessories which may be selected, depending on steam conditions, ratings, and application:

1. Speed governor system with option for pressure control or load sharing.
2. Nozzle control valve(s) which control(s) steam flow to a group of nozzles to permit efficient operation at reduced power or with varying steam conditions for single-valve turbines.
3. Trip devices to close the trip valve or the trip-and-throttle valve in response to a pneumatic, electric,

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or hydraulic signal, or on high exhaust pressure, low oil pressure, high oil temperature, excessive vibration or high bearing temperature.

4. Constant-Level oilers for nonpressure-lubrication systems.
5. Insulation for the high-temperature section of the turbine.
6. Gland leakage evacuating apparatus with the piping adjacent to the turbine when the gland casing design requires its use.
7. Trip-and-throttle valve.
8. Tachometer—the tachometer should be of the vibrating reed, mechanical, or electric type, and should indicate speeds from above the trip speed to below the minimum operating speed. Tachometers should be suitable for the specified environment.
9. Gauges and instrumentation to monitor turbine operation.

Additional items may be available.

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2.2.2.27 BASIC FEATURES FOR EXTRACTION AND INDUCTION TURBINES

Extraction and induction turbines shall include basic features listed in 2.2.2.25.

Controlled extraction turbines shall have a pressure-regulating system for controlling the pressure of the extracted steam by regulating the flow of steam to the turbine stages beyond the extraction openings. A nonreturn valve for the extraction opening(s), which is also actuated by the over-speed trip system, is required for installation in the extraction steam line(s).

Controlled induction turbines shall have a pressure-regulating system for controlling the pressure of the induction steam to regulate the flow of steam to the turbine. A trip valve which is also actuated by the overspeed trip system is required for installation in the induction steam line.

Depending on the source of induction steam the user shall consider the need for a steam strainer in this line to protect the lower pressure stages of the turbine. Controlled extraction turbines and controlled induction turbines shall have a compensated-control system which provides interconnection between the pressure-regulating system and the speed/load-regulating system.

Controlled induction extraction turbines shall include a combination of the foregoing items.

Noncontrolled extraction turbines shall include a nonreturn valve for each extraction opening.

Noncontrolled induction turbines shall include a stop valve for each induction opening.

NEMA Standard 6-12-1985.

2.2.2.28 TURBINE CONNECTIONS

1. *Steam Connections*

Turbine flanged steam connections shall be faced and drilled for bolting to flanges which are in accordance with American National Standards B16.1-1980.

Cast iron flanged connections shall be flat faced.

The thickness of cast iron exhaust flanged connections under 10 inches (250 mm) in diameter shall not be less than Class 250 of American National Standard B16.1-1980.

Single-stage horizontally split casing turbines shall have steam connections in the lower half of the turbine.

Threaded connections for making up to pipe not over 2 inches in diameter (50 mm nominal diameter) shall have internal taper threads conforming to American National Standard B1.20.1-1983.

NEMA Standard 6-12-1985.

2. *Auxiliary Connections*

Auxiliary connections that are threaded shall conform to American National Standard B1.20.1-1983. Typically, these are: ring pressure gauge connection; drain connections for casing and steam chest; casing sealing glands and bearing housings; cooling water; valve steam leakoffs, as required; and so forth.

NEMA Standard 6-12-1985.

2.2.2.29 NAMEPLATE DATA

The following minimum data shall be given on the turbine nameplate:

1. Manufacturer's name and location.
2. Serial number (also stamped on the turbine casing).
3. Model/type.
4. Rated kilowatts.
5. Rated speed.
6. Maximum inlet steam pressure.
7. Maximum inlet steam temperature.
8. Maximum exhaust steam pressure.
9. Maximum extraction/induction pressure (if applicable).
10. Trip speed.
11. First lateral critical speed.
12. Purchaser's equipment item number (when specified).

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2.3 REDUCTION GEAR CONSTRUCTION

2.3.1 Types

The reduction gears most commonly used in turbine

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generator sets are of the parallel shaft type, which are discussed in this section. Other types of gears are available which may be used with turbine generator sets.

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2.3.2 Service Factor

The service factor for continuous duty shall be the minimum used in selecting the gear unit, per AGMA Standard 421.06.

NEMA Standard 6-12-1985.

2.3.3 Basic Features

Parallel shaft gears shall include at least the following basic features which are necessary for proper functioning and safety of operation:

1. Casing to enclose the rotating elements of the gear.
2. Rotating elements having gear teeth with surface quality, hardness, and strength to provide long service life.
3. Bearings to support rotating elements.
4. Covered opening to allow for internal inspection.
5. Provisions for lifting the upper half of the gear casing.
6. Lubrication.

NEMA Standard 6-12-1985.

2.3.4 Accessories

The following are accessories which may be selected, depending on rating and application:

1. Bearing temperature indicators.
2. Vibration monitoring devices.

Additional items may be available.

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2.3.5 Nameplate Data

The following minimum data shall be given upon the gear nameplate:

1. Manufacturer's name and location.
2. Serial number.
3. Model/type.
4. Rated power.
5. Service factor.
6. Input speed/output speed.
7. Gear ratio.

NEMA Standard 6-12-1985.

2.4 GENERATOR CONSTRUCTION

2.4.1 Types

2.4.1.1 Synchronous Alternating Current Generators

1. *Salient Pole*

This type of generator is constructed with projecting pole pieces (salient poles) on the rotor. Each pole piece is wound with conductors to form a magnetic pole when the rotor is energized by the exciter.

Salient pole construction is normally used for generators operated at speeds of 1800 RPM and below.

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2. *Non-Salient Pole*

This type of generator is constructed with a cylindrical rotor (non-salient poles) into which slots are machined. Electrical conductors are inserted into the slots to form the electrical path in the rotor.

Non-salient pole construction is normally used for generators operated above 1800 RPM.

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2.4.1.2 Induction Generators

An induction generator is an ac machine which is driven above synchronous speed to induce electric power (kw). Excitation is taken from the system to which the generator is connected and it is not self-excited.

NEMA Standard 6-12-1985.

2.4.2 Basis of Rating

2.4.2.1 Class of Insulation System

An insulation system is an assembly of insulating materials in association with the conductors and the supporting structural parts of a motor or generator. Insulation systems are divided into classes according to the thermal endurance of the system for temperature rating purposes. Four classes of insulation systems are used in motors and generators, namely, Classes A, B, F and H. These classes have been established in accordance with IEEE Standard 1.

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2.4.2.2 Power

The rating of the generator shall be the real output power in kilowatts measured at the output terminals when the generator is operating at the design power factor, voltage, and frequency under design environmental conditions. The rating shall include the excitation power requirements. The power absorbed by a separate excitation system, when supplied, shall be deducted from the real output power at the generator terminals.

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The rating may also be the apparent output power in kilovolt-amperes measured at the output terminals at design operating conditions.

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2.4.2.3 TEMPERATURE RISE

The observable temperature rise for each of the various parts of the machine above the temperature of the cooling air, referred to as the cold air temperature, shall not exceed the values given in Table 2-3 when the machine is operated at output rating conditions. The temperature rises in the Table are based on a maximum cold air temperature of 40°C.

For open machines and for parts of enclosed machines that are cooled by open ventilation passages, that is, collector rings, the cold air temperature is the average temperature of the external air as it enters the ventilating openings of the machine.

Table 2-3
TEMPERATURE RISE

Item	Machine Part	Temperature Method of Determination	Temperature Rise (°C) Class A	Class B	Class F	Class H
Induction						
(1)	Armature Winding					
	(A) All kilowatt ratings	Resistance	60	80	105	125
	(B) 1119 kilowatt and less	Embedded detector*	70	90	115	140
	(C) Over 1119 kilowatt					
	(1) 7000 volts and less	Embedded detector*	65	85	110	135
	(2) Over 7000 volts	Embedded detector*	60	80	105	125
(2)	Cores, squirrel cage windings, and mechanical parts, such as collector rings and brushes, shall be permitted to attain such temperatures as will not injure the machine in any respect.					
Salient-Pole						
(1)	Armature Winding					
	(A) All KVA ratings	Resistance	60	80	105	125
	(B) 1563 KVA and less	Embedded detector*	70	90	115	140
	(C) Over 1563 KVA					
	(1) 7000 volts and less	Embedded detector*	65	85	110	135
	(2) Over 7000 volts	Embedded detector*	60	80	105	125
(2)	Field Winding	Resistance	60	80	105	125
(3)	Cores, amortisseur windings, and mechanical parts, such as collector rings, brushholders, and brushes, shall be permitted to attain such temperatures as will not injure the machine in any respect.					
Cylindrical Rotor (Non-Salient Pole)						
(1)	Armature Winding					
	(A) Below 10000 KVA	Resistance		80	105	125
	(B) 1563 KVA and less	Embedded detector*		90	115	140
	(C) 1564 KVA to 10000 KVA					
	(1) 7000 volts and less	Embedded detector*		85	110	135
	(2) Over 7000 volts	Embedded detector*		80	105	125
	(D) 10000 KVA and above	Embedded detector*		70	90	110
(2)	Field Winding	Resistance		80	105	125
(3)	Cores and mechnical parts in contact with or adjacent to insulation	Detector or Thermometer		70	90	110
(4)	Collector Rings	Thermometer		85	85	85
(5)	Miscellaneous parts (such as brushholders, brushes, and so forth shall be permitted to attain such temperature as will not injure the machine in any respect.					

*Embedded detectors are located within the slot of the machine and shall be either resistance elements or thermocouples. For generators equipped with embedded detectors, this method shall be used to demonstrate conformity with the standard.

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For totally enclosed machines, the cold air temperature is the average temperature of the air leaving the cooler or coolers. The cold air temperature at rating, when the coolers are supplied with water of the rated amount and temperature, is specified as 40°C.

For machines that operate under prevailing barometric pressure and are designed not to exceed standard temperature rise at altitudes from 3300 feet (1000 m) to 13,000 feet (4000 m), the temperature rises, as checked by test at low altitude, shall be less than those listed in Table 2-3 by 1 percent of the specified temperature rise for each 330 feet (100 m) of altitude in excess of 3300 feet (1000 m).

When designing to meet the temperature rises in Table 2-3 it is intended that the hot test-spot temperature should not exceed 130°C for Class B, 155°C for Class F, and 180°C for Class H insulation systems.

For machines of 10,000 kVA and above, the relationship between hottest-spot temperature and the temperatures specified in the table for the armature and field windings shall be demonstrable by direct measurement or recognized methods of calculation corrected to special factory tests on a basically similar machine.

Temperatures shall be determined in accordance with IEEE Standard 115 or IEEE Standard 112.

2.4.2.4 FREQUENCY

Frequency shall be 50 or 60 Hertz.

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Other frequencies are available for special applications.

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2.4.2.5 VOLTAGE

The generator voltage shall be specified by the user.

NEMA Standard 6-12-1985.

Typical voltages are as shown in Table 2-4.

Authorized Engineering Information 6-12-1985.

Table 2-4
TYPICAL VOLTAGES FOR TURBINE DRIVEN GENERATORS

60 Hz Voltage		120	240	208	480	2400	4160	4160Y/2400	7200	12000	12470	13800
50 Hz Voltage		120	240	—	400	1900	3300	3300Y/1900	6600	11000	—	13200
PHASES		1	1	3	3	3	3	3	3	3	3	3
KW Rating	KVA Rating											
100	125	X	X	X	X							
500	625			X	X	X	X	X				
1000	1250				X	X	X	X				
1500	1875				X	X	X	X	X	X	X	X
2000	2500				X	X	X	X	X	X	X	X
2500	3125					X	X	X	X	X	X	X
3000	3750					X	X	X	X	X	X	X
4000	5000					X	X	X	X	X	X	X
5000	6250					X	X	X	X	X	X	X
6000	7500					X	X	X	X	X	X	X
7500	9375						X		X	X	X	X
10000	12500						X		X	X	X	X
12500	15625						X		X	X	X	X
15000	18750								X	X	X	X
20000	25000								X	X	X	X
30000	37500									X	X	X
33000	41250									X	X	X

Note: Other voltages such as 600 V and 6900 V may be available at the ratings shown for 480 V and 7200 V respectively.

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2.4.2.6 VARIATIONS FROM RATED VOLTAGE

Synchronous generators shall operate successfully at rated kVA, frequency and power factor at any voltage not more than 5 percent above or below rated voltage but not necessarily in accordance with the standards of performance established for operation at normal rating.

NEMA Standard 6-12-1985.

2.4.2.7 VARIATIONS FROM RATED VOLTAGE AND RATED FREQUENCY

Induction generators shall operate successfully under running conditions at rated load with a variation in the voltage or the frequency up to the following:

1. Plus or minus 10 percent of rated voltage, with rated frequency.
2. Plus or minus 5 percent of rated frequency, with rated voltage.
3. A combined variation in voltage and frequency of plus or minus 10 percent (sum of absolute values) of the rated values, provided the frequency variation does not exceed plus or minus 5 percent of rated frequency.

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Performance within these voltage and frequency variations will not necessarily be in accordance with the standards established for operation at rated voltage and frequency.

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2.4.2.8 MAXIMUM MOMENTARY OVERLOAD

Generators shall be capable of carrying a 1-minute overload of 50 percent of normal rated current with the field set for normal rated load excitation. The voltage power factor and temperature rise will differ from rated values when generators are subjected to the overload conditions.

NEMA Standard 6-12-1985.

2.4.2.9 MAXIMUM DEVIATION FACTOR

The deviation factor of the open-circuit line-to-line terminal voltage of generators shall not exceed 0.1.

NEMA Standard 6-12-1985.

2.4.2.10 TELEPHONE INFLUENCE FACTOR (TIF)

When specified, the balanced telephone influence factor (TIF) based on the weighting factors given in Table 2-5 shall not exceed the following values:

Table 2-5
TELEPHONE INFLUENCE FACTOR

kVA Rating of Generator	TIF
62.5 to 299	350
300 to 699	250
700 to 4999	150
5000 to 19999	100
20000 and above	70

When specified, the residual component telephone influence factor based on the weighting factors given in Table 2-5 shall not exceed the following values. The residual component applies only to those generators having voltage ratings of 2000 volts and higher.

kVA Rating of Generator	TIF
	Residual
1000 to 4999	100
5000 to 19999	75
20000 and above	50

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The single-frequency telephone influence weighting factors (TIF_f), according to the 1960 single frequency weighting factors are shown in Table 2-6.

The telephone influence factor shall be measured in accordance with IEEE Standard 115. TIF shall be measured at the generator terminals on open circuit at rated voltage and frequency.

NEMA Standard 6-12-1985.

2.4.2.11 EFFICIENCY

Efficiency and losses shall be determined in accordance with IEEE Standard 115. The efficiency shall be determined at rated output, voltage, frequency, and balanced load conditions.

The following losses shall be included in determining the efficiency:

1. I^2R loss of armature.
2. I^2R loss of field.
3. Core loss.
4. Stray load loss.
5. Friction and windage loss.
6. Exciter power requirements.

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Table 2-6
1960 SINGLE-FREQUENCY TIF_f WEIGHTING FACTORS

Frequency	TIF_f	Frequency	TIF_f
60	0.5	1,800	7,570
180	30	1,860	7,820
300	225	1,980	8,330
360	400	2,100	8,830
420	650	2,160	9,080
540	1,320	2,220	9,330
660	2,260	2,340	9,840
720	2,760	2,460	10,340
780	3,360	2,580	10,600
900	4,350	2,820	10,210
1,000	5,000	2,940	9,820
1,020	5,100	3,000	9,670
1,030	5,400	3,180	8,740
1,140	5,630	3,300	8,090
1,260	6,050	3,540	6,730
1,380	6,370	3,660	6,130
1,440	6,650	3,900	4,400
1,500	6,680	4,020	3,700
1,620	6,970	4,260	2,750
1,740	7,320	4,380	2,190
		5,000	840

2.4.2.12 SHORT CIRCUIT REQUIREMENTS

A synchronous generator shall be capable of withstanding, without injury, a 30-second 3-phase short circuit at its terminals when operating at rated kVA and power factor, at 5 percent overvoltage, with fixed excitation. The generator shall also be capable of withstanding, without injury, any other short circuit at its terminals of 30 seconds or less, provided:

1. The machine phase currents under fault conditions are such that the negative phase sequence current (I_2) expressed in per unit of stator current at rated kVA, and the duration of the fault in seconds, t, are limited to values which give an integrated product, $(I_2)^2t$, equal to or less than 40, and
2. The maximum phase current is limited by external means to a value which does not exceed the maximum phase current obtained from the 3-phase fault.

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2.4.2.13 OVERSPEED LIMITATIONS

Generators shall be so constructed that, in an emergency, they will withstand without mechanical injury overspeeds above synchronous speed in accordance with the following:

Synchronous Speed, RPM	Overspeed, Percent of Synchronous Speed
1801 and over	20
1800 and below	25

NEMA Standard 6-12-1985.

2.4.2.14 MOTOR STARTING CAPABILITIES

If a synchronous generator provides a substantial amount of the power in an electrical system, it shall be capable of starting the largest motor in the system without allowing an excessive voltage dip. The size of the largest motor and the allowable voltage dip shall be specified by the user.

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In order to meet the motor starting requirements, it may be necessary to increase the size of the generator and increase the capacity of the exciter and the voltage regulator.

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2.4.2.15 GENERATOR CONSTANTS

Direct-Axis Synchronous Reactance (x_d). Used to determine current flow at steady-state conditions.

Direct-Axis Transient Reactance (x'_d). Used to calculate the short circuit current produced by the generator after the first few cycles following a fault (six cycles to five seconds). Also used to determine voltage dips resulting from load applications.

Direct-Axis Subtransient Reactance (x''_d). This is the apparent reactance of the stator winding at the instant short circuit occurs. It is used to calculate the current flow during the first few cycles after a short circuit. The subtransient reactance is important when determining the required capacity of a circuit breaker to interrupt a fault within a system.

Negative Sequence Reactance (x_2). Used to determine line-to-line short circuit currents.

Zero Sequence Reactance (x_o). Used to determine line-to-neutral short circuit currents.

Potier Reactance (x_p). Used to calculate excitation of the generator at different loads and power factors.

Direct-Axis Transient Short-Circuit Time Constant (T'_d). Time (seconds) for the slowly decreasing component of the armature current to reach 36.8 percent of its initial value after application of a short circuit condition to a generator running at rated speed.

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Direct-Axis Subtransient Short Circuit Time Constant ($T''d$). Time (seconds) for the rapidly decreasing component of the armature current (present during the first cycles after a short circuit) to reach 36.8 percent of its initial value after sudden application of a short circuit condition when the unit is running at rated speed.

Direct-Axis Transient Open Circuit Time Constant ($T'd_o$). Time measured in seconds for the open circuit voltage of the armature to drop to 36.8 percent of its initial value after the field winding is short circuited.

NEMA Standard 6-12-1985.

2.4.3 Basic Features

The generator shall include at least the following basic features which are deemed necessary for proper functioning and safety of operation:

1. Enclosure to guard against the entrance of moisture, dust, and foreign objects into the generator. An open drip-proof enclosure shall be the basic enclosure for a generator driven by a steam turbine.
2. Frame which rigidly supports the machine to provide low vibration and long life.
3. Stator composed of a support structure and a core made up of electrical steel laminations and insulated windings (coils). The stator shall be set into the frame in a way which will permit the circulation of cooling air around the core. The insulation system shall maintain its insulating properties at the maximum operating rated temperatures as specified in 2.4.2.3 (Temperature Rise).
4. Rotor consisting of the shaft, field poles, field windings, and one or more fans to circulate cooling air. The rotating element of the exciter shall be mounted on the rotor shaft. The coupling, if integral with the shaft, is also part of the rotor. The insulation system shall maintain its insulating properties at the maximum operating rated temperatures as specified in 2.4.2.3 (Temperature Rise).
5. Bearings to support the rotor.
6. Lubrication.
7. Power terminals.
8. Excitation system for synchronous generators only. The basic excitation system shall be the brushless type with a rotating armature generating a 3 phase ac voltage with full wave rectification to dc for field excitation.

