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Steam Turbines for Mechanical Drive Service

NEMA

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

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NEMA SM 23-1985

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STEAM TURBINES FOR MECHANICAL DRIVE SERVICE

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Foreword

This standard has been developed by the Steam Turbine Section of NEMA. In its preparation and revision, consideration has been given to the work of other organizations, such as the American National Standards Institute, the American Petroleum Institute, the American Society of Mechancial Engineers, and the American Gear Manufacturers, 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 standard for single-stage and multistage mechanical drive steam turbines is to facilitate the application of these turbines by engineers, users, and contractors, to promote economies in driving rotating mechanical equipment, and to assist in the proper selection and application of the differing mechanical designs of turbines.

NEMA Standards Publication SM 23-1985 revises and supersedes the NEMA Standards Publication *Steam Turbines for Mechanical Drive Service,* SM 23-1979.

User needs have been considered throughout the development of this standard. Proposed or recommended revisions should be submitted to:

Manager, Engineering Department
National Electrical Manufacturers Association
2101 L Street, NW
Washington, DC 20037

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Scope

These standards cover single-stage and multistage mechanical drive steam turbines intended to drive pumps, fans, compressors, generators, and so forth. This standard is also applicable to turbines expanding various gases or compressed air.

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STEAM TURBINES FOR MECHANICAL DRIVE SERVICE

Section 1

REFERENCED STANDARDS

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 National Standards Institute
1430 Broadway
New York, NY 10018

B16.1-1975	*Cast Iron Pipe Flanges and Flanged Fittings Class 25, 125, 250, and 800*
B16.5-1981	*Fittings, Flanges, and Valves*
S1.4-1983	*Specification for Sound Level Meters*
S1.11-1966	*Specifications for Octave, Half-Octave, and Third Octave Band Filter-Sets*
S5.1-1971	*Test Code for the Measurement of Sound from Pneumatic Equipment*
ANSI/ASME	
B1.20.1-1983	*General Purpose Pipe Threads (Inch)*
B31.3-1984	*Chemical Plant and Petroleum Refinery Piping*

Expansion Joint Manufacturers Association
25 North Broadway
Tarrytown, NY 10591

The Standard of the Expansion Joint Manufacturers Association (1980)

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Section 2

GENERAL

2.1 STEAM TURBINE

A steam turbine is a prime mover which converts the thermal energy of steam directly into mechanical energy of rotation.

NEMA Standard 11-13-1969.

2.2 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 11-13-1969.

2.3 CONDENSING TURBINE

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

NEMA Standard 11-13-1969.

2.4 STAGE, TURBINE

A steam turbine stage consists of a "matched set" of stationary nozzles and rotating blades. A pressure drop occurs in a steam turbine stage generating kinetic energy which is converted to mechanical work.

2.4.1 Impulse Stage

An impulse stage consists of stationary expansion nozzle(s) discharging the high-velocity steam jets on the rotating blades. A pressure drop occurs only in the stationary nozzle(s). Impulse stages consist of two types:

2.4.1.1 A pressure impulse or Rateau stage consists of stationary expansion nozzle(s) and one row of rotating blades.

2.4.1.2 A velocity-compounded impulse or Curtis stage consists of stationary expansion nozzle(s) and two or more rows of rotating blades.

NEMA Standard 6-21-1979.

The pressure drop across a Rateau stage is relatively low in comparison to the pressure drop across a Curtis stage.

Authorized Engineering Information 6-21-1979.

2.4.2 Reaction Stage

A reaction stage consists of stationary expansion nozzle(s) discharging high-velocity steam jets on the rotating blades. A pressure drop occurs in both the stationary and rotating elements.

NEMA Standard 6-21-1979.

2.5 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 6-21-1979.

2.6 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 6-21-1979.

2.7 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 6-21-1979.

2.8 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 6-21-1979.

2.9 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 6-21-1979.

2.10 NONCONTROLLED EXTRACTION TURBINE

A noncontrolled-extraction turbine is a steam turbine which has an opening(s) in the turbine casing for the

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extraction of steam but which does not have means for controlling the pressure of the extracted steam.

NEMA Standard 6-21-1979.

2.11 NONCONTROLLED INDUCTION TURBINE

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

NEMA Standard 11-14-1985.

2.12 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 6-21-1979.

2.13 INDUCTION EXTRACTION TURBINE

An induction extraction turbine is one which combines the features of extraction (controlled or noncontrolled) with the features of induction. (See 2.9, 2.10, and 2.11.)

NEMA Standard 6-21-1979.