NEMA Standard 6-12-1985.

2.4.4 Accessories

The following are accessories which may be selected, depending on ratings, voltage, and applications:

1. Enclosure other than drip-proof type where necessitated by environmental conditions.
2. Stator temperature indicators.
3. Bearing temperature indicators.
4. Vibration monitoring devices.
5. Space heaters.
6. Terminal box.
7. Surge suppressors.
8. Lightning arresters.
9. Current transformer(s).
10. Potential transformer(s).

Additional items may be available.

Authorized Engineering Information 6-12-1985.

2.4.5 Power Terminals

Synchronous generators should be wye connected unless delta connection is specified by the user. Wye connection with the neutral made up externally permits installation of current transformers in each phase for differential protection. Delta wound connections do not include a neutral lead.

Induction generators may be delta or wye connected.

An enclosure should be provided for mounting the current transformer and connecting the generator terminals. The enclosure may contain lightning arresters and surge capacitors when required by the user.

Delta wound generators may also be available. If the user requires a delta wound generator, the requirement must be divided as a part of the job specifications to the manufacturer. There is no neutral lead in a delta wound generator.

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2.4.6 Location of Terminals

On horizontal synchronous generators furnished without bearings (or with pedestal-type bearings) and without a terminal box, the recommended location of the armature winding terminals is at the bottom edge of the stator frame within 30 degrees of the vertical centerline. On all other types of horizontal synchronous generators, the recommended location is on the left-hand side of the generator, viewing the end of the generator opposite the drive.

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2.4.7 Numerals on Terminals of Alternating Current Polyphase Generators

2.4.7.1 SYNCHRONOUS GENERATORS

The numerals 1, 2, 3, and so forth, indicate the order in which the voltages at the terminals reach their maximum positive values (phase sequence) with clockwise

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shaft rotation when facing the connection end of the coil windings; hence, for counterclockwise shaft rotation (not standard) when facing the same end, the phase sequence shall be 1, 3, 2.

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2.4.7.2 INDUCTION GENERATORS

Terminal markings of polyphase induction generators are not related to the direction of rotation.

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2.4.8 Phase Sequence

The order of numerals on terminal leads does not necessarily indicate the phase sequence, but the phase sequence is determined by the direction of shaft rotation relative to the connection end of the coil winding.

NEMA Standard 6-12-1985.

2.4.9 Direction of Rotation of Vectors

Vector diagrams shall be shown so that advance in phase of one vector with respect to another is in the counterclockwise direction. See Figure 2-2 in which vector 1 is 120 degrees in advance of vector 2 and the phase sequence is 1, 2, 3.

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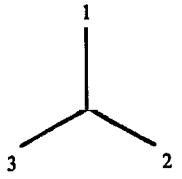


Figure 2-2

2.4.10 Open Generator Enclosures

An open generator is one having ventilating openings which permit passage of external cooling air over and around the windings of the generator. The term "open generator," when applied to large apparatus without qualification, designates a generator having no restriction to ventilation other than that necessitated by mechanical construction.

NEMA Standard 6-12-1985.

2.4.10.1 DRIPPROOF

A dripproof generator is one in which the ventilating openings are so constructed that successful operation is not interfered with when drops of liquid or solid particles strike or enter the enclosure at any angle from 0 to 15 degrees downward from the vertical.

NEMA Standard 6-12-1985.

2.4.10.2 SPLASH-PROOF

A splash-proof generator is one in which the ventilating openings are so constructed that successful operation is not interfered with when drops of liquid or solid particles strike or enter the enclosure at any angle not greater than 100 degrees downward from the vertical.

NEMA Standard 6-12-1985.

2.4.10.3 SEMI-GUARDED

A semi-guarded generator is one in which part of the ventilating openings in the machine, usually in the top half, are guarded as in the case of a "guarded machine" but the others are left open.

NEMA Standard 6-12-1985.

2.4.10.4 GUARDED

A guarded generator is one in which all openings giving direct access to live metal or rotating parts (except smooth rotating surfaces) are limited in size by the structural parts or by screens, baffles, grilles, expanded metal, or other means to prevent accidental contact with hazardous parts.

NEMA Standard 6-12-1985.

2.4.10.5 DRIPPROOF GUARDED

A dripproof guarded generator is one whose ventilating openings are guarded in accordance with 2.4.10.4.

NEMA Standard 6-12-1985.

2.4.10.6 OPEN PIPE-VENTILATED

An open pipe-ventilated generator is an open generator except that openings for the admission of the ventilating air are so arranged that inlet ducts or pipes can be connected to them. Open pipe-ventilated machines may be self-ventilated (air circulated by means integral with the machine) or force-ventilated (air circulated by means external to and not a part of the machine).

NEMA Standard 6-12-1985.

2.4.10.7 WEATHER-PROTECTED

Type I—A weather-protected Type I generator is an open generator with ventilating passages so constructed as to minimize the entrance of rain, snow, and air-borne particles to the electric parts and having its ventilated openings so constructed as to prevent the passage of a cylindrical rod 0.75 inch (19 mm) in diameter.

Type II—A weather-protected Type II generator shall have, in addition to the enclosure defined for a weather protected Type I generator, ventilating passages at both intake and discharge so arranged that high-velocity air and

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air-borne particles blown into the generator by storms or high winds can be discharged without entering the internal ventilating passages leading directly to the electric parts of the generator itself. The normal path of the ventilating air which enters the electric parts of the generator shall be so arranged by baffling or separate housings as to provide at least three abrupt changes in direction, none of which shall be less then 90 degrees. In addition, an area of low velocity not exceeding 10 feet (3 meters) per second shall be provided in the intake air path to minimize the possibility of moisture or dirt being carried into the electric parts of the generator.

NEMA Standard 6-12-1985.

2.4.11 Totally-Enclosed

A totally-enclosed generator is one enclosed to prevent the free exchange of air between the inside and the outside of the case but not sufficiently enclosed to be termed air-tight.

NEMA Standard 6-12-1985.

2.4.11.1 Totally-Enclosed Nonventilated

A totally-enclosed nonventilated generator is a totally-enclosed generator which is not equipped for cooling by means external to the enclosing parts.

NEMA Standard 6-12-1985.

2.4.11.2 Totally-Enclosed Fan-Cooled

A totally-enclosed fan-cooled generator is a totally-enclosed generator equipped for exterior cooling by means of a fan or fans integral with the machine but external to the enclosing parts.

NEMA Standard 6-12-1985.

2.4.11.3 Explosion-Proof

An explosion-proof generator is a totally-enclosed generator whose enclosure is designed and constructed to withstand an explosion of a specified gas or vapor which may occur within it and to prevent the ignition of the specified gas or vapor surrounding the machine by sparks, flashes, or explosions of the specified gas or vapor which may occur within the generator casing.

NEMA Standard 6-12-1985.

2.4.11.4 Dust-Ignition-Proof

A dust-ignition-proof generator is a totally-enclosed generator whose enclosure is designed and constructed in a manner which will exclude ignitable amounts of dust or amounts which might affect performance or rating, and which will not permit arcs, sparks, or heat otherwise generated or liberated inside of the enclosure to cause ignition of exterior accumulations or atmospheric suspensions of a specific dust on or in the vicinity of the enclosure.

NEMA Standard 6-12-1985.

2.4.11.5 Water-Proof

A water-proof generator is a totally-enclosed generator so constructed that it will exclude water applied in the form of steam from a hose, except that leakage may occur around the shaft provided it is prevented from entering the oil reservoir and provision is made for automatically draining the generator. The means for automatic draining may be a check valve or a tapped hole at the lowest part of the frame which will serve for application of a drain pipe.

NEMA Standard 6-12-1985.

2.4.11.6 Totally-Enclosed Pipe-Ventilated

A totally-enclosed pipe-ventilated generator is a generator with openings so arranged that when inlet and outlet ducts or pipes are connected to them there is no free exchange of the internal air and the air outside the case. Totally-enclosed pipe-ventilated generators shall be self-ventilated (air circulated by means integral with the generator) or force-ventilated (air circulated by means external to and not part of the generator).

NEMA Standard 6-12-1985.

2.4.11.7 Totally-Enclosed Water-Cooled

A totally-enclosed water-cooled generator is a totally enclosed generator which is cooled by circulating water, the water or water conductors coming in direct contact with the generator parts.

NEMA Standard 6-12-1985.

2.4.11.8 Totally-Enclosed Water-Air-Cooled

A totally-enclosed water-air-cooled generator is a totally-enclosed generator which is cooled by circulating air which, in turn, is cooled by circulating water. It is provided with a water-cooled heat exchanger for cooling the internal air and a fan or fans integral with the rotor shaft or separate, for circulating the internal air.

NEMA Standard 6-12-1985.

2.4.11.9 Totally-Enclosed Air-to-Air Cooled

A totally-enclosed air-to-air cooled generator is a totally-enclosed generator which is cooled by circulating the internal air through a heat exchanger which, in turn, is cooled by circulating external air. It is provided with an air-to-air heat exchanger for cooling the internal air

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and a fan or fans, integral with the rotor shaft or separate, for circulating the internal air and a separate fan for circulating the external air.

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2.4.11.10 TOTALLY-ENCLOSED, FAN-COOLED GUARDED

A totally-enclosed, fan-cooled guarded generator is a totally-enclosed fan-cooled generator in which all openings giving direct access to the fan are limited in size by the design of the structural parts or by screens, grilles, expanded metal, and so forth, to prevent accidental contact with the fan.

NEMA Standard 6-12-1985.

2.4.11.11 TOTALLY-ENCLOSED AIR-OVER

A totally-enclosed air-over generator is a totally-enclosed generator intended for exterior cooling by a ventilating means external to the generator.

NEMA Standard 6-12-1985.

2.4.12 Nameplate Data

The following minimum data shall be given on the generator nameplate:

1. Manufacturer's name and location
2. Serial number
3. Model/type
4. Kilovolt-ampere rating
5. Kilowatt rating
6. Power factor
7. Time rating
8. Temperature rise for rated continuous load
9. Rated speed in RPM
10. Voltage
11. Rated current in amperes per terminal
12. Number of phases
13. Frequency
14. Rated field current (separate exciters)
15. Rated excitation voltage (separate exciters).

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Section 3

CONTROLS

3.1 INTRODUCTION

Turbine generator controls regulate the output of the turbine generator set in terms of load (kw), voltage and frequency in response to normal operating requirements.

Authorized Engineering Information 6-12-1985.

The type of controls shall be consistent with the application of the turbine generator set and the type of generator.

NEMA Standard 6-12-1985.

3.2 SYNCHRONOUS GENERATOR

3.2.1 Frequency Control

Generator frequency is directly proportional to turbine speed when the turbine generator set is operating independent of utility power. Therefore, the required frequency is maintained by controlling the turbine speed with a governor.

When the turbine generator set is operating in parallel with a large synchronous power system, change in turbine speed setting on the governor results in a change in turbine load because the frequency of the turbine generator set is locked to the frequency of the connected power system.

Authorized Engineering Information 6-12-1985.

3.2.2 Voltage Control

A voltage regulator shall be supplied for synchronous generators to maintain system voltage when (1) operating independently, (2) when in the process of paralleling, or (3) when controlling the reactive KVA loading of the generator.

NEMA Standard 6-12-1985.

3.2.3 Load Control

For nonparallel operation of synchronous generators, the turbine speed control shall maintain the frequency within the required limits while operating from no load to full load.

For parallel operation, the governor shall be supplied with a local or remotely adjustable speed changer to allow the generator frequency and phase to be matched with the connected power system in order to synchronize the turbine generator set on-line.

For parallel operation, the governor shall be supplied with a droop adjustment or isochronous load sharing capability to allow load sharing between the turbine generator set and the connected system.

NEMA Standard 6-12-1985.

3.3 INDUCTION GENERATOR

A turbine induction generator set is not suitable for isolated operation; it must be operated in parallel with a utility. A speed governor is not required for speed and phase matching before an induction generator's breaker is closed to the utility. However, a speed governor should be considered in order to bring the turbine generator set to synchronous speed before closing the circuit breaker.

In the application of a turbine induction generator set as a pressure reducing valve, the output of the turbine generator set is regulated by a pressure control. In this application, a speed governor can be used as a pre-emergency governor, with its speed setting just above the full load speed of the generator.

In application of induction generators, such as peak shaving units where load is to be controlled, the governor will be used to set generator load.

Authorized Engineering Information 6-12-1985.

3.4 SYSTEM CONTROL

When the steam turbine generator set produces power as a by-product of an industrial process, an external control such as system pressure, flow or temperature, may be used to control the steam flow through the turbine generator to insure that kilowatts are produced as a function of the system steam demand.

Authorized Engineering Information 6-12-1985.

3.5 GOVERNING SYSTEM

The governing system includes the speed governor, the control mechanism, the governor-controlled valve(s), the speed changer, and external control devices. The governing system is the primary system necessary to match the turbine generator set to the application. Various types of governors are available to meet specific user requirements.

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3.5.1 Speed Governor

The speed governor includes those elements which are directly responsive to speed and which position or influence the action of other elements of the governing system to maintain the operating speed within the limits shown in 3.6.

NEMA Standard 6-12-1985.

3.5.2 Control Mechanism

The control mechanism includes all of the equipment between the speed governor and the governor-controlled valves(s) (levers, linkages, relays, servomotors, and pressure or power amplifying devices).

NEMA Standard 6-12-1985.

3.5.3 Governor-Controlled Valve(s)

The governor-controlled valve(s) controls the flow of steam to the turbine in response to the speed governor or external controlling devices.

There are two methods of controlling the admission of steam:

1. A single throttling valve
2. Multiple automatic valves.

NEMA Standard 6-12-1985.

3.5.4 Servomotor System

A servomotor system consists of a pilot valve actuated by the speed governor or control mechanism, and a power cylinder to actuate the governor-controlled valve(s) which allows steam to enter the turbine. The pilot valve controls the flow of high-pressure fluid to the power cylinder. This flow of high-pressure fluid causes the piston in the power cylinder to move in response to the signal from the speed governor or control mechanism.

NEMA Standard 6-12-1985.

3.5.5 External Control Devices

External control devices shall be one of two types described below:

1. *Speed-Changer Type*

The speed-changer type is incorporated directly into the speed governor system which in turn positions the governor-controlled valve(s). The external signal changes the speed governor set point. The speed governor shall be selected to provide the specified adjustable speed range.

2. *Valve-Actuating Type*

The valve-actuating type is separate from the speed governor. The external signal acts to position either the governor-controlled valve(s) or a separate line-mounted valve. In this case, the speed governor acts only as a speed-limiting (pre-emergency) governor.

NEMA Standard 6-12-1985.

3.5.6 Speed Changer

The speed changer is a device for changing the setting of the speed-governing system within the specified speed range while the turbine is in operation.

NEMA Standard 6-12-1985.

3.6 SPEED-GOVERNING SYSTEM CLASSIFICATION

Speed-governing systems shall be classified as shown in Table 3-1.

NEMA Standard 6-12-1985.

Table 3-1
SPEED-GOVERNING SYSTEM CLASSIFICATION

	Percent of Rate Speed		
Class of Governing System	Maximum Speed Regulation, Percent	Maximum Speed Variation, Percent ±	Maximum Speed Rise, Percent
A	10	0.75	13
B	6	0.50	7
C	4	0.25	7
D	0.50	0.25	7

3.6.1 Speed Range

Speed range, expressed as a percentage of rated speed, is the specified range of operating speeds below or above rated speed, or both, for which the governor shall be adjustable when the turbine is operating under the control of the speed governor.

NEMA Standard 6-12-1985.

Normally a speed range of ±5 percent will allow for adequate frequency control of a turbine generator set.

Authorized Engineering Information 6-12-1985.

3.6.2 Maximum Speed Rise

The maximum speed rise expressed as a percentage of rated speed, is the maximum momentary increase in speed which is obtained when the turbine is developing rated power output at rated speed and the load is suddenly and completely reduced to zero.

$$\text{Maximum speed rise (\%)} = \frac{\text{Maximum speed at zero power output} - \text{Rated speed}}{\text{Rated speed}} \times 100$$

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For non-parallel operation, frequency rise is the same as speed rise. (See Figure 3-1.)

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3.6.3 Speed Variation

Speed variation, expressed as a percentage of rated speed, is the total magnitude of speed change or fluctuations from the speed setting under the steady-state conditions given in 3.6.4. The speed change is defined as the difference in speed variation between the governing system in operation and the governing system blocked to be inoperative, with all other conditions constant. Speed variation includes dead band and sustained oscillations.

$$\text{Speed variation } (\pm\%) = \frac{\text{Change in rpm above set speed} + \text{Change in rpm below set speed}}{2 \times \text{Rated speed}} \times 100$$

1. *Dead Band*

Dead band is the total magnitude of the change in steady-state speed within which there is no resulting measurable change in the position of the governor-controlled valve(s). It is a measure of the speed-governing system insensitivity and is expressed in percent of rated speed.

2. *Stability*

Stability is the capability of the speed-governing system to position the steam turbine governor-controlled valves so that sustained oscillations of steam turbine speed or of energy input to the turbine are not produced by the speed-governing system during operation under sustained load demand or following a change to a new sustained load demand.

For the purpose of this standard, sustained oscillations produced by the speed-governing system—

(a) of turbine speed, for isolated operation under sustained load demand, or

(b) of energy input, for parallel operation with a constant-frequency alternating current power system, or

(c) of energy input for parallel operation with a constant-voltage direct current power system—

are defined as the difference between those existing with the speed-governing system in service and those existing with the speed-governing system blocked or inoperative.

In the case of parallel operation with an alternating current power system of other than constant frequency, energy input changes which correspond to variations in power-system frequency and to the incremental speed regulation of the speed-governing system covered by this standard are excluded in determining stability. Similarly, in the case of parallel operation with a direct current power system or other than constant voltage, energy input changes which correspond to the voltage regulation of the driven generator and to the variations in voltage of the power system are deducted in determining stability.

NEMA Standard 6-12-1985.

3.6.4 Speed Regulation, Steady State

Speed regulation, expressed as a percentage of rated speed, is the change in sustained speed when the power output of the turbine is gradually changed from rated power output to zero power output under the following state conditions:

1. When the steam conditions (inlet pressure, inlet temperature, and exhaust pressure) are set at rated values and held constant.
2. When the speed changer is adjusted to give rated speed with rated power output.
3. When any external control device is rendered inoperative and blocked in the open position so as to offer no restrictions to the free flow of steam to the governor-controlled valve(s).

$$\text{Speed regulation } (\%) = \frac{\text{Speed at zero power output} - \text{Speed at rated power output}}{\text{Speed at rated power output}} \times 100$$

For non-parallel operation, frequency regulation is the same as speed regulation. (See Figure 3-2.)

Speed regulation is referred to as droop when the speed change is from no load to full load.

NEMA Standard 6-12-1985.

3.7 STEAM PRESSURE CONTROL

3.7.1 Pressure-Regulating System

The pressure-regulating system includes the pressure regulator(s), the pressure-control mechanism(s) and the pressure-controlled valve(s).

NEMA Standard 6-12-1985.

3.7.2 Pressure Regulator

The pressure regulator includes only those elements that are directly responsive to pressure and which position or influence the action of other elements of the pressure-regulating system.

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3.7.3 Control Mechanism

The control mechanism includes all of the equipment, such as relays, servomotors, pressure or power amplifying devices, levers and linkages between the pressure regulator(s) and the pressure-controlled valve(s).

NEMA Standard 6-12-1985.

3.7.4 Pressure-Controlled Valves

The pressure-controlled valves include those valves which control the flow of steam through the lower pressure stages of the turbine and which are actuated by the pressure regulator(s) through the medium of the control mechanism(s).

NEMA Standard 6-12-1985.

In the case of non-condensing turbines provided with exhaust pressure regulators and also compensated automatic-extraction or mixed-pressure type turbines, the governor-controlled valves may serve also as pressure-controlled valves.

Authorized Engineering Information 6-12-1985.

3.7.5 Pressure Changer

The pressure changer is a device by means of which the setting of the pressure-regulating system may be changed for the purpose of adjusting the pressure of the exhaust steam or of the extraction or induction steam while the turbine is in operation.

NEMA Standard 6-12-1985.

3.7.6 Steady-State Pressure Regulation

For automatic-extraction- or mixed-pressure-type turbines, the steady-state pressure regulation is the change in sustained extraction or induction pressure when, with identical settings of all parts of the speed-governing system and of the pressure-regulating system(s), the extraction or induction flow is gradually changed from rated flow to zero flow.

For noncondensing turbines provided with exhaust-pressure regulators, the steady-state pressure regulation is the change in sustained exhaust pressure when, with identical settings of all parts of the speed-governing system and of the pressure regulating system and through the action of the pressure regulator, the power output of the steam turbine is gradually reduced from rated power output to zero power output.

NEMA Standard 6-12-1985.

3.7.7 Stability

Stability is the capability of the pressure-regulating system(s) to position the pressure-controlled valve(s) so that sustained oscillations of the controlled pressure(s) or of the energy input to the steam turbine are not produced by the pressure-regulating system(s) during operation under sustained flow demands or following a change to another value of sustained flow demand.

For the purposes of this standard, sustained oscillations produced by the pressure-regulating system of controlled pressure or of energy input, are defined as the difference between those existing with the pressure-regulating system in service and those existing with the pressure-regulating system blocked or inoperative.

NEMA Standard 6-12-1985.

3.7.8 Pressure Regulation

Pressure regulation is considered positive when pressure increases with decrease in steam flow.

NEMA Standard 6-12-1985.

3.8 COMPENSATED-CONTROL SYSTEM

A compensated-control system is one which is provided with interconnections between its control mechanisms so that the action of the speed governor or of the pressure regulator(s) also directly actuates the other control mechanism.

NEMA Standard 6-12-1985.

3.9 GENERATOR VOLTAGE CONTROL

3.9.1 Basic Features

The synchronous generator shall be supplied with an automatic voltage regulator which shall have a means of adjustment. The regulator shall control current in the the field of the exciter to maintain generator voltages during changes in load.

The voltage regulator shall hold the generator output voltage within a specified range (from ½ to 1½ percent) of nominal voltage for all steady state loads from no load to full load.

When two or more ac generators operate in parallel, the voltage regulator shall have paralleling provisions to permit it to control the reactive load while it is in parallel operation.

The regulator shall have a sufficiently short response time to minimize voltage dips or rises after load transients. In hospitals, where light flicker must not occur and x-ray equipment would be affected by voltage variations, the generator shall be of sufficient size and design capability to minimize the effect of load.

A power isolation transformer for use with the voltage regulator shall be supplied when required by the application.

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3.9.2 Accessories

The following are accessories which the manufacturer may select, depending on rating, voltage, and application:

1. *Excitation Support System*

Voltage regulation systems can be made sensitive not only to voltage, but also to current output of the generator. Under large load transients, when there is a rush of current through the generator leads, a large current is automatically induced in the exciter field, greatly increasing its output to combat the voltage dip of the generator. This is known as series boost, short circuit boost, or short circuit sustaining. This accessory is used for heavy motor starting or fault-clearing applications.

Alternately, a small separate shaft mounted permanent magnet generator may be used to supply power to the voltage regulator. It is independent of the line voltage drop and maintains a supply voltage to the regulator regardless of load.

2. *Under Frequency/Overvoltage Protection*

This accessory automatically protects the generator from the effects of under frequency and overvoltage operation by disconnecting the voltage regulator in the event of severe under frequency or overvoltage conditions.

3. *Remote Manual Voltage Control*

4. *Automatic Power Factor Controller*

Additional items may be available.

Authorized Engineering Information 6-12-1985.

3.10 ELECTRONIC GOVERNING SYSTEM

3.10.1 Basic Features

An electronic governing system shall include the following basic components:

1. A sensor which measures an operating parameter of the turbine generator set or system, and produces a corresponding electric signal.
2. A governor which compares signal(s) from the sensor(s) with the selected set point(s) and produces a signal(s) to the valve actuator(s) to maintain system parameters.
3. An actuator(s) which positions the valve(s) directly or through a control mechanism in response to the governor signal.

One or more of the following parameters shall be controlled by the governing system:

1. Speed
2. Inlet steam pressure
3. Each induction/extraction pressure
4. Exhaust pressure
5. Generator output
6. Others for specific applications.

NEMA Standard 6-12-1985.

3.10.2 Accessories

The following are accessories which may be selected, depending on rating and application:

1. *Signal selector*

A signal selector may be incorporated in the governor to allow the governor to receive signals from several sensors and to choose the signal which will result in the proper valve opening.

Any parameter may be primary which the governing system maintains as constant during normal operation. Any parameter could be secondary which is ignored as long as it is below the preset value.

2. *Control of induction or extraction.*

The governor may be designed to control the low pressure valve(s) of an induction or extraction turbine in conjunction with the high pressure valve(s). In this case, the governor controls the flow to maintain the steam pressure at each controlled extraction or induction opening.

A governor with this capability incorporates features to adjust all the controlled valves in response to a change in any controlled parameters.

3. *Import/Export control*

Import/export control allows the governor to regulate the exchange of electric power between the utility and the system to which it is connected. Import/export control may be used as a primary parameter or a secondary parameter.

4. *Isochronous load sharing*

Isochronous load sharing which allows two or more synchronous turbine generator sets operating in parallel to maintain constant system frequency from zero system load to maximum system load without the need for any adjustments by operating personnel. This allows each turbine generator set to operate at the same percentage of its full load rating. Therefore, if the load on the system is 60 percent of the maximum system capacity, each turbine generator set in the system will be operating at 60 percent load.

In order for isochronous load sharing to be used, each turbine generator set in the system must have a governor with the isochronous load sharing feature.

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5. *Missing signal detection feature*

The missing signal detection feature monitors all input signals and determines if they are in the correct range. Any signal that is out of range should cause immediate action by the electronic governor to ensure safe operation of the turbine.

6. *Sensor redundancy*

7. *Overspeed trip*

The overspeed trip feature can be provided as a back up to the primary trip.

8. *Automatic synchronizer*

The automatic synchronizer adjusts turbine speed to match bus frequency and generator phase to match the bus phase. They can also provide voltage matching. The synchronizer will generate a breaker close command when everything is within specified limits.

9. *Kilowatt limit control*

Other accessories are available.

Authorized Engineering Information 6-12-1985.

3.11 AUTOMATIC START CONTROLS

Automatic start controls are available for turbine generator sets. The turbine generator manufacturer should be consulted for recommended equipment and procedures.

Authorized Engineering Information 6-12-1985.

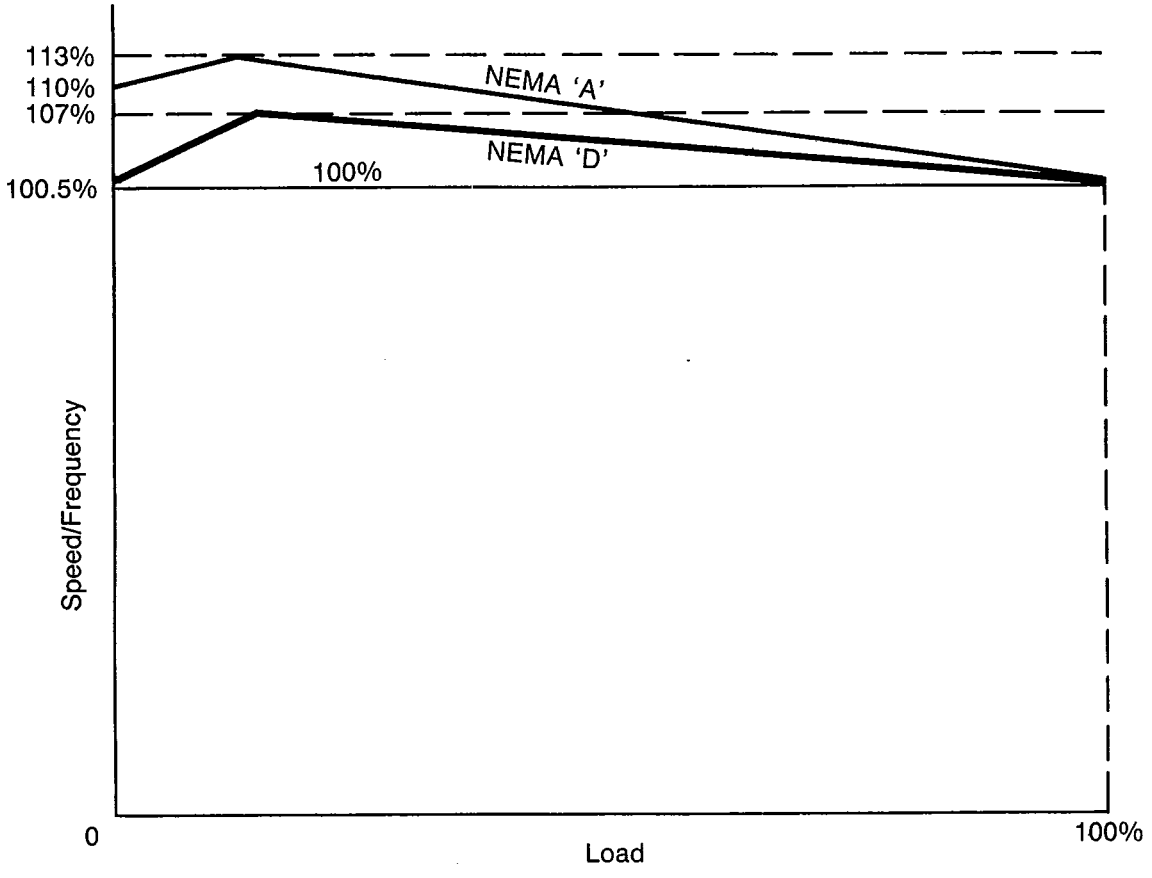


Figure 3-1
SPEED/FREQUENCY RISE FOR NON-PARALLEL SYNCHRONOUS TURBINE GENERATOR SET

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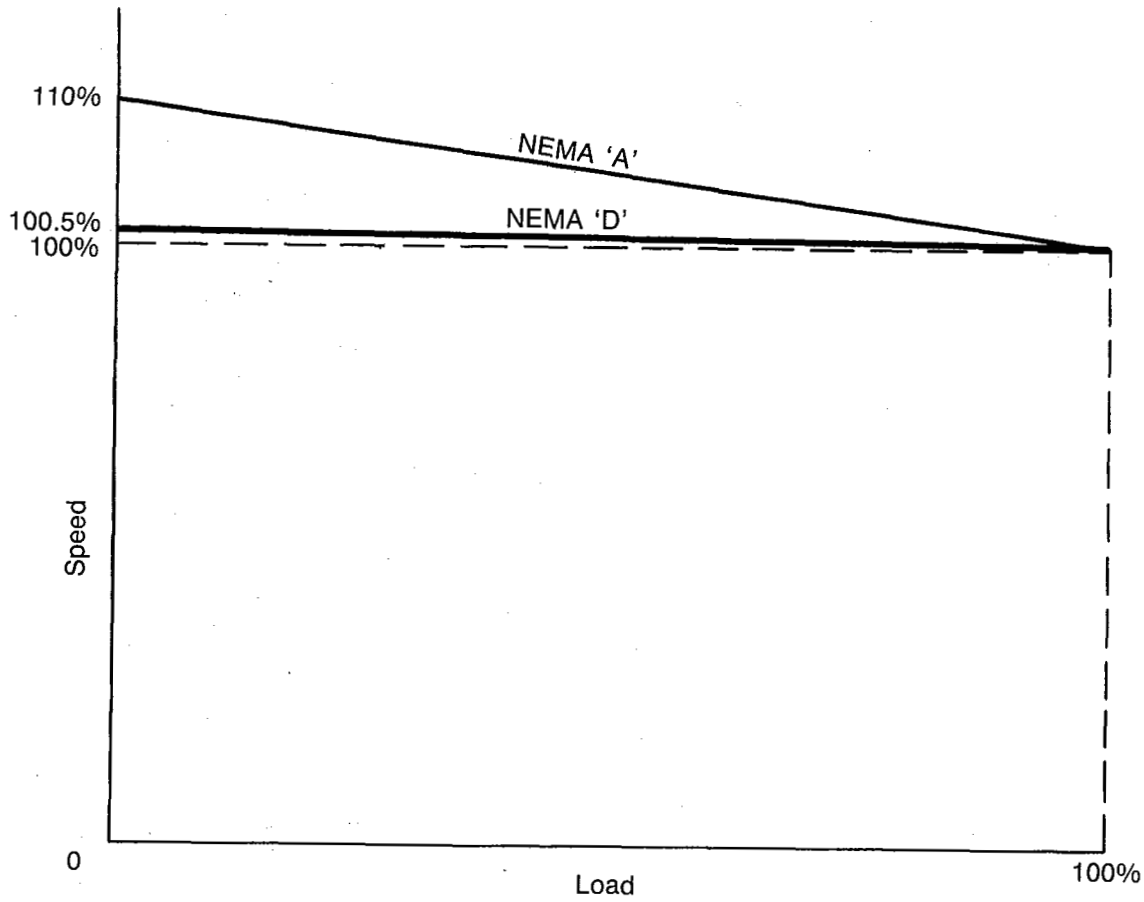


Figure 3-2
STEADY STATE SPEED/FREQUENCY REGULATION FOR NON-PARALLEL SYNCHRONOUS TURBINE GENERATOR SET

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Section 4

PROTECTION

4.1 BASIC FEATURES

The following features and accessories are necessary for the proper functioning of equipment and safety of operation:

4.1.1 Manual Trip

Each turbine shall be provided with a manual tripping device to close the trip valve or trip-and-throttle valve.

NEMA Standard 6-12-1985.

4.1.2 Overspeed Trip System

The overspeed trip system shall be spark-proof and shall include the overspeed sensing device, linkage, and a trip valve or a trip-and-throttle valve separate from the speed governor-controlled valve(s).

1. *Overspeed Sensing Device*

The overspeed sensing device includes those elements which are directly responsive to speed and which initiate action to close the trip valve at a predetermined speed.

2. *Trip Valve*

The trip valve is separate from the governor-controlled valve and is closed (tripped) in response to the action of the overspeed sensing device or other safety devices or is manually tripped.

3. *Overspeed Trip System Setting*

The trip speed settings shown in Table 4-1 shall be above the speed reached due to the maximum speed rise characteristic of the governing system to avoid tripping the turbine on sudden loss of load.

NEMA Standard 6-12-1985.

Table 4-1
TRIP SPEED SETTINGS

Class of Governing System	Trip Speed Setting, Percent*
A	115
B	110
C	110
D	110

*All values are in percent of rated speed.

4.1.3 Overcurrent

A circuit breaker or contactor shall be supplied to protect the generator and controls from overload or short-circuits.

The circuit breaker shall continuously carry the generator's rated output current at rated voltage and shall be capable of interrupting the maximum available short circuit current.

The circuit breaker shall have provisions for manual opening and closing and for automatic tripping due to overcurrent.

The circuit breaker shall be designed to carry a specified overcurrent for a specified period of time without tripping.

Low voltage circuit breakers (up to and including 600V) shall be in accordance with NEMA Standard AB 1-1975 (R 1981), or ANSI/IEEE C37.13-1981 Standard.

NEMA Standard 6-12-1985.

A shunt trip should be supplied if necessary to trip the breaker in response to an external signal. Auxiliary contacts may be supplied for automatic closing of the breaker in response to other signals, or for indication of the breaker's position.

Authorized Engineering Information 6-12-1985.

4.2 ACCESSORIES

The following are accessories which the manufacturer may select, depending on steam conditions, ratings, and application:

1. Trip-and-throttle valve
2. Trip system which can be tested during operation
3. Solenoid trip
4. Shaft grounding device
5. Vacuum breaker
6. Surge capacitors
7. Lightning arresters
8. Redundant overspeed trip
9. Turbine trip or alarms in response to any of the following functions:
   a. low oil pressure
   b. high vibration
   c. high bearing temperature
   d. turbine rotor axial position
   e. high steam pressure

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f. high steam temperature
g. high oil temperature
h. high/low oil reservoir levels
i. high differential filter(s)
j. governor failure

10. Circuit breaker trip or alarm in response to any of the following functions:
    a. high stator temperature
    b. over/under voltage
    c. over/under frequency
    d. reverse power
    e. differential protection
    f. high coolant temperature (air or water)
    g. ground fault
    h. open phase/phase balance
    i. loss of excitation
    j. turbine trips
11. Other accessories are available.

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Section 5

GENERATOR CONTROL PANEL AND SWITCHGEAR

5.1 INTRODUCTION

Generators for industrial plant or commercial class power system service usually have ratings varying from 480 volts through 13,800 volts.

The generator switchgear is to provide protection for the equipment and its operating personnel. The degree of switchgear protection recommended for generators is based on the cost and service requirements. Additional protection can be justified on the basis that greater fault sensitivity and faster response can minimize fault damage and considerably lessen repair costs and downtime.

WHEN THE GENERATOR IS TO BE PARALLELED WITH THE UTILITY SYSTEM, THE PROTECTION AND METERING REQUIREMENT OF THE UTILITY SHOULD BE CONSIDERED. PRIOR TO INSTALLATION THE PURCHASER OR USER SHOULD OBTAIN APPROVAL FROM THE UTILITY FOR THE EQUIPMENT BEING SUPPLIED.

When used with steam turbine generator sets, the switchgear and controls covered in this section should perform the following functions:

1. Connect the generator output to and disconnect it from the power bus.
2. Provide instrumentation to monitor the various parameters necessary to operate the equipment.
3. Control the generator voltage.
4. Protect the generator and the associated equipment against faults, detect faults if they occur and provide an alarm or shutdown, or both.

This section covers basic equipment up to and including the generator circuit breaker.

Authorized Engineering Information 6-12-1985.

5.2 GENERAL

The equipment described in this section for factory-built alternating current switchgear is considered minimum for typical 3-phase, 3-wire circuits.

For other system requirements, additional equipment should be added, in which case the manufacturer should be consulted.

The following covers metal-enclosed units and the devices associated with them for use on 3-phase circuits.

Adequate surface area and mounting facilities should be provided for all standard panel-mounted items. Space should be provided in auxiliary compartments, when required, in addition to that available in the standard unit assemblies to house buses, connections, operating transformers, instrument transformers, rheostats, field control equipment, and other devices.

Enclosures should be suitable for the site environment. (For 1000 volts maximum, see NEMA Standards Publication 250-1985.)

When the switchgear is intended for outdoor use, the equipment should be located within a weatherproof housing, with each housing having:

1. Suitable weatherproof access door or doors with provision for locking.
2. Protected openings for ventilation, as required.
3. Interior lighting and utility outlets with protective devices.
4. Heaters with protective devices.

Authorized Engineering Information 6-12-1985.

5.3 LOW VOLTAGE POWER CIRCUIT BREAKER SWITCHGEAR (Up to 600 Volts)

5.3.1 Non-Paralleling Synchronous Units (See Figure 5-1)

Equipment located either in a cabinet on the generator enclosure, or in a separate wall or floor mounted unit, shall include:

1. Voltmeter
2. Ammeter
3. Frequency meter
4. Wattmeter
5. Combination selector switch (voltmeter/ammeter)
6. Current transformers as necessary
7. Potential transformers as necessary
8. Automatic voltage regulator with manual adjustment
9. Power isolation transformer for voltage regulator, if required
10. Low voltage power circuit breaker operated manually or electrically
11. Suitable control wiring and terminal blocks

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5.3.2 Manual Paralleling Low Voltage Synchronous Units (See Figure 5-2)

Equipment located either in a cabinet on the generator enclosure or in a separate wall or floor mounted unit shall include:

1. Voltmeters—bus side and generator side
2. Ammeter
3. Frequency meters—bus side and generator side
4. Wattmeter
5. Combination selector switches (voltmeter/ammeter)
6. Current transformers as necessary
7. Potential transformers as necessary
8. Automatic voltage regulator with manual adjustment and cross current compensation for paralleling
9. Power isolation transformer for voltage regulator, if required
10. Low voltage power circuit breaker operated manually or electrically
11. Synchronizing switch
12. Two synchronizing lights
13. Synchroscope
14. Reverse power relay
15. Suitable control wiring and terminal blocks
16. Overcurrent time delay relay

NEMA Standard 6-12-1985.