STEAM TURBINE COMPONENTS

2.20 TURBINE CASING

A turbine 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:

NEMA Standard 6-21-1979.

2.20.1 Steam Inlet End Section

The steam inlet end section is that portion of the casing which contains the higher pressure steam.

NEMA Standard 6-21-1979.

2.20.2 Exhaust End Section

The exhaust end section is 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.

NEMA Standard 6-21-1979.

2.20.3 Intermediate Section

The intermediate section (multistage turbines only) is 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 6-21-1979.

2.21 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 6-21-1979.

2.22 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.

NEMA Standard 6-21-1979.

2.23 NOZZLES

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

NEMA Standard 11-13-1969.

2.24 STATIONARY REVERSING BLADES (CHAMBERS)

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

NEMA Standard 11-13-1969.

2.25 DIAPHRAGM

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

NEMA Standard 6-21-1979.

2.26 CASING SHAFT SEALS

Casing shaft seals minimize the leakage of steam out of the casing along the 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 a constant low pressure and low temperature.

NEMA Standard 6-21-1979.

2.27 INTERSTAGE SHAFT SEALS

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

NEMA Standard 6-21-1979.

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2.28 BEARING HOUSING

A bearing housing contains and supports a bearing(s) and is equipped with seals to prevent leakage of oil and the entrance of moisture, dust, and foreign materials.

NEMA Standard 6-21-1979.

2.29 SHAFT BEARINGS

2.29.1 Radial Bearings

Radial bearings are bearings which support the rotating element. They are of the sleeve, tilting pad, or antifriction type. In vertical shaft turbines, these bearings radially position the rotor assembly.

NEMA Standard 6-21-1979.

2.29.2 Thrust Bearings

Thrust bearings are bearings which transmit the axial thrust of the rotating element to the bearing housing and maintain the axial position of the rotor assembly in the casing. They are of the antifriction, land, or segmental tilting pad type.

NEMA Standard 6-21-1979.

2.29.3 Antifriction Bearings

Antifriction bearings should have a minimum rating life of 3 years of 25,000 hours when operated continuously at maximum thrust and radial loads and at rated speed. The rating life is the number of hours at constant speed that 90 percent of a group of identical bearings will operate before the first evidence of fatigue develops.

Authorized Engineering Information 6-21-1979.

2.30 ROTOR ASSEMBLY

The rotor assembly is the rotating element of the turbine which includes all parts attached to the shaft, excluding the coupling.

NEMA Standard 6-21-1979.

2.31 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 6-21-1979.

2.32 BLADES (BUCKETS)

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

NEMA Standard 6-21-1979.

2.33 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 6-21-1979.

2.34 NOZZLE CONTROL VALVE(S)

A nozzle control valve(s) is the valve which controls steam flow to a group of nozzles to permit efficient operation at reduced power or with dual steam conditions.

NEMA Standard 6-21-1979.

2.35 PROTECTIVE DEVICE

A protective device is one which, alone or as part of a system, responds in some predetermined manner to abnormal conditions attending the operation of the unit or system to which it is connected.

NEMA Standard 6-21-1979.

2.36 CONTROLLING DEVICE

A controlling device is one which manually or automatically initiates action of a system which controls normal operation of the turbine.

NEMA Standard 11-13-1969.

2.37 EXTERNAL CONTROL DEVICE

An external control device is an element which is responsive to signals other than turbine speed, i.e., flow, pressure, temperature, and so forth, and acts to control the flow of steam to the turbine. It shall be pneumatically, hydraulically, or electrically actuated from the signal source to position the governor valve(s).

NEMA Standard 6-21-1979.

2.38 WARNING DEVICE

A warning device is one which, by visible or audible means, or both, indicates that an abnormal operating condition exists.

NEMA Standard 6-21-1979.

2.39 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 so located as to be plainly visible.

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

NEMA Standard 6-21-1979.

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2.40 SOLEPLATE(S)

A soleplate(s) is a machined flat steel plate or casting for mounting of the turbine supports and for grouting to the foundation.

NEMA Standard 11-13-1969.

2.41 BASEPLATE

A baseplate is a fabricated or cast continuous structure having machined pads for mounting of the turbine and for grouting to the foundation.

NEMA Standard 11-13-1969.

2.42 TURBINE RATING

2.42.1 Rated Power

Rated power is the maximum specified power output of the turbine. It is measured at the output of the turbine.

NEMA Standard 6-21-1979.

2.42.2 Rated Speed

Rated speed is the speed corresponding to rated power. It is measured at the output shaft of the turbine, is expressed in revolutions per minute, and is equal to or less than maximum continuous speed.