5.4 HIGH VOLTAGE POWER CIRCUIT BREAKER SWITCHGEAR (601 to 13,800 Volts)

5.4.1 Non-Paralleling High Voltage Synchronous Unit (See Figure 5-3)

The following instrumentation and equipment shall be mounted in one or more free-standing enclosures:

1. Voltmeter with switch
2. Ammeter with switch
3. Frequency meter
4. Wattmeter
5. Current transformers as necessary
6. Potential transformers as necessary
7. Automatic voltage regulator with manual adjustment
8. Power isolation transformer for voltage regulator, if required
9. Power circuit breaker of suitable rating and interrupting capacity, electrically operated with closing relays and shunt trip
10. Control switch for circuit breaker with indicating lights for open/close positions
11. Overcurrent relays for phase protection
12. Governor control switch
13. Differential protection with lockout relay
14. Ground fault relay
15. Suitable control wiring and terminal block

NEMA Standard 6-12-1985.

5.4.2 Manual Paralleling High Voltage Synchronous Units (See Figure 5-4)

The following instrumentation and equipment shall be mounted in one or more free-standing enclosures:

1. Voltmeters with switch on generator side
2. Ammeter with switch
3. Frequency meters
4. Wattmeter
5. Current transformers as necessary
6. Potential transformers as necessary
7. Automatic voltage regulator with manual adjustment and cross current compensation
8. Power isolation transformer for voltage regulator, if required
9. Power circuit breaker of suitable rating and interrupting capacity, electrically operated with closing relays and shunt trip
10. Control switch for circuit breaker with indicating lights for open/close positions
11. Overcurrent relays for phase protection
12. Governor control switch
13. Differential protection with lockout relay
14. Stator ground fault relay
15. Synchronizing switch
16. Synchroscope
17. Two synchronizing lights
18. Reverse power relay
19. Suitable control wiring and terminal block

NEMA Standard 6-12-1985.

5.4.3 Induction Generator Units (See Figure 5-5)

The following instrumentation and equipment shall be mounted in one or more free-standing enclosures:

1. Ammeter with switch
2. Wattmeter
3. Voltmeter with switch
4. Manually or electrically-operated power circuit breaker with shunt trip or a contactor with fuses
5. Reverse power relay
6. Panel lights for indicating motoring or generating
7. Current transformers as necessary
8. Potential transformers as necessary
9. Suitable control wiring and terminal block

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5.5 GENERATOR ACCESSORIES

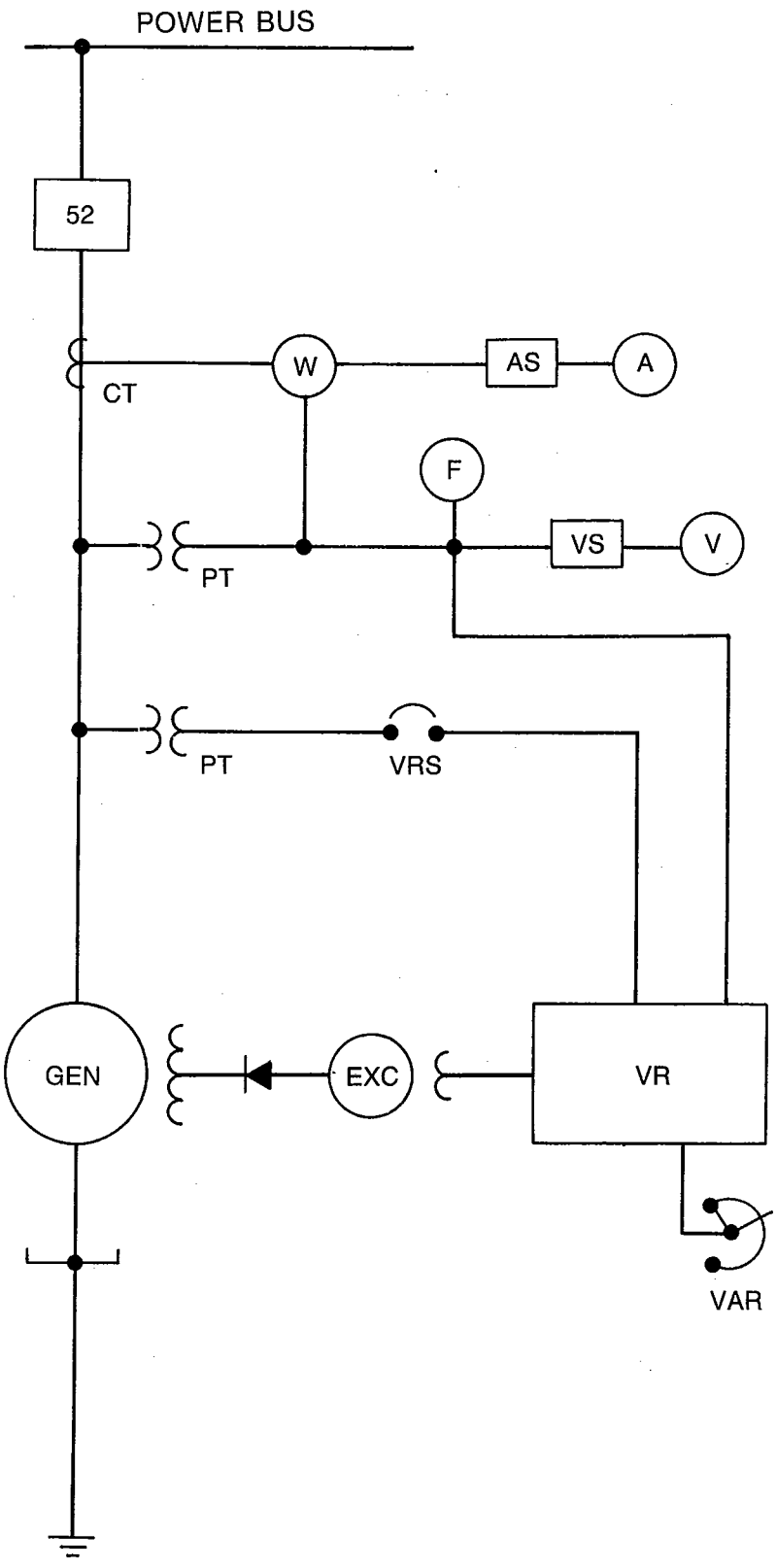
The following are accessories which the manufacturer may select, depending on ratings, voltage and application:

1. Power Factor Meter
2. Varmeter
3. Under/Over Frequency Protection
4. Under/Over Voltage Protection
5. Short Circuit Sustaining Protection
6. Ground Fault Protection
7. Differential Protection
8. Surge Protection
9. Lightning Arrester
10. Synchronizing Check Relay
11. Other options as required for the particular application.

Additional items may be available.

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52	Circuit Breaker
A	Ammeter
F	Frequency Meter
V	Voltage Meter
AS	Ammeter Switch
CT	Current Transformer
EXC	Exciter
GEN	Generator
PT	Potential Transformer
VAR	Voltage Adjusting Rheostat
VR	Voltage Regulator
VRS	Voltage Regulator Cutout Switch
VS	Voltmeter Switch
W	Wattmeter

Figure 5-1
NON-PARALLELING LOW VOLTAGE SYNCHRONOUS UNITS (5.3.1)

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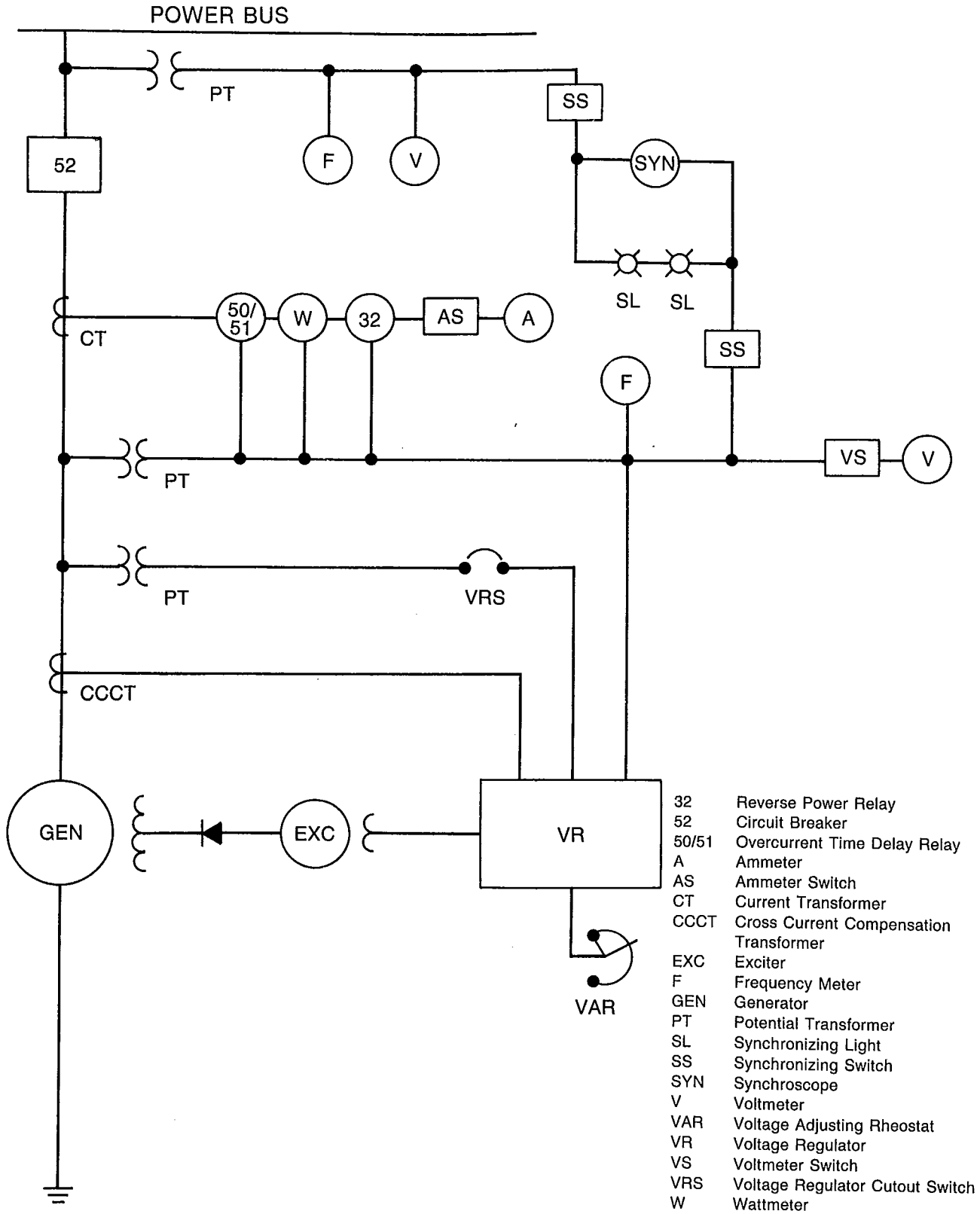
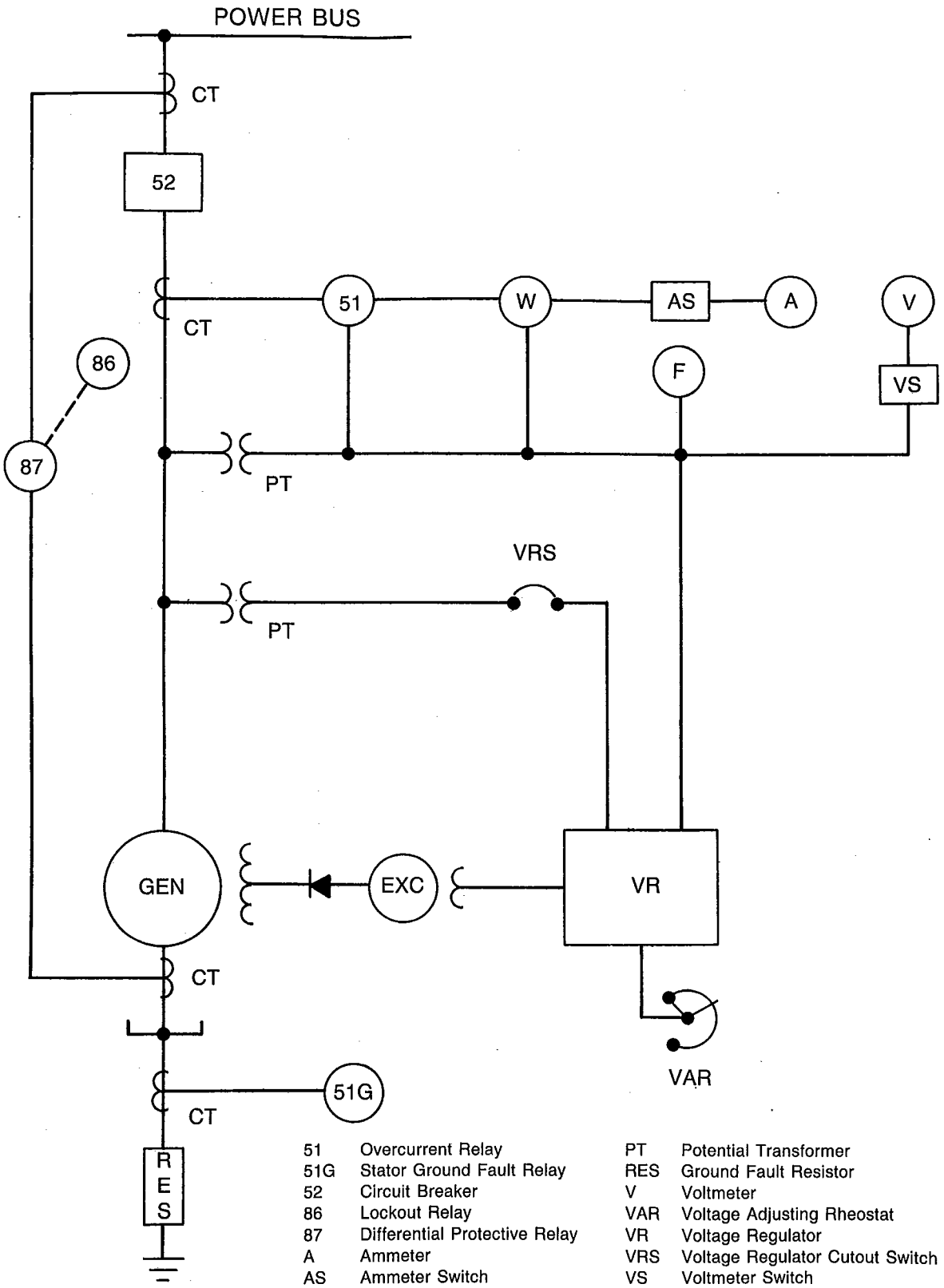


Figure 5-2
MANUAL PARALLELING LOW VOLTAGE SYNCHRONOUS UNITS (5.3.2)

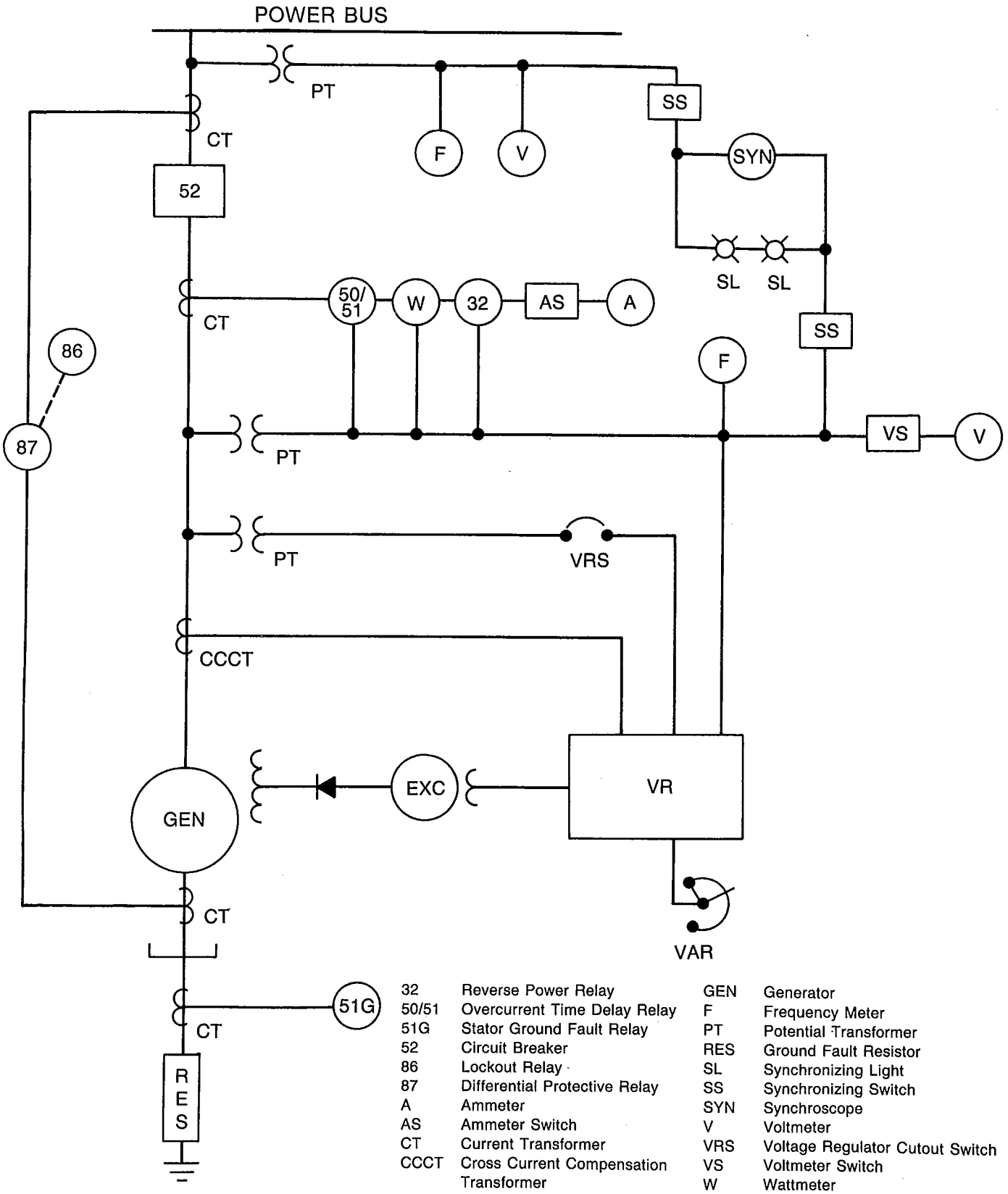
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51	Overcurrent Relay	PT	Potential Transformer
51G	Stator Ground Fault Relay	RES	Ground Fault Resistor
52	Circuit Breaker	V	Voltmeter
86	Lockout Relay	VAR	Voltage Adjusting Rheostat
87	Differential Protective Relay	VR	Voltage Regulator
A	Ammeter	VRS	Voltage Regulator Cutout Switch
AS	Ammeter Switch	VS	Voltmeter Switch
CT	Current Transformer	FR	Frequency Meter
EXC	Exciter	W	Wattmeter
GEN	Generator		

Figure 5-3
NON-PARALLEL HIGH VOLTAGE SYNCHRONOUS UNITS (5.4.1)

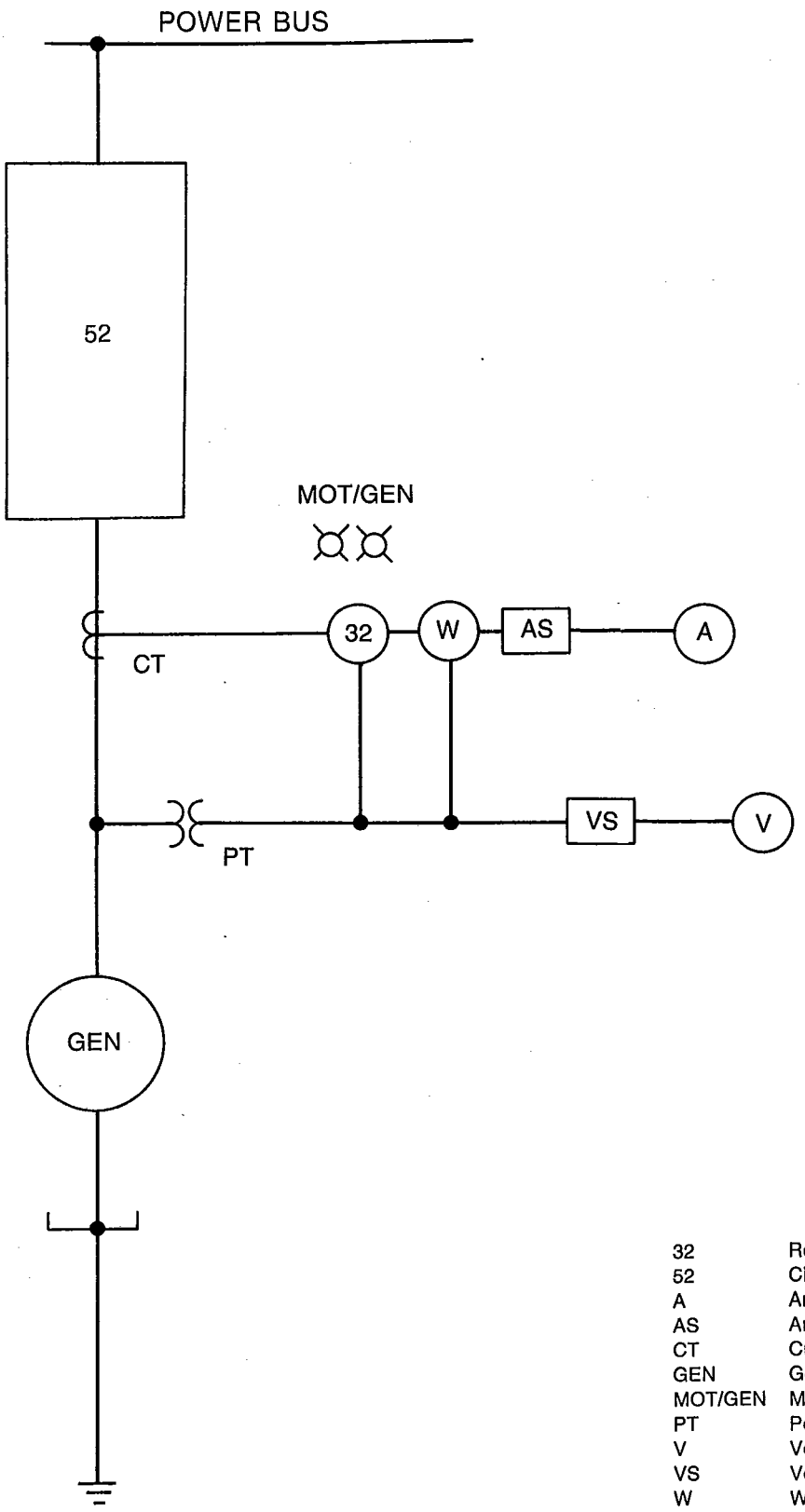
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32	Reverse Power Relay	GEN	Generator
50/51	Overcurrent Time Delay Relay	F	Frequency Meter
51G	Stator Ground Fault Relay	PT	Potential Transformer
52	Circuit Breaker	RES	Ground Fault Resistor
86	Lockout Relay	SL	Synchronizing Light
87	Differential Protective Relay	SS	Synchronizing Switch
A	Ammeter	SYN	Synchroscope
AS	Ammeter Switch	V	Voltmeter
CT	Current Transformer	VRS	Voltage Regulator Cutout Switch
CCCT	Cross Current Compensation Transformer	VS	Voltmeter Switch
EXC	Exciter	W	Wattmeter

Figure 5-4
MANUAL PARALLELING HIGH VOLTAGE SYNCHRONOUS UNITS (5.4.2)

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32	Reverse Power Relay
52	Circuit Breaker
A	Ammeter
AS	Ammeter Switch
CT	Current Transformer
GEN	Generator
MOT/GEN	Motor Generating Lights
PT	Potential Transformer
V	Voltmeter
VS	Voltmeter Switch
W	Wattmeter

Figure 5-5
INDUCTION GENERATOR UNITS (5.4.3)

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Section 6

FACTORY TESTING

6.1 TURBINE

6.1.1 Hydro Test

1. All parts of the turbine which contain steam under pressure shall be hydro-tested at a pressure not less than 1½ times their maximum steam pressure. For steam temperatures above 750 °F (400 °C), the values of the test pressure shall be multiplied by a factor obtained by dividing the maximum allowable hoop-stress value of the material at room temperature by that of the corresponding stress value at steam temperature. Condensing turbine exhaust casings shall be steam or hydro tested at a minimum of 25 psig (272 kPa).
2. Water jackets, coils, or coolers shall be hydro tested to 1½ times the specified cooling water pressure, but not less than 115 psig (900 kPa).
3. Pressure(s) shall be maintained for a period of 15 minutes. The test shall be considered satisfactory when no external leaks from the item under test are observed.
4. Casings shall not be painted until hydro testing is completed.

NEMA Standard 6-12-1985.

6.1.2 No-Load Running Test

The turbine shall be operated at the specified operating speed at no-load. The following tests and observations shall be made:

1. Check general operation
2. Measure vibration
3. Adjust the turbine control mechanism(s) and observe the operation of the speed governor and all other control devices
4. Check for steam and oil tightness
5. Check the setting of the overspeed trip and other safety devices
6. Check the control and lubricating oil temperatures and pressures after the oil has reached stable temperature conditions. The turbine shall be operated for a period of one hour without undue rise in oil temperature.

NEMA Standard 6-12-1985.

6.2 GEAR

6.2.1 No-Load Running Test

The gear shall be operated at the specified operating speed at no-load. The following tests and observations shall be made:

1. Check general operation
2. Measure vibration
3. Check for oil tightness
4. Check the lubricating oil temperature and pressure after the oil has reached stable temperature conditions
5. Check any other safety devices.

NEMA Standard 6-12-1985.

6.3 GENERATOR

The following tests shall be made on all generators:

1. Check the resistance of armature and field windings
2. Check the exciter field current at no load with normal voltage and frequency on the generator
3. Check the high-potential test in accordance with NEMA Standard MG 1-1978 (R 1981)
4. Check general operation
5. Measure vibration
6. Check for oil tightness
7. Check the lubricating oil temperature and pressure after the oil has reached stable temperature conditions
8. Check any other safety devices.

NEMA Standard 6-12-1985.

6.4 COMBINED TEST (Optional)

For factory assembled turbine generator sets where a combined no load running test is applicable, the following tests and observations shall be made:

1. Check alignment
2. Check general operation
3. Measure vibration
4. Check for oil tightness
5. Adjust and check operation of turbine trip devices
6. Check the control and lubricating oil temperatures and pressures after the oil has reached stable temperature conditions.

Where a turbine generator set is assembled on site, a factory combined running test is not performed.

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Section 7

SOUND PRESSURE LEVELS

7.1 GENERAL

It is the manufacturer's intention to design and manufacture turbine-generator units with satisfactory sound levels and to work cooperatively with the user to make an overall installation which will be as quiet as possible. The sound pressure level(s) measurement procedure described in these standards is presented as a guide to the user. To be meaningful, this measurement(s) should be taken on the installed turbine generator set.

However, the manufacturer does not have control over such factors as foundations, piping, and building configurations which emit, reflect, focus, or amplify the sound of the unit as well as generate other sounds. For example, piping will usually be a strong emissive source of sound-generating impulses originating in the turbine as well as the sound caused by the passage of steam in the piping system.

The user should control noise from other sources so that it does not significantly add to or completely mask that from the turbine generator set. In order to achieve this, the user should suitably insulate the steam piping.

Furthermore, it is generally impractical to isolate the turbine generator set from its environment sufficiently to separately measure its sound emission. The physical size of the equipment and the fact that it must be connected to piping makes isolation for sound measurement difficult, if not impossible. Sound pressure levels listed in Table 7-1 represent sound pressure levels of the turbine, gear, and generator when operating at the maximum steam flow for which the turbine is designed. The maximum steam flow may be greater than that specified for operation at normal power, speed, and steam conditions.

Reduced sound pressure levels can be achieved through acoustic treatment. Sound pressure levels are recognized as being beneficial in planning for noise control. Sound pressure levels are primary data upon which sound power levels can be estimated, but standard conversion procedures have not been adopted which are practical for the variety of acoustical environmentals encountered.

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7.2 SOUND QUALITY

Sound quality is determined by the distribution of effective sound intensities as a function of frequency. It plays a significant role in determining how acceptable the sound is to the human ear.

Although the overall A-weighted sound does not completely define sound acceptability, because machines with the same overall decibel sound level may have a different sound quality, it does provide a quantitative measure of loudness and hearing damage potential. It may be necessary to describe the sound profile in more detail. If so, the manufacturer should be consulted.

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7.3 SOUND PRESSURE LEVEL MEASUREMENT PROCEDURE

Sound pressure levels shall be measured in accordance with American National Standards S5.1-1971, Section 7.0, as it is applicable, summarized as follows:

Acoustical performance is based on a sound pressure level which is dependent on acoustical characteristics of the space in which the unit operates. All measured sound levels are assumed to be in hemispherical free field or semi-reverberant field which has room constant large enough so as to not significantly affect sound pressure levels at the measuring point.

A 6-decibel drop-off in sound pressure level in each octave band of interest, as the microphone is moved from each measurement location in all directions around the machine, regardless of distance, indicates approximate free field conditions. Corrections must be made for environment when the drop-off is less than 6 decibels.

All sound-pressure readings shall be recorded as sound-pressure levels in decibels at reference pressure of 2 times 10^{-5} Newton per square meter.

All sound pressure readings shall be made using slow meter scale and C network of sound level meter which has a flat response-frequency characteristic, recording visual average of reading.

Fluctuating noise levels equal to or higher than plus or minus 2 dBA overall shall be recorded.

The microphone shall be protected from external disturbing influences (vibration, air currents, and electric or magnetic fields) which may affect readings.

Microphone locations shall be approximately, but not less than, 1 meter from any sound source being measured and at a height 1.5 meters above the floor. Care shall be taken to avoid a position at the nodal point of standing wave. One set of readings should be all that is required

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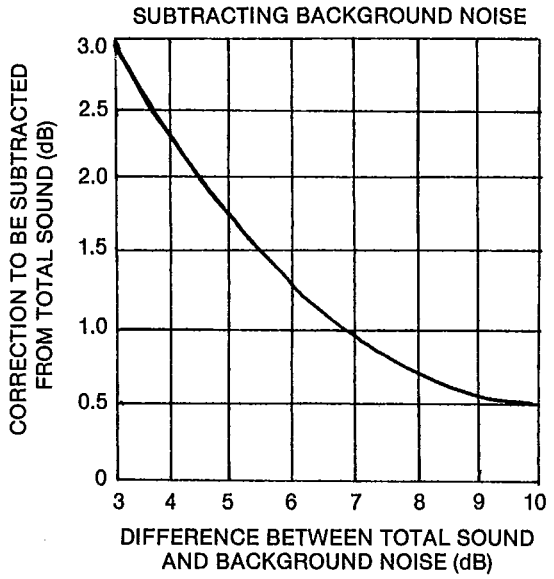


Figure 7-1
CORRECTION FOR BACKGROUND NOISE

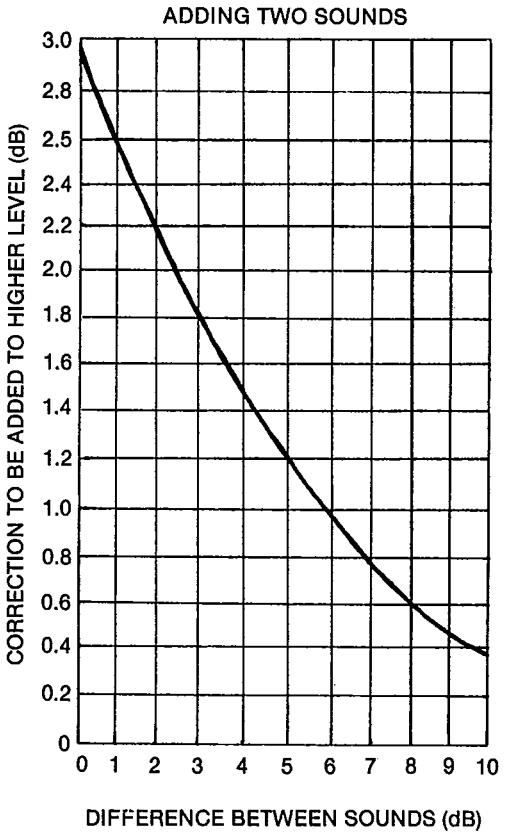


Figure 7-2
SOUND RESOLUTION

if the microphone is so positioned. (This sentence is approved as Authorized Engineering Information.) The position of the microphone for measuring background ambient sound and total sound shall be identical.

NEMA Standard 6-12-1985.

7.4 CORRECTION FOR BACKGROUND NOISE

Measurements of sound pressure levels should be corrected for ambient background sound pressure levels. Levels at each location should exceed background levels by at least 10 decibels in each octave band. If the difference between measured sound level and background sound level is less than 3 decibels in given octave band, valid equipment sound level in that band cannot be determined. When the difference is greater, the correction factor shown in Figure 7-1 should be subtracted from the measured sound level.

Consideration should also be given to effects of extraneous sound sources, e.g., piping driven equipment that are part of the system, and also to steam leakoffs or leakage from valves and piping system.

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7.5 SOUND RESOLUTION

Two measurements often must be added to determine the combined noise level of several sources or subtracted to find the noise output of one particular source in a noisy environment. However, noise measurements cannot be added or subtracted directly. Rather, measurements can be combined with a correction number. The correction numbers obtained from Figure 7-2 are approximate. However, the graphic results are fast and sufficiently accurate for most engineering applications.

The correction number is based on the difference in amplitude of two sounds—whether the sounds are being added or subtracted. When sounds are added, the correction number is added to the total. For example, 80- and 86-decibel sound levels differ in amplitude by 6 decibels, a difference that yields a correction number of 1 from the graph. Thus, total sound level is 87 decibels.

When background noise is subtracted from the total sound level, the correction number is subtracted also. For example, a 90-decibel background noise and a 97-decibel total sound level differ in amplitude by 7 decibels, a difference that yields a correction number of 1 from the graph. Thus, the sound level without the background noise is 96 decibels.

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7.6 INSTRUMENTS

Sound pressure levels should be measured by means of a sound level meter which meets the requirements of American National Standard S1.4-1983.

Instruments, including microphones, should receive an acoustic check on overall calibration before and after every sound pressure level test.

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7.7 SOUND ATTENUATION

It is recommended that acoustical treatment for turbine generator units be applied after installation of the equipment and ensuing plant operation. Factors which affect sound levels are many and varied and may not be associated as closely with the machinery itself as with steam velocities in piping and other sound sources.

After installation and operation has commenced, an overall plant sound level can be established and corrective measures taken to isolate the major sound producing portions of the process.

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7.8 SOUND PRESSURE LEVELS

Expected maximum sound pressure levels for turbines, gears, and generators at rated operating conditions when measured in accordance with 7.3 are shown in Table 7-1.

Table 7-1
SOUND PRESSURE LEVELS (dB)

Freq. Band (Hz)	Mid-Band Freq. (Hz)	Turbine			Generators	
		Single Stage	Multi-Stage	Gears	Open	Enclosed
45-90	63	98	106	105	102	92
90-180	125	94	98	101	101	91
180-355	250	91	97	97	102	92
355-710	500	89	92	95	102	92
710-1400	1000	89	90	95	101	91
1400-2800	2000	89	90	95	99	89
2800-5600	4000	89	90	95	97	87
5600-11200	8000	89	90	95	94	84
Overall dBA	93	93	95	105	95	

Actual sound pressure levels may not equal maximum tabulated values for all frequency bands. Overall dBA is, therefore, less than the sum of individual values.

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Section 8

PREPARATION FOR SHIPMENT AND STORAGE

8.1 SHIPPING PREPARATION

The turbine, gear (if used), generator, and all separate parts shall be properly tagged and identified.

At the time of shipment, all exposed non-machined surfaces shall be protected with one coat of shop paint and coating or covering or both. All exposed machined surfaces and oil reservoir interiors shall be protected with a rust preventative. All openings except for air passageways on open type generators shall be plugged or covered. The interiors of the turbine, gear (if used), and generator bearing housing shall be suitably treated to prevent rust.

Prior to shipment, the rotor of a generator with sleeve bearings shall be braced in place to prevent axial movement of the rotor during shipment.

Ocean freight or extended storage shall require additional protection and packaging.

NEMA Standard 6-12-1985.

8.2 SHIPMENT

The purchaser, since he has the most complete knowledge of local conditions, should specify the delivery point and provide information on the method of handling from the nearest rail siding to the point of installation.

The manufacturer should use shipping methods and ship parts in the sequence required for orderly installation and identify all shipments by marking individual parts, assemblies, or packages prior to shipment.

When the manufacturer is notified by the purchaser that installation will be delayed, the manufacturer should specify the additional preparation and protective coatings that should be provided to protect the equipment.

The purchaser should advise the manufacturer of the unloading facilities available and whether parts, with skids for rolling large assemblies into position, will be necessary.

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8.3 RECEIPT AND STORAGE OF EQUIPMENT

Upon receipt, the purchaser should check all equipment for damage which may have occurred in transit. Any damage or shortages should be reported immediately to the transportation company and a copy of the report forwarded to the manufacturer.

All material should be checked against the manufacturer's packing list, and any discrepancies reported immediately to the manufacturer.

The equipment should at all times be stored in a clean, noncorrosive atmosphere and protected against loss, weather, damage, and foreign materials such as dust, sand, and so forth. Indoor storage where constant temperature is maintained at a level which will prevent condensation is preferred. The user should seek the manufacturer's advice if storage conditions are other than the above.

Special attention and care should be given to the storage of parts having exposed machined surfaces.

The generator should be stored with enough packaging removed to allow circulation of air through the windings. The winding temperature should be maintained at approximately 10 °F (−12 °C) above ambient temperature by means of the generator's space heaters (if the generator is so equipped) or other reliable means.

The resistance of the generator insulation should be measured at the start of storage, every three months thereafter, and just prior to energization.

Before start-up, the oil or preservative used in the bearing housing and gear casing should be flushed out and replaced with clean lubricating oil of the recommended type. Grease lubricated bearings may require lubrication prior to start-up.

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Section 9

INSTALLATION

9.1 INTRODUCTION

The turbine generator set should be installed in accordance with recommendations and instructions issued by the manufacturer.

The information contained in Section 9 is provided to assist the purchaser or his contractor in the proper handling and installation of turbine-generator sets. There are many variables involved in the equipment furnished, method of shipment, and types of installation, therefore, it is not feasible to detail step-by-step procedures.

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9.2 SUPERVISION OF INSTALLATION

It is recommended that the manufacturer's representative supervise the installation of the turbine-generator set. The installation procedure should be in accordance with recommendations and instructions issued by the manufacturer either on drawings or by other means. Such procedures are arranged and planned to obtain the most satisfactory installation and operation of the equipment.

Fully qualified labor, including qualified supervision, is required for proper installation, start-up, and operation.

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9.3 INSTALLATION

Proper installation is necessary for satisfactory operation. The user should provide an adequate foundation to maintain alignment and should install piping to minimize external forces and moments on the turbine.