NEMA Standard 6-21-1979.

2.42.3 Normal Power and Speed and Steam Conditions

Normal power and speed and steam conditions are those conditions found in usual operation and at which the steam rate will be guaranteed.

NEMA Standard 6-21-1979.

2.42.4 Minimum Steam Conditions

Minimum steam conditions are the lowest inlet steam pressure and temperature and corresponding exhaust pressure at which the turbine produces rated power and speed.

NEMA Standard 6-21-1979.

2.42.5 Maximum Steam Conditions

Maximum steam conditions are the highest inlet steam pressure and temperature and exhaust pressure to which the turbine is subjected in usual operation.

NEMA Standard 6-21-1979.

2.42.6 Maximum Continuous Speed

Maximum continuous speed is the highest specified operating speed. It is equal to or greater than rated speed.

NEMA Standard 6-21-1979.

2.42.7 Maximum Allowable Speed

Maximum allowable speed is the highest speed at which a turbine can be operated continuously provided proper overspeed and governor mechanisms are installed.

NEMA Standard 6-21-1979.

THERMODYNAMIC TERMS

2.50 STEAM RATES

2.50.1 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 usually expressed in pounds of steam per horsepower-hour (or in kilograms of steam per kilowatt-hour). Therefore:

$$\text{Theoretical steam rate in lb/hp-hr with h in Btu per pound} = \frac{2545}{h_1 - h_2}$$

$$\text{Theoretical steam rate in kg/kw-hr with h in kilojoule per kilogram} = \frac{3600}{h_1 - h_2}$$

[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 kilogram, 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 6-21-1979.

2.50.2 Actual Steam Rates

2.50.2.1 TURBINE STEAM RATE—Turbine steam rate is the quantity of steam required by the turbine per unit of power output, measured at the output shaft of the turbine. It is usually expressed in pounds of steam per horsepower-hour (or in kilograms of steam per kilowatt-hour).

2.50.2.2 TURBINE GEAR STEAM RATE—When a gear is provided by the turbine manufacturer, the turbine gear steam rate is the quantity of steam required by the tur-

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bine gear set per unit of power output, measured at the output shaft of the gear.

NEMA Standard 6-21-1979.

2.50.3 Guaranteed Steam Rate

The guaranteed steam rate is the steam rate which will not be exceeded when the turbine is operated at normal power, speed, and steam conditions.

NEMA Standard 6-21-1979.

2.51 STEAM PRESSURE

2.51.1 Inlet Steam Pressure

Inlet steam pressure is the pressure of the steam supplied to the turbine. It is measured at the steam inlet connection of the turbine and is usually expressed as a gauge pressure.*

NEMA Standard 6-21-1979.

2.51.2 Exhaust Steam Pressure

Exhaust steam pressure is the pressure of the steam system to which the turbine exhausts. It is measured at the exhaust connection of the turbine and is usually expressed as a gauge pressure* for noncondensing turbines and as an absolute pressure ** for condensing turbines.

NEMA Standard 6-21-1979.

2.51.3 Extraction Steam Pressure

Extraction steam pressure is the pressure of the steam extracted from the turbine. It is measured at the extraction connection of the turbine, and is usually expressed as a gauge pressure.*

NEMA Standard 6-21-1979.

2.51.4 Induction Steam Pressure

Induction steam pressure is the pressure of the secondary steam supplied to the turbine. It is measured at the induction connection of the turbine and is usually expressed as a gauge pressure.*

NEMA Standard 6-21-1979.

2.52 STEAM TEMPERATURE

2.52.1 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 6-21-1979.

2.52.2 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 6-21-1979.

2.52.3 Extraction Steam Temperature

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

NEMA Standard 6-21-1979.

2.52.4 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 6-21-1979.

2.53 DUAL STEAM CONDITIONS

Dual steam conditions are two or more combinations of inlet steam pressure, inlet steam temperature, or exhaust steam pressure.

NEMA Standard 6-21-1979.

2.54 VARIATIONS IN STEAM CONDITIONS

The rating, capability, steam flow, speed regulation, and pressure control shall be based on operation at maximum steam conditions as defined in 2.42.5.

Steam turbines shall be capable of operating under the following variations in 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 6-21-1979.

2.54.1 Variations from Maximum Inlet Steam Pressure

The turbine shall be capable of operating without damage at less than 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 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

*Gauge pressure equals absolute pressure less atmospheric pressure. Gauge pressure is measured in pounds per square inch or in bar.