Sufficient space and necessary openings in the foundations and building structure should be provided for the installation of the equipment. Suitable openings should be provided in the building to admit the equipment. The purchaser should provide sufficient space around the equipment for servicing. Adequate space should be provided above the turbine to allow removal of the casing cover, and adequate space should be allowed behind the generator for removal of the generator rotor. Adequate floor space should be allowed for setting down the turbine cover, gear casing cover (if a gear is used), and the properly supported rotating elements of the turbine, gear (if used), and generator.

9.3.1 Foundation

Foundations should be sufficiently heavy and rigid to form a permanently nonwarping structure.

The manufacturer should furnish dimensional drawings to enable the purchaser to design a suitable foundation of ample proportion and strength for the equipment specified. The foundation should be designed so that it will absorb to a large extent the vibration of the unit installed on it. The foundation should be isolated from the building structure by means of spacers (felt, cork, and so forth) so that outside vibration will not be transmitted to the foundations. The natural frequency of the foundation should not correspond to any operating speed of the unit.

9.3.2 Steam Inlet and Exhaust Piping

The user should insulate steam lines and the turbine to limit heat losses and to protect operating personnel.

Steam piping should be as short and as direct as possible and so arranged that no undue strain is imposed on the turbine due to expansion and contraction of the steam lines or the weight of the steam lines.

Expansion in the high-pressure steam lines should be taken care of by bends, supports, or other suitable methods in the piping system. On low-pressure lines, expansion and contraction should be taken care of by expansion joints or other suitable devices. To avoid localized heating, lines carrying high pressure steam should not be located too close to the foundation-bearing supports, and so forth.

The pressure losses in the inlet and exhaust steam piping should be taken into account when determining the required pipe sizes. The piping should be of sufficient size to give no less than the minimum specified initial and no more than the maximum specified exhaust pressure at the turbine connections when the turbine is developing rated power at rated speed.

Steam piping should be designed in accordance with appropriate codes and specifications. In order to minimize pressure drop, noise, and erosion, it is recommended that piping be sized so that the following steam velocities shown in Table 9-1 will not be exceeded in the steam piping when the turbine is operating at rated power and rated steam conditions.

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Table 9-1
MAXIMUM STEAM VELOCITY, IN PIPING

	Noncondensing Turbine		Condensing Turbine	
	Ft./Sec	M/Sec	Ft./Sec	M/Sec
Inlet	175	53.34	175	53.34
Exhaust	250	76.2	450	137
Induction	175	53.34	175	53.34
Extraction	250	76.2	250	76.2

Steam piping should be blown down to remove debris prior to final connection.

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9.4 STEAM PIPING SYSTEMS

9.4.1 Introduction

Reactions of piping systems connected to steam turbines, if of sufficient magnitude, will result in misalignment of the turbine sufficient to cause rough operation and serious mechanical damage. Steam turbines have been very carefully designed to provide for thermal expansion and, at the same time, maintain close alignment between the turbine rotating and stationary parts, and also the turbine and driven equipment. The provisions for turbine thermal expansions by necessity limits the allowable values of forces and moments applied to the turbine structure by the piping connected to it.

It is the purpose here to briefly discuss piping arrangements and recommend flange loading limitations imposed on steam turbines by piping. This information is presented as an aid to the purchaser and is not intended as a self-contained thesis on piping.

The recommendations to be discussed should provide allowable values of forces and moments at the turbine connections for steam inlet, extraction, and exhaust piping.

It is not considered necessary to supply values for auxiliary piping such as steam leakoff, lubricating oil, and cooling water, but even so, this auxiliary piping should also be designed such that turbine expansion is not restrained.

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9.4.2 The Piping Problem as Applied to Turbines

One of the first considerations in designing any piping system is to keep the stresses in the pipe within the limits of the established rules of national codes such as the ANSI/ASME B31.3-1984, and any local codes that may be applicable. In general, the jurisdiction of such authorities stops at the turbine inlet and exhaust connections or other openings on the machine to which external piping systems connect.

In order to keep the strains due to forces and bending moments on the turbine connections, including the weight of the pipe, within recommended limits, the piping system design should be such that restraints and freedom of movement match the requirements of the turbine. Pipe forces which seem small may lead to large moments at the connections to the turbine and to very large forces at the turbine supports.

The forces in a piping system under operating conditions can be grouped into three classes: those due to steam pressure, temperature, and dead weight.

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9.4.3 Forces Due to Steam Pressure

These are most commonly associated with low-pressure and vacuum lines where expansion joints are often used to provide flexibility. If an expansion joint is improperly used, it may cause a pipe reaction greater than the one which it is supposed to eliminate. An unrestrained expansion joint will cause an axial thrust equal to the effective area of the bellows times the internal pressure. The force necessary to compress or elongate an expansion joint can be quite large, and either of these forces may be greater than the limits for the exhaust flange. In order to have the lowest reaction when it is found that expansion joints are required, the Standard of the Expansion Joint Manufacturers Association should be consulted.

The following figures and paragraphs represent typical installations and are offered only as guides.

Figure 9-1 shows an expansion joint in a pressure line. The axial thrust from the expansion joint tends to separate the turbine and the elbow. To prevent this, the elbow should have an anchor to keep it from moving. The turbine should also absorb this thrust and, in doing so, becomes an anchor. This force on the turbine case may be greater than can be allowed. In general, this method should be discouraged.

Figure 9-2 shows the same piping arrangement as Figure 9-1, except for the addition of tie rods on the expansion joint. The tie rods prevent the elongation of the joint and take the axial thrust created by the internal pressure of the expansion joint so it is not transmitted to the turbine flange. The tie rods eliminate any axial flexibility, but the joint is still flexible in shear; that is, the flanges may move in parallel planes. The location of this type of joint in the piping should be such that movement of the pipe puts the expansion joint in shear instead of

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tension or compression.

Figure 9-3 is an arrangement frequently used, having tie rods as indicated for noncondensing operation. This arrangement should prevent any thrust due to internal pressure of the expansion joint from being transmitted to the exhaust flange and retains the axial flexibility of the joint. It may be used for either vacuum or pressure service (by suitable arrangement of tie rods).

Figure 9-4 shows a suggested arrangement for a condensing turbine with an "up" exhaust. Due to the large exhaust pipe size normally encountered on condensing turbines, the exhaust piping may be relatively stiff, and an expansion joint should be used at some point to take care of thermal expansion. An unrestricted expansion joint placed at the exhaust flange of the turbine may exert an upward or lifting force on the turbine flange which in many cases is excessive. Figure 9-4 provides the necessary flexibility to take care of thermal expansion without imposing any unnecessary lifting force on the turbine. The expansion joint is in shear which is the preferred use. The relatively small vertical expansion may compress one joint and elongate the other which causes a small reaction only and may be well within the turbine flange limits.

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9.4.4 Forces Due to Temperature

If a pipe is connected to some point as A in Figure 9-5, and has the configuration shown by the solid line, it may assume the approximate position shown by the dash line when heated to a higher temperature, providing no restraint is offered by point B.

If both points A and B are rigid points which may not move, the pipe may assume a shape similar to that shown by the dash line in Figure 9-6 when heated.

The stresses may be reduced by using expansion loops such as shown in Figure 9-7. When the piping does not have to be confined to one plane, torsional flexibility may be effectively used to reduce stresses. Prestressing the pipe in the cold condition or "cold springing" may also be used to reduce the stresses in operation. These principles may be used in combination to produce a design with flexibility sufficient to keep the stresses, forces, and moments within the permissible limits in both the hot and cold conditions.

The piping system should be designed with sufficient inherent flexibility to take care of thermal expansion. Prestressing (cold springing) to reduce the maximum values of both connection reactions and piping stress is accomplished by cutting the pipe short by a predetermined amount and then forcing it into place during installation as illustrated in Figure 9-8. Forces and moments in the hot condition are thus reduced below the values they would have if the system were not cold-sprung. Points A and C of Figure 9-8 are the points to be connected by a piping system and X and Y are the respective expansions.

In the case of welded connections, it is necessary to bend the pipe by putting a moment on it when connecting it to point C to make the weld preparations parallel, as well as just pulling B up to C. If this is not done, a moment may exist in the hot condition, and desired reduction in forces and moments may not be obtained. Wherever possible, it is wise to facilitate assembly by locating field welds at points of minimum moment. Points D and E are such points.

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9.4.5 Forces Due to Dead Weight

The dead weight of the piping should be entirely supported by pipe hangers or supports. There are basically two types of supports—rigid and spring. Rigid supports are necessary when an unrestricted expansion joint is used. Rigid supports may be used to limit the movement of a line to prevent excessive deflection at any point. A rigid support is not satisfactory where thermal expansion may cause the pipe to move away from the support.

On the two types of rigid supports shown in Figure 9-9, the rise of the turbine case due to temperature may lift the base elbow from the support so the turbine would have to support the weight of the pipe. The expansion of the vertical run of pipe would relieve the pipe hanger of its load so the turbine would again have to support the weight of the pipe.

If an expansion joint with restraining tie rods is used, either a rigid pipe hanger or a base elbow with a sliding or rolling contact surface can be used as shown in Figure 9-10.

When the thrust due to an expansion joint is less than the exhaust flange limits and no restraining tie rods are used, the pipe should have an anchor as shown in Figure 9-11. Since this condition rarely exists, it is better to use the preferred arrangement such as shown in Figure 9-10, and eliminate as much pipe reaction as possible rather than just stay within the limits.

Spring hangers or supports are best suited to carry the dead weight when there is thermal expansion to be considered. The movement of the pipe may change the spring tension or compression a small amount and the hanger loading a small amount but may not remove the load from the hanger. Published manuals on pipe design provide information on hanger spacing to give proper support. In addition to this, it may be found necessary to add additional supports or move existing supports if resonant vibration appears in the piping.

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A spring support should not be used to oppose the thrust of an expansion joint. When the pressure is removed from the line, the spring support may exert a force the same as the expansion joint only in the opposite direction.

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9.4.6 Allowable Forces and Moments on Steam Turbines

The forces and moments acting on steam turbines due to the steam inlet, extraction, and exhaust connections should be limited by the following:

1. The total resultant force and total resultant moment imposed on the turbine at any connection should not exceed the values per Equation 1.

$$F_R + \frac{M_R}{3} = 167\ D_e \qquad \text{(equation 1)}$$

where:

F_R = Resultant force in pounds including pressure forces where unrestrained expansion joints are used at the connection except on vertical exhausts. Full vacuum load is allowed on vertical down exhaust flanges. It is not included as part of the piping load from Figure 9-12:

$$F_R = \sqrt{F_x^2 + F_y^2 + F_z^2}$$

M_R = Resultant moment in foot-pounds, from Figure 9-12.

$$M_R = \sqrt{M_x^2 + M_y^2 + M_z^2}$$

D_e = Nominal pipe size of the connection in inches up to 8 inches in diameter.

For sizes greater than this, use a value of

$$D_e = \frac{(16 + D_{nom})\ \text{Inches}}{3}$$

2. The combined resultants of the forces and moments of the inlet, extraction, and exhaust connections, resolved at the centerlines of the exhaust connection should not exceed the values per Equation 2.
   a. These resultants shall not exceed:

$$F_c = \frac{250\ D_c - M_c}{2} \qquad \text{(equation 2)}$$

where:

F_c = Combined resultant of inlet, extraction, and exhaust forces, in pounds.

M_c = Combined resultant of inlet, extraction, and exhaust moments, and moments resulting from forces in pound-feet.

D_c = diameter in inches of a circular opening equal to the total areas of the inlet, extraction, and exhaust openings up to a value of 9 inches in diameter. For values beyond this, use a value of D_c equal to:

$$\frac{(18 + \text{Equivalent diameter})}{3} = \text{inches}$$

   b. The components (Figure 9-12) of these resultants should not exceed:

$F_x = 50\ D_c$	$M_x = 250\ D_c$
$F_y = 125\ D_c$	$M_y = 125\ D_c$
$F_z = 100\ D_c$	$M_z = 125\ D_c$

The components are as follows:

F_x = Horizontal component of F_c parallel to the turbine shaft.

F_y = Vertical component of F_c.

F_z = Horizontal component of F_c at right angles to the turbine shaft.

M_x = Component of M_c around the horizontal axis parallel to the turbine shaft.

M_y = Component of M_c around the vertical axis.

M_z = Component of M_c around the horizontal axis at right angles to the turbine shaft.

3. For installation of turbines with a vertical exhaust and an unrestrained expansion joint at the exhaust, an additional amount of force caused by pressure loading is allowed. (This additional force is perpendicular to the face of the exhaust flange and central.) For this type of application, calculate the vertical force component on the exhaust connection excluding pressure loading. Compare this with one sixth of the pressure loading on the exhaust. Use the larger of these two numbers for vertical force component on the exhaust connection in making calculations outlined in items 1 and 2.

   The force caused by the pressure loading on the exhaust is allowed in addition to the values established by the foregoing up to a maximum value of vertical force in pounds on the exhaust connection (including pressure loading) of 15½ times the exhaust area in square inches.

4. These values of allowable force and moment pertain to the turbine structure only. They do not pertain to the forces and moments in the connecting piping, flange, and flange bolting, which should not exceed the allowable stress as defined by applicable codes and regulatory bodies.

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9.5 DRAIN PIPING

Individual drain piping should be provided with shutoff

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valves or traps.

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9.6 LEAK-OFFS

Leak-offs should be piped directly to an open drain vented to the atmosphere without valves or restrictions, or to a condensate recovery system. The pipe should be adequately sized to avoid pressure buildup.

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9.7 FULL-FLOW RELIEF VALVE

The turbine casing and internal parts should be protected against excessive pressure by the installation of a full-flow relief valve. The relief valve is connected into the piping system between the turbine exhaust connection and the first shut-off valve. This relief valve should not be confused with the sentinel warning valve which is mounted on the turbine casing when supplied.

The full-flow relief valve should be provided by the user as a part of the piping installation which is external to the turbine. In condensing applications, a full-flow relief valve or rupture disc may be provided as part of the condenser or the turbine.

The size of the full-flow relief valve should be such that it will exhaust to the atmosphere the maximum quantity of steam (as determined by the turbine manufacturer) which will pass through the turbine nozzles with maximum initial steam conditions.

The full-relief valve should start to open at the setting of the casing sentinel warning valve and be fully open with the additional rise in pressure not to exceed 10 percent. The sentinel warning device will then give a visual indication when the full-flow relief valve starts to open.

If a high-back pressure or high-extraction or admission-pressure trip is furnished, the relief valve pressures should be raised 5 psi and the high-steam-pressure trip should be set at the above "start-to-open" pressure.

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9.8 COUPLING ALIGNMENT

The alignment of the couplings should be correct for successful operation.

Flexible couplings will not compensate for any appreciable misalignment. Rapid wear, noise, vibration, and actual damage may be caused by misalignment. The turbine generator set, including base plate mounted equipment, should be checked for alignment after installation and prior to start up.

Coupling alignment may be made by adjustment of the shims under the turbine, gear, and generator supports.

In the actual alignment of couplings, allowances should be made for expected changes in operating temperatures of the driving unit and also of the driven unit. An allowance for external expansion should be made in the "cold" coupling alignment. The final coupling alignment check should be made with the turbine and driven unit at operating temperatures.

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9.9 GROUTING

After the turbine generator set has been leveled, the coupling alignment checked, and the foundation bolts lightly tightened, the grout should be poured to completely fill the space between the foundation and the soleplate or baseplate. There should be no air pockets in the grout. After the grout is dry, connect the piping, fully tighten the foundation bolts, and recheck the alignment.

A mixture of cement and fine sand is normally used as grout. There are other materials available which have proven successful. Care must be exercised in the use of materials which expand while setting, as they may over-expand and present more of a problem than conventional materials such as cement and sand, which have a tendency to shrink slightly. (Figures 9-13 and 9-14 represent typical installations and are presented only as guides.)

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9.10 GENERATOR LEADS

Generator leads should be sized for the current which they will carry. These leads should be insulated or shielded to avoid hazard to operating personnel.

Undesirable local heating of foundations can be prevented by bringing the leads of all phases out through the same conduit or by using nonmetallic conduits. Heat from reinforcing steel within the concrete can be avoided by making sure that continuous individual paths close to and around individual leads are not formed by this steel.

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9.11 FLUSHING OIL SYSTEM

When a forced-feed lubrication system is provided, flushing of the lubrication system should be performed prior to the initial start-up in accordance with the manufacturer's recommendations.

1. Flushing oil should be compatible with the final turbine oil.
2. Oil must be circulated through the entire system as long as necessary to remove or to flush particular matter back to the oil reservoir. A periodic check of the oil filters or temporary screens should serve as a guide to determine when the oil is clean.

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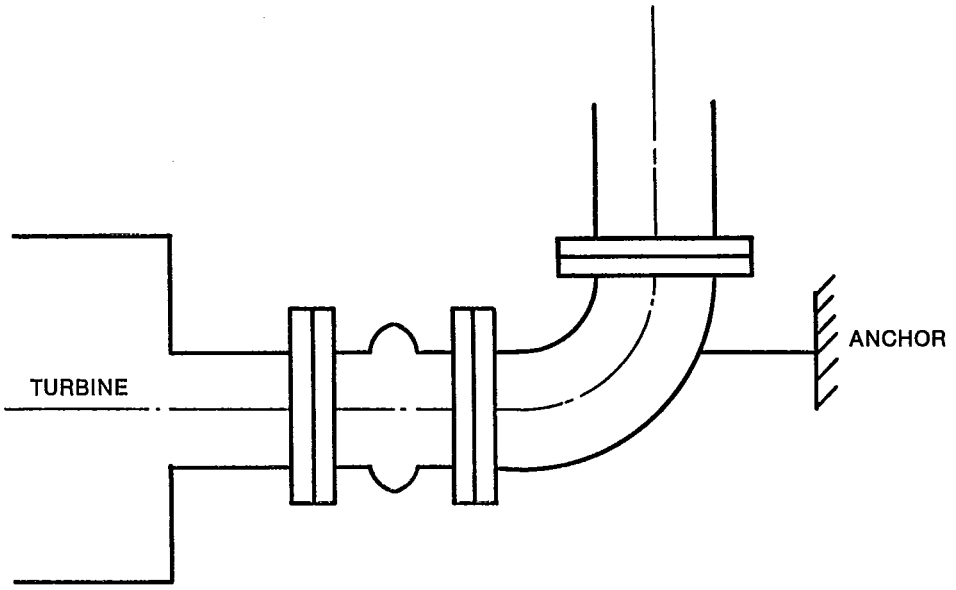