**Absolute pressure is measured in inches of mercury at 32°F (0°C) or in millibar. Unless otherwise specified, atmospheric pressure is assumed equal to 14.696 psi (pounds per square inch), or 1.013 25 bar, or 101.325 K PA (kilopascal).

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turbine inlet connection shall be permitted to exceed maximum pressure briefly by as much as 20 percent, but the aggregate duration of such swings beyond 105 percent of maximum pressure shall not exceed 12 hours per 12-month operating period.

NEMA Standard 6-21-1979.

2.54.2 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 than 400 hours per 12-month operating period nor by more than 50 °F (28 °C) for swings of 15 minutes duration of less, aggregating not more than 80 hours per 12-month operating period.

NEMA Standard 6-21-1979.

2.54.3 Variations from Maximum Exhaust Steam Pressure on Noncondensing Turbines

The exhaust pressure shall average not more than 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 than 20 percent below maximum exhaust pressure.

NEMA Standard 6-21-1979.

2.54.4 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.

Authorized Engineering Information 6-21-1979.

2.55 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 indicates 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.)

Authorized Engineering Information 11-13-1969.

2.56 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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Section 3

CONSTRUCTION

3.1 BASIC FEATURES

Steam turbines 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. Governing system with at least a 20-percent (for example, plus 5 percent minus 15 percent) adjustable speed range.
3. Overspeed trip system.
4. Lubrication.
5. Excessive-exhaust-pressure warning device mounted on the turbine casing.
6. Exhaust casing gland sealing connection (for condensing turbines only).
7. Eyebolts or other provisions for lifting the upper half of the casing on an axially split turbine.

NEMA Standard 11-14-1985.

3.2 OPTIONAL FEATURES AND ACCESSORIES

In addition to the features listed in 3.1, the following are optional features and accessories.

1. Governing systems with other than 20-percent adjustable speed range.
2. Nozzle control valve(s) for reduced power or dual steam conditions for single-valve turbines.
3. Trip devices to close the trip valve or the combined trip-and-throttle valve in response to a pneumatic, electric, or hydraulic signal, or on high exhaust pressure, low oil pressure, high oil temperature, or excessive vibration.
4. Provision to close the trip valve or the combined trip-and-throttle valve when the bearing oil pressure (pressure type lubrication) drops to a predetermined value.
5. Constant-level oilers for nonpressure-lubrication systems.
6. Insulation for the high-temperature section of the turbine.
7. Steam pressure gauges to indicate inlet steam pressure, steam ring pressure, first stage pressure, and exhaust steam pressure.
8. Coupling between the turbine and driven machine (normally furnished by the manufacturer of the driven equipment).
9. Coupling guard easily removable and supported from the baseplate or from the adjacent bearing housing(s). The coupling guard should be sufficiently rigid to withstand deflection and prevent rubbing as a result of normal bodily contact by personnel. When continuously lubricated couplings are specified, the coupling guard or housing should be fitted so that oil leaks will be prevented.
10. Gland leakage evacuating apparatus when the gland casing design requires its use.
11. Vibration monitoring devices.
12. Axial shaft movement monitoring devices.
13. Bearing temperature indicators.
14. Combined trip-and-throttle valve.
15. Tachometer—of the vibrating reed, mechanical, or electric type, indicating speeds from above the trip speed to below the minimum operating speed. Tachometers should be suitable for the specified environment.

Additional items may be available.

Authorized Engineering Information 11-14-1985.

3.3 CONTROLLED EXTRACTION AND CONTROLLED INDUCTION TURBINES

Controlled extraction, controlled induction, and controlled induction extraction turbines shall include basic features listed in items 1 through 7 of 3.1, together with those listed in 3.3.1 through 3.3.4.

NEMA Standard 11-14-1985.

3.3.1 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 following the extraction opening(s). A nonreturn valve for the extraction opening(s), which is also actuated by the overspeed trip system, is required for installation in the extraction steam line.

NEMA Standard 11-14-1985.

3.3.2 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 stages following the induction opening. A trip valve which is also actuated by the overspeed trip system is required for installation in the induction steam line.

NEMA Standard 11-14-1985.

3.3.3 Depending on the source of induction steam, the user should consider the need for a steam strainer in this line to protect the lower pressure stages of the turbine.

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3.3.4 Controlled extraction turbines and controlled induction turbines shall have a multivariable control system which provides interconnection between the pressure-regulating system and the speed governing system.

NEMA Standard 11-14-1985.

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

NEMA Standard 6-21-1979.