Figure 9-1
EXPANSION JOINT

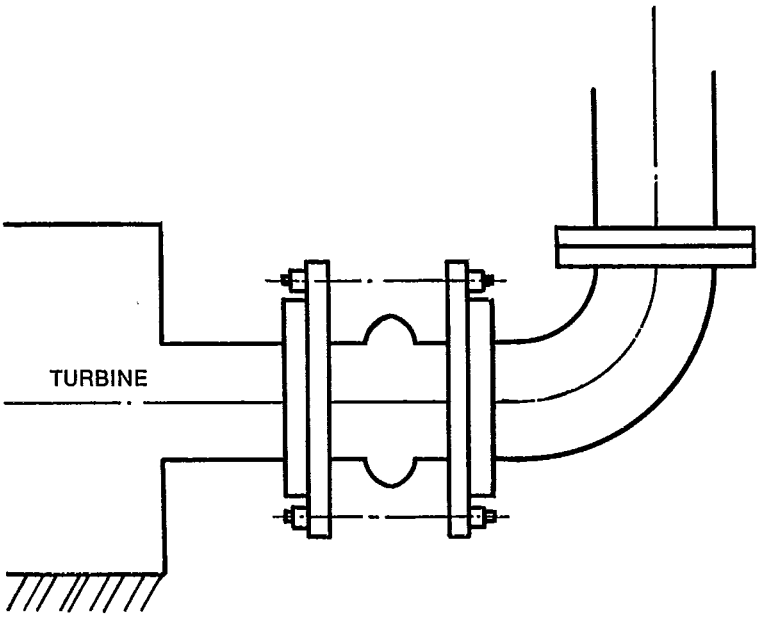


Figure 9-2
EXPANSION JOINT WITH TIE RODS

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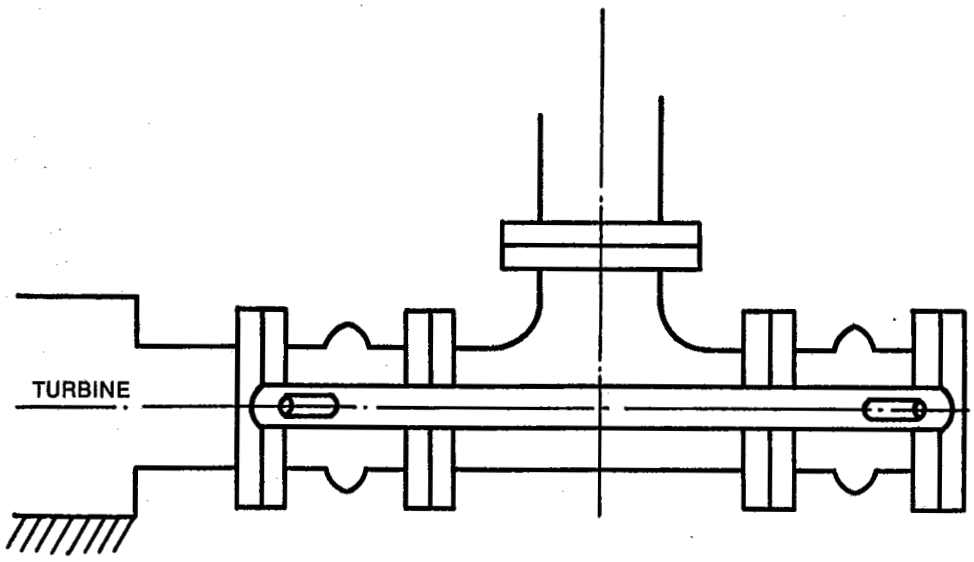


Figure 9-3
EXPANSION JOINT WITH TIE RODS FOR NONCONDENSING OPERATION

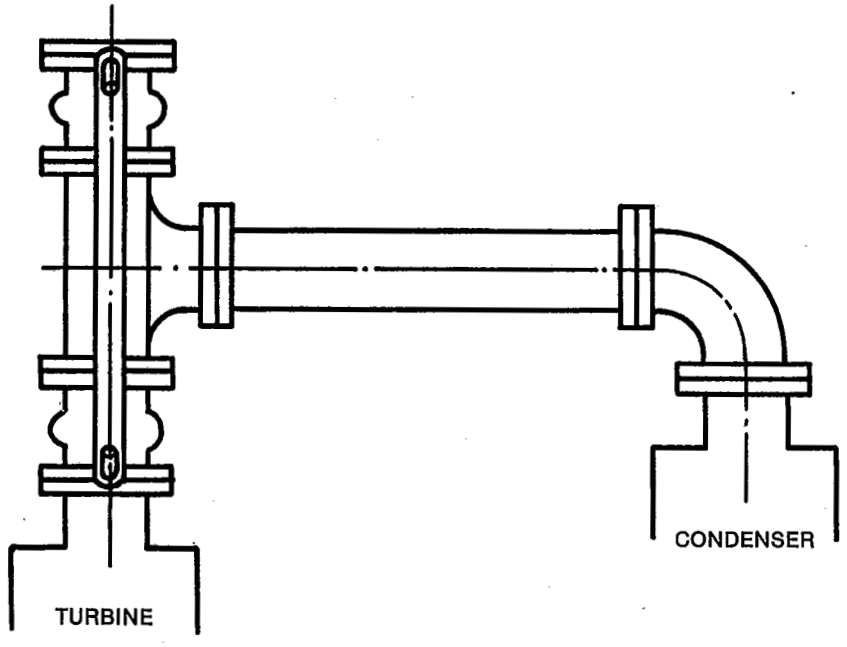


Figure 9-4
EXPANSION JOINT WITH TIE RODS FOR CONDENSING OPERATION WITH "UP" EXHAUST

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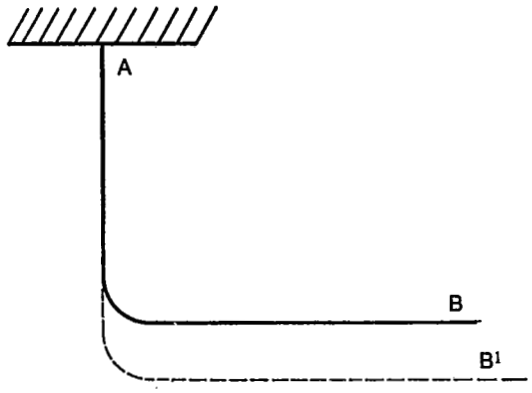


Figure 9-5
FREE EXPANSION

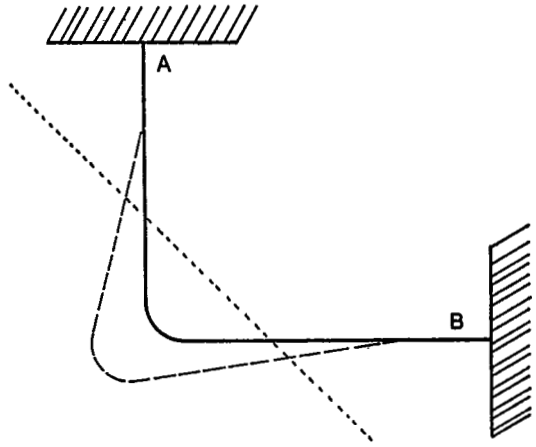


Figure 9-6
RESTRAINED EXPANSION

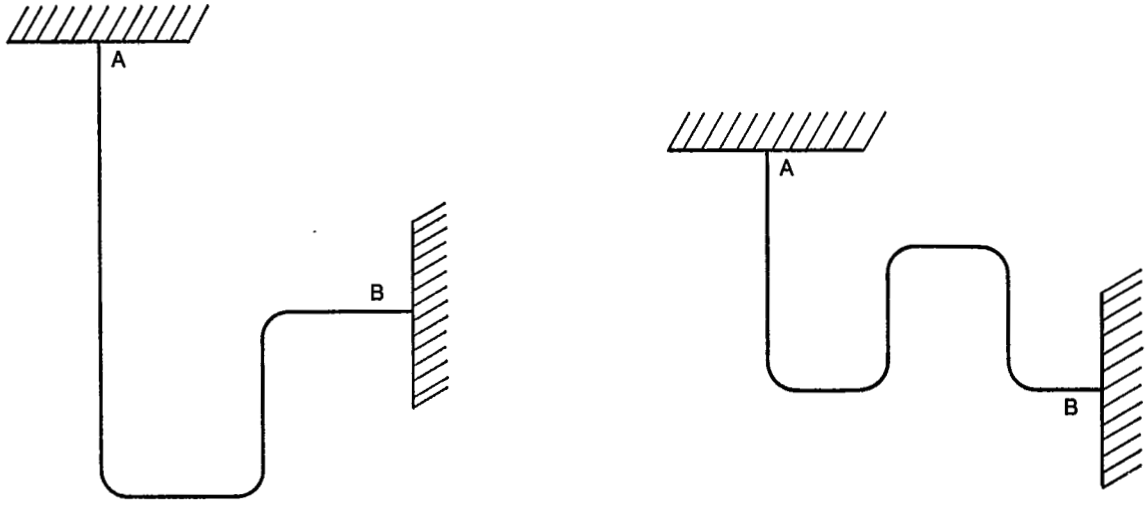


Figure 9-7
EXPANSION LOOPS

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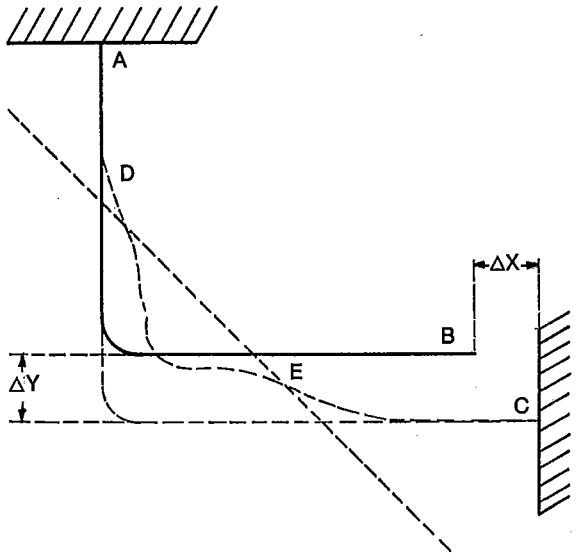


Figure 9-8
PRE-STRESSING (COLD SPRINGING)

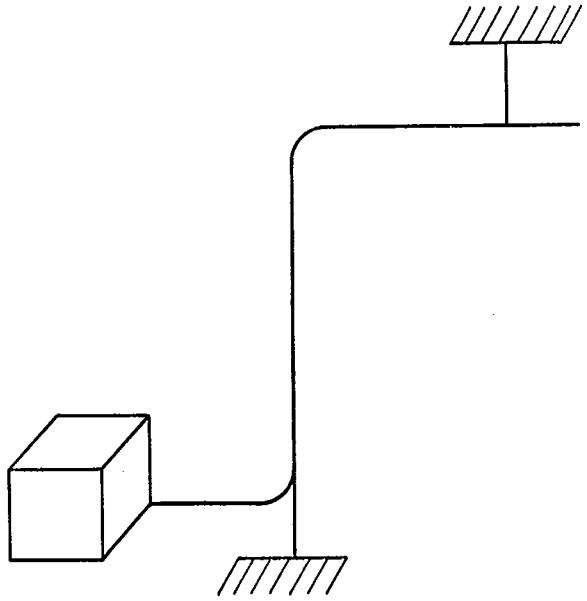


Figure 9-9
DEAD WEIGHT SUPPORT

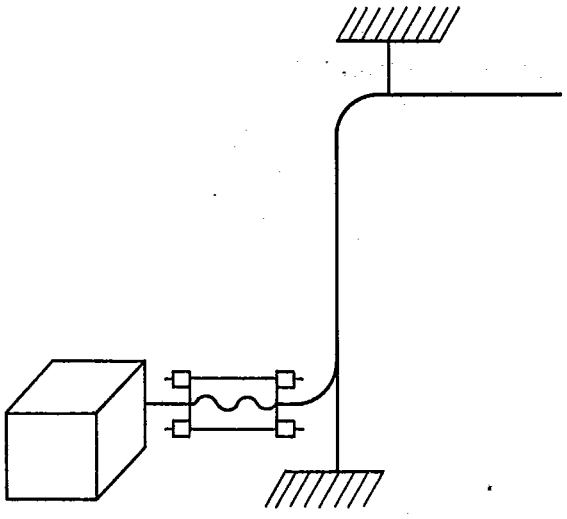


Figure 9-10
DEAD WEIGHT SUPPORT WITH RESTRAINED EXPANSION JOINT

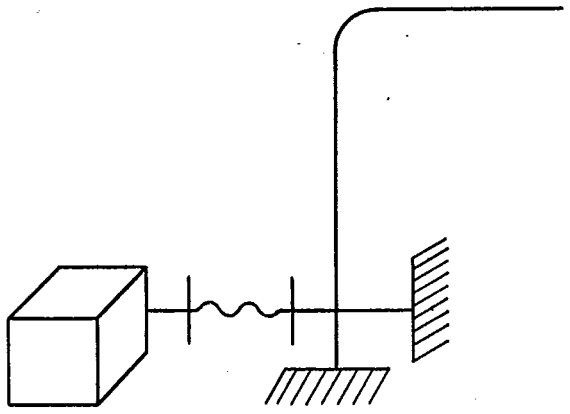


Figure 9-11
DEAD WEIGHT SUPPORT WITH UNRESTRAINED EXPANSION JOINT

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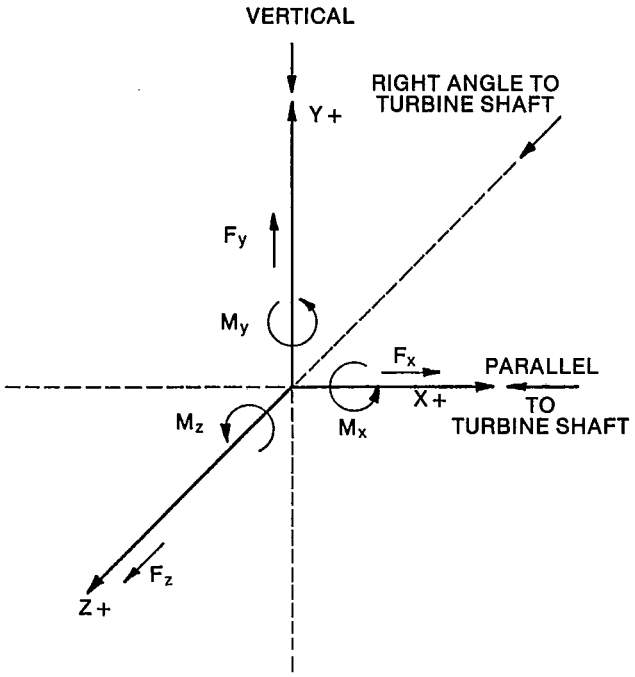
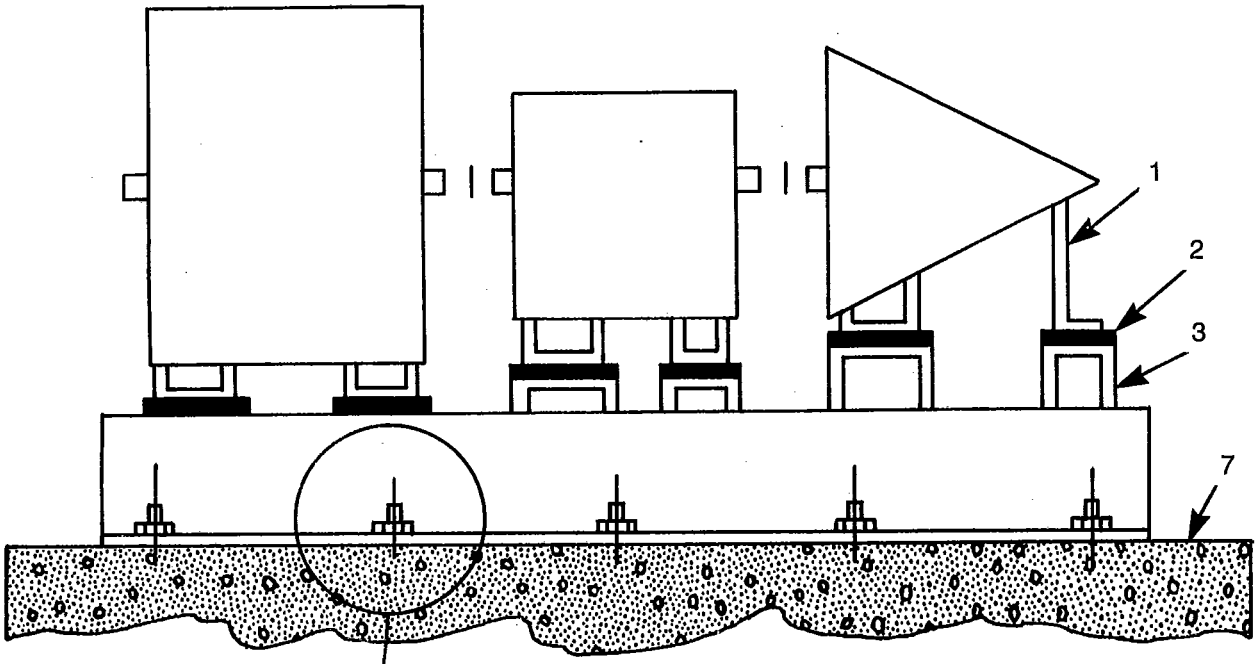
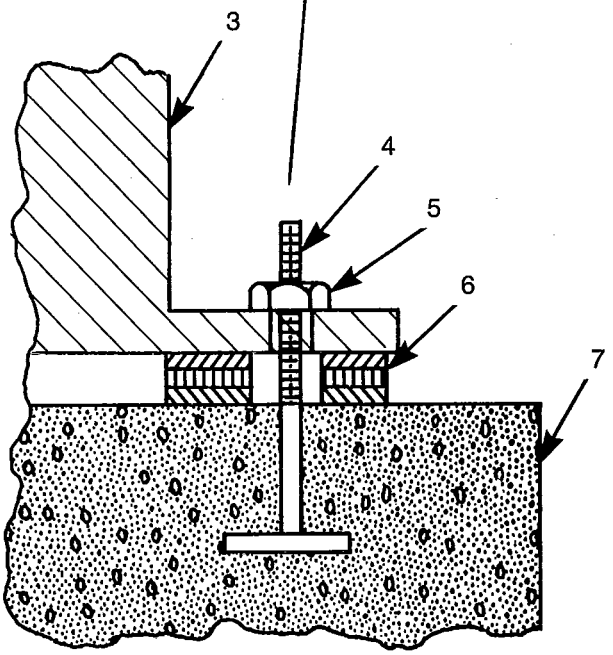


Figure 9-12
COMPONENTS OF FORCES AND MOMENTS ON TURBINE CONSTRUCTION

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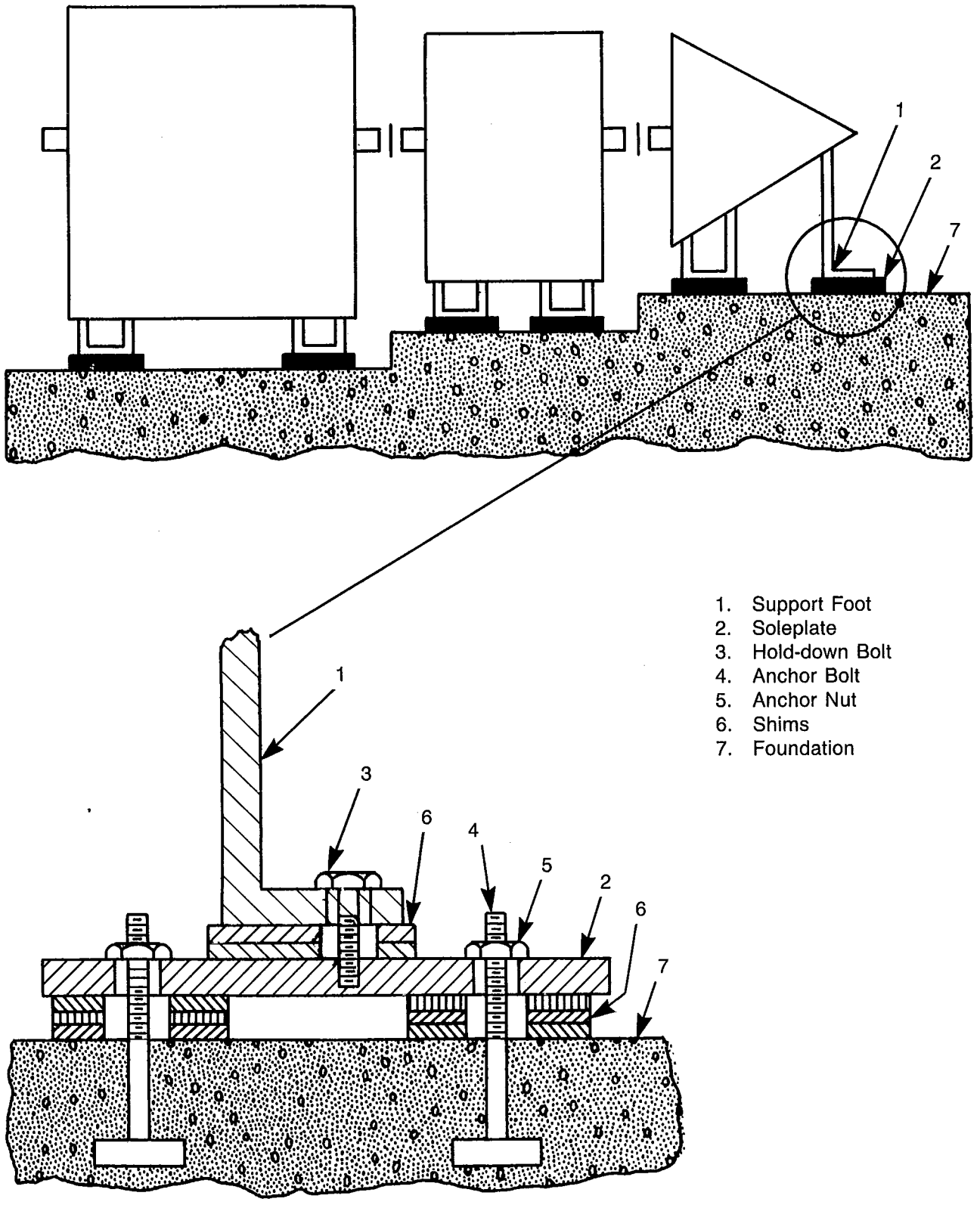




1. Support Foot
2. Mounting Pad
3. Baseplate
4. Anchor Bolt
5. Anchor Nut
6. Shims
7. Foundation

Figure 9-13
BASEPLATE MOUNTED TURBINE GENERATOR SET

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1. Support Foot
2. Soleplate
3. Hold-down Bolt
4. Anchor Bolt
5. Anchor Nut
6. Shims
7. Foundation

Figure 9-14
SOLEPLATE MOUNTED TURBINE GENERATOR SET

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Section 10

OPERATION AND MAINTENANCE

10.1 INTRODUCTION

To ensure that the turbine-generator set receives the care and attention necessary and usual for this type of equipment, specific instructions with respect to starting up, shutting down, and routine operation should be provided by the manufacturer in the instruction manual furnished with the set.

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10.2 OPERATION

The following should be given careful consideration by the operator:

1. The steam supplied to the set should be free of debris. To ensure maximum protection, steam lines should be blown prior to starting.
2. The steam turbine operator should be aware of the hazards associated with contamination of the process steam with agents which promote stress corrosion cracking.
3. Avoid slugs of water and unduly wet steam.
4. Avoid great or sudden fluctuations in pressure and temperature of steam supply.
5. Provide an adequate supply of clean water free from acid or scale-forming impurities for oil coolers, air coolers, and the gland condensing system.
6. Provide lubricating oil of proper quality and characteristics, including initial flushing change.
7. Maintain a log of operating conditions, including steam inlet pressures and temperatures, stage pressures, oil pressures, exhaust pressures, vibration, and so forth. This is important in predicting and scheduling inspection outages.
8. Check trip valves or trip-and-throttle valve for operation.
9. Check overspeed trip at appropriate intervals.
10. Check auxiliary oil pumps.

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10.3 NONCONDENSING TURBINE OPERATION OF A MULTISTAGE CONDENSING TURBINE

Noncondensing operation of a multistage condensing turbine is not recommended due to the possibility of high exhaust-casing temperature causing distortion and damage, and misalignment with driven machines. An increase in exhaust temperature and pressure may also affect piping forces. (See piping force calculations given in Section 9.)

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10.4 TYPICAL STARTING SEQUENCE FOR A STEAM TURBINE GENERATOR SET

1. Open exhaust shut off valve
2. Start cooling water
3. Start lubrication oil system
4. Open case drains
5. Set or reset trip valve
6. Crack open isolating valve
7. Allow casing to heat up
8. Slowly open isolating valve until governor takes control (observe manufacturer's instructions regarding critical speed)
9. Fully open isolating valve
10. Adjust governor speed
11. Close casing drains
12. Match line voltage if unit is to parallel
13. Synchronize if unit is to parallel
14. Close main circuit breaker
15. Load either automatically or manually
16. Monitor turbine generator set operation until stable operation is achieved.

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10.5 MAINTENANCE

10.5.1 Introduction

Inspection and service should follow manufacturer's instructions. Frequency of inspection and degree of thoroughness may vary and will have to be determined by the maintenance engineer.

The following is a typical maintenance program:

Daily

1. Visually inspect turbine generator set for external damage and leaks
2. Check oil level in reservoir and governor
3. Check for unusual vibration and noise levels
4. Check oil temperature and pressures

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Weekly

1. Check operation of auxiliary oil pump, if applicable
2. Check operation of all shut down devices
3. Check that shafts are free of oil or grease
4. Exercise the trip valve
5. Examine fuses, switches, and other controls

Monthly

1. Check overspeed governor
2. Check foundation bolts for tightness
3. Check oil and filter

Annually

Shut down the turbine generator set and perform the following:

1. Remove and clean steam strainer.
2. Check shaft seals or labyrinth for wear.
3. Check thrust bearing end play.
4. Remove sentinel warning valve and check for proper operation.
5. Drain water and clean foreign material from oil reservoir.
6. Drain oil from governor and flush clean (if applicable).
7. Check coupling alignment and lubrication.
8. Drain small quantity of oil from system and conduct an oil analysis. If system is equipped with an oil filter element, change the element at the time of oil change.
9. Examine grease in ball or roller bearing housings and renew if necessary (if applicable).
10. Check bearing clearance and end play.
11. Check tooth wear pattern.
12. Check foundation.
13. Check alignment.
14. Check and recalibrate gauges.
15. Check generator thoroughly, blowing dirt from windings and air gap.
16. Test insulation by megger.
17. Check air gap clearance.

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10.6 INTERNAL WATER WASHING

INTERNAL WATER WASHING OF A TURBINE SHOULD BE PERFORMED IN ACCORDANCE WITH THE MANUFACTURER'S INSTRUCTIONS. IT IS BETTER TO PREVENT THE BUILD UP OF SOLIDS THAT TO HAVE TO REMOVE DEPOSITS AFTER THEY HAVE FORMED.

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10.7 STEAM PURITY

Steam turbine users should be aware of the hazards associated with contamination of the steam by agents which might promote stress corrosion cracking, solids build-up, erosion, and corrosion. Contaminants such as sodium, hydroxides, chlorides, sulfates, copper, lead, and silicates may result in shortened turbine life and failure of internal parts of the turbine.

Since it is not possible to prescribe the degree of contamination that steam turbine materials can tolerate in order to achieve the long life expected of internal turbine components, only general guidelines can be offered.

For small low pressure application, turbines may operate satisfactorily on steam having purity limits set by the American Boiler Manufacturers Association. See Table 10-1.

Table 10-1
WATERTUBE BOILERS

RECOMMENDED BOILER WATER LIMITS AND ASSOCIATED STEAM PURITY AT STEADY STATE FULL LOAD OPERATION

DRUM TYPE BOILERS

Drum Pressure psig	Range Total Dissolved Solids[1] Boiler Water ppm (max)	Range Total Alkalinity[2] Boiler Water ppm	Suspended Solids Boiler Water ppm (max)	Range Total Dissolved Solids [2,3] Steam ppm (max expected value)
0-300	700-3500	140-700	15	0.2-1.0
301-450	600-3000	120-600	10	0.2-1.0
451-600	500-2500	100-500	8	0.2-1.0
601-750	400-2000	80-400	6	0.2-1.0
751-900	300-1500	60-300	4	0.2-1.0
901-1000	250-1250	50-250	2	0.2-1.0

[1]Actual values within the range reflect the TDS in the feed water. Higher values are for high solids, lower values are for low solids in the feed water.
[2]Actual values within the range are directly proportional to the actual value of TDS of boiler water. Higher values are for the high solids, lower values are for low solids in the boiler water.
[3]These values are exclusive of silica.

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For larger high pressure applications and for improved reliability, the suggested guidelines for steam purity limits for both start-up and continuous operation of steam turbines are shown in Table 10-2.

Table 10-2
STEAM PURITY LIMITS

	Continuous	Start-Up
Conductivity—		
Micromhs/cm at 25 °C		
Drum	0.3	1.0
Once through	0.2	0.5
SiO, ppb, max.	20	50
Fe, ppb, max.	20	50
Cu, ppb, max.	3	10
Na + K, ppb, max.		
Up to 800 psig	20	20
801 to 1450 psig	10	10
1451 to 2400 psig	5	5
Over 2400 psig	3	3

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Section 11

INQUIRY GUIDE

(AUTHORIZED ENGINEERING INFORMATION)

Job No. _____
Item No. _____
Date _____

User _____
Site _____
Service _____
No. Required _____
Gear Yes/No _____

TURBINE GENERATOR OPERATING CONDITIONS

Power	Guar.	Rated	Normal	Max.	Min.	Other	Units
TURBINE OPERATING STEAM CONDITIONS							
Inlet Pressure							
Inlet Temperature							
Exhaust Pressure							
Extraction/Induction Pressure							
Extraction/Induction Temperature							
Inlet Flow							
Extraction/Induction Flow							
Other Performance Requirements							

GENERATOR OPERATING CONDITIONS

_____ KVA _____ KW _____ P.F. _____ RPM
_____ Volts _____ Phase _____ Cycles

Duty: _____ Continuous _____ Intermittent _____ Standby _____

Location:

_____ Indoor _____ Heated _____ Under Roof
_____ Outdoor _____ Unheated _____ Partial Sides
_____ Grade _____ Mezzanine
_____ Winterization Required
_____ Tropicalization Required

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Site Data:

_____ Ft. Elevation
_____ Barometric Pressure
Temperature: _____ °F Summer
_____ °F Winter
Relative Humidity _____ %

Evaluation

Approximate normal steam rate desired _____
Steam cost $_____
Payout Period: No. of years _____
Hours per Year of Operation _____

Turbine Construction

Single Valve _____
Multi-Valve _____
Automatic Extraction/Induction _____

Speed Governor System

NEMA Class _____
Speed Changer Type:
Manual _____ Pneumatic _____ Electric _____
Lubrication _____
Manufacturer's Standard _____
Other _____

Unit Mounting

Baseplate _____ Soleplate(s) _____

Unit Accessories

_____
_____
_____
_____

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Generator Construction

Type: _____ Sync. _____ Induction
Winding Connection: _____ Delta _____ Wye
Insulation Class: _____
Ambient Temperature: 40°C Standard _____ Other _____
Temperature Rise: _____ °C

Short Circuit Ratio: _____
Parallel Operation: _____ Yes _____ No
Enclosure: _____
Exciter: _____ Rotating Brushless _____ Static
Permanent Magnet Generator: _____ Yes _____ No
Voltage Regulator Type: _____ Static _____ Other
Voltage Regulation: _____ %
Voltage Adjuster: _____ Motor _____ Manual
Telephone Influence Factor: _____ Standard _____ Special
Space Heaters: _____ No _____ Yes _____ Volts
Temperature Detectors: _____
Surge Capacitors: _____ Yes _____ No
Surge Arresters: _____ Yes _____ No
Motor Starting Requirement _____

Gear Construction (If Required)

Construction: Manufacturer's Standard _____ Other _____
Service Factor _____

Coupling(s)

Manufacturer's Standard _____ Other _____

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Factory Testing

	Required Yes	Witnessed Yes/No
Manufacturer's Standard		
Other		

Paint

Manufacturer's Standard _____ Other _____

Shipping Preparation

Manufacturer's Standard _____ Other _____

Site Utilities

Cooling Water: None _____ Fresh _____ Brackish _____
Other _____ Temperature _____ Pressure _____

Electrical Supply: AC/DC
Control(s) Volts _____ Phase _____ Hz _____
Motor(s) Volts _____ Phase _____ Hz _____

Area Classification Class _____ Group _____ Div. _____

Control(s)
- Explosion Proof _____
- Weatherproof _____
- General Purpose _____

Motor(s)
- TEFC _____
- Explosion Proof _____
- General Purpose _____
- Other _____

Remarks

_____
_____
_____
_____

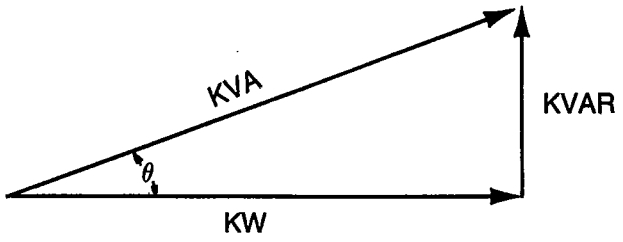
Drawings and Data to be Supplied

Certified Outline Drawings _____
Recommended Spare Parts List _____
Instruction Books _____ No. _____
Other _____
_____
_____
_____

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APPENDIX

AC Power—Power used in an alternating current electrical circuit. AC power has two components, (1) real power and (2) reactive power. These components are added vectorially to determine the apparent power.



$$KVA = \sqrt{(KW)^2 + (KVAR)^2}$$

Where:

KVA = apparent power, kilovolt-amperes
KW = real power, kilowatts
KVAR = reactive power, kilovolt-amperes reactive

Apparent power in 3-phase circuits can also be determined by the formula:

$$KVA = \frac{(V)\ (I)\ \sqrt{3}}{1000}$$

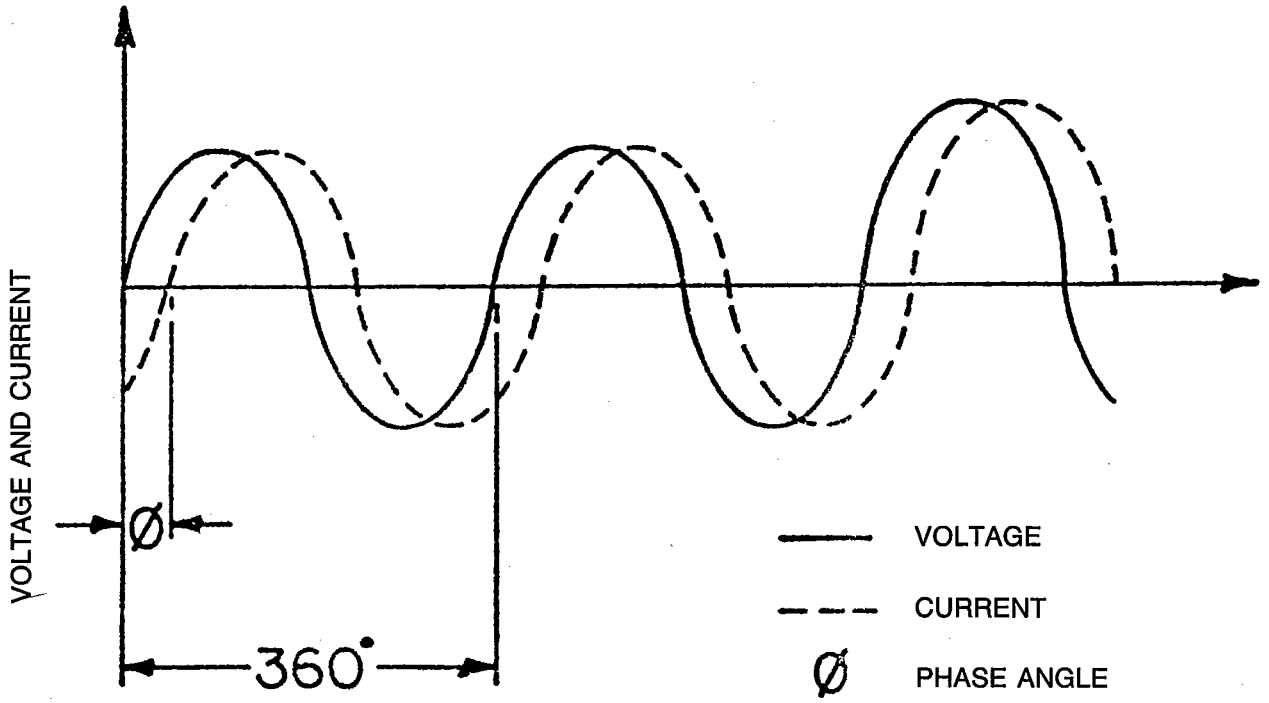
Where:

V = potential difference per phase, volts
I = current per phase, amperes

Power factor of an electric circuit is the ratio of $\frac{\text{real power}}{\text{apparent power}}$

The power factor of an electric circuit will be less than unity if the voltage wave and the current wave do not rise through the zero point at the same time. If the circuit has more inductance than capacitance, current will lag behind voltage. If the circuit has more capacitance than inductance, current will lead voltage. Considering one full cycle to be 360 degrees, the amount by which the zero point for the current wave differs from the zero point for the voltage wave is expressed as the phase angle, θ. The power factor for the circuit equals the cosine of the phase angle. A capacitive circuit will produce a leading power factor. An inductive circuit will produce a lagging power factor.

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Real power produces light, heat, or mechanical power in the equipment which makes up the load in the electrical circuit. The real power requirement of the electrical circuit determines the mechanical power which must be produced by the driver(s) of the generator(s) in the circuit.

Reactive power provides magnetization for motors in the circuit. The need for reactive power increases the current which must be carried by the electrical conductors in the circuit, but it does not add to the load which must be carried by the driver(s) of the generator(s) in the circuit.

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NEMA STANDARDIZATION

The purpose of NEMA Standards, their classification and status are set forth in certain clauses of the NEMA Bylaws, which are quoted below:

Purpose of Standards

National Electrical Manufacturers Association Standards are adopted in the public interest and are designed to eliminate misunderstandings between the manufacturer and the purchaser and to assist the purchaser in selecting and obtaining the proper product for its particular need. Existence of a National Electrical Manufacturers Association Standard does not in any respect preclude any member or nonmember from manufacturing or selling products not conforming to the standard.

(Bylaw—Art. V, Sec. 1)

Definition of a Standard

A standard of the National Electrical Manufacturers Association defines a product, process or procedure with reference to one or more of the following: nomenclature, composition, construction, dimensions, tolerances, safety, operating characteristics, performance, rating, testing, and the service for which they are designed.

(Bylaw—Art. V, Sec. 2, Subsection A)

Dimensions

Where dimensions are given for interchangeability purposes, alternate dimensions satisfying the other provisions of the standards publication may be capable of otherwise equivalent performance.

(NEMA Policy Memorandum 84-2, dated June 7, 1984)

Classes of Standards

National Electrical Manufacturers Association Standards are of two classes:

1. NEMA Standard, which relates to a product commercially standardized and subject to repetitive manufacture, which standard has been approved by at least 90 percent of the members of the Subdivision eligible to vote thereon;
2. Suggested Standard for Future Design, which may not have been regularly applied to a commercial product, but which suggests a sound engineering approach to future development, which standard has been approved by at least two-thirds of the members of the Subdivision eligible to vote thereon.

(Bylaw—Art. V, Sec. 2, Subsection B)

Authorized Engineering Information

Authorized Engineering Information consists of explanatory data and other engineering information of an informative character not falling within the classification of NEMA Standard or Suggested Standard for Future Design.

(Bylaw—Art. V, Sec. 6, 1st Sentence)

Official Standards Proposal

An Official Standards Proposal is an official draft of a proposed standard which is formally recommended to an outside organization(s) for consideration, comment and/or approval.

(Bylaw—Art. V, Sec. 4, Subsection A)

Identification of Status

Standards in NEMA Standards Publications are identified in the foreword or following each standard as "NEMA Standard" or "Suggested Standard for Future Design." These indicate the status of the standard. These words are followed by a date which indicates when the standard was adopted in its present form by the Association.

The material identified as "Authorized Engineering Information" and "Official Standards Proposal" is designated similarly.

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STEAM TURBINE SECTION

OF THE

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION

MEMBER COMPANIES

Carling Turbine Blower Company
Worcester, MA 01613

Coppus Engineering Corporation
Worcester, MA 01610

Elliot Company
A Sub. of United Technologies Corp.
Jeannette, PA 15644

General Electric Company
Schenectady, NY 12345

Murray Turbomachinery Corp.
Sub. of Coppus Engineering Corp.
Burlington, IA 52601

Skinner Engine Company
Division of Banner Industries
Erie, PA 16512

Terry Corporation
Sub. of Ingersoll-Rand Corporation
Windsor, CT 06095

Transamerica Delaval
Trenton, NJ 08650

Turbodyne Division
Dresser Industries, Inc.
Wellsville, NY 14895

Westinghouse Electric Corporation
Broomall, PA 19008

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