3.4 NONCONTROLLED EXTRACTION TURBINES

Noncontrolled extraction turbines shall include the basic features listed in items 1 through 7 of 3.1, together with a nonreturn valve for the extraction opening(s).

NEMA Standard 6-21-1979.

3.5 NONCONTROLLED INDUCTION TURBINES

Noncontrolled induction turbines shall include the basic features listed in items 1 through 7 of 3.1, together with a trip valve for the induction openings.

NEMA Standard 11-14-1985.

3.6 GENERAL PRESSURE AND TEMPERATURE RANGES

Steam turbines should be designed and proportioned for operation at maximum steam conditions. General pressure and temperature ranges are shown in Table 3-1. The ranges are general, according to temperature/pressure combinations at which point material or design changes, or both, may be required.

Authorized Engineering Information 6-21-1979.

3.7 OUTPUT SHAFT EXTENSIONS

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

NEMA Standard 11-14-1985.

3.7.2 When a tapered shaft extension with keyway(s) is specified, the taper, coupling hub, and coupling nut shall be in accordance with Figure 3-1.

NEMA Standard 11-14-1985.

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

Authorized Engineering Information 11-14-1985.

3.7.4 When a hydraulic fit coupling is specified, the mounting method should be reviewed with the turbine manufacturer.

Authorized Engineering Information 11-14-1985.

3.7.5 Recommended use of one and two keys and key fits shown in Table 3-2:

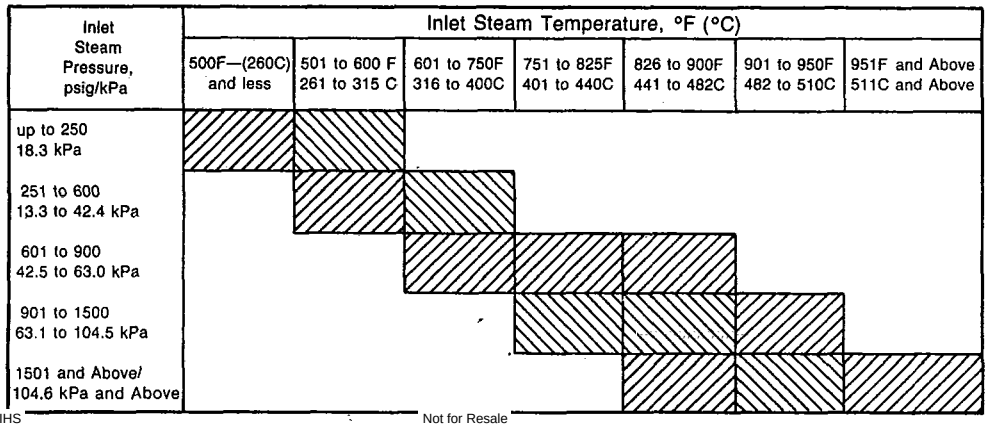
Authorized Engineering Information 11-14-1985.

Table 3-2
RECOMMENDED KEY FITS

Nominal Shaft Diameter	Maximum Speed for One Key, R/Min
1.50 up to & including	16,000
2	14,000
2.50	12,500
3	11,500
3.50	10,500
4	10,500
4.50	9,500
5	9,000
5.50	8,500
6	8,500
6.50	7,500
7	7,500
7.50	7,000
8	7,000
9	6,500
10	5,000

Two keys may be used in any case.

Table 3-1
GENERAL PRESSURE AND TEMPERATURE RANGES



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3.8 TURBINE CONNECTIONS

3.8.1 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 or B16.5 as applicable.

Cast iron flanged connections shall be flat faced.

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

Single-stage axially 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.

NEMA Standard 11-14-1985.

3.8.2 Auxiliary Connections

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

NEMA Standard 11-14-1985.

3.9 VIBRATION

The vibration of the turbine rotor (double amplitude) within the specified operating speed range as measured on the surface of the shaft adjacent to the radial bearings shall be in accordance with the following:

NEMA Standard 11-14-1985.

3.9.1 Single-Stage Turbines

The maximum permissible vibration shall be not greater than 2.0 mils for speeds 4000 rpm and lower, or 1.5 mils for speeds 4001 rpm and higher.

NEMA Standard 11-14-1985.

3.9.2 Multistage Turbines

The maximum permissible vibration shall be in accordance with Figure 3-2. The absolute values for vibration levels above 3000 rpm can be derived from the following formula:

$$\sqrt{\frac{12{,}000 \text{ rpm}}{\text{maximum continuous speed}}}$$

Shaft mechanical and electrical runout shall be determined by slow rolling the rotor in its bearings while 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 or .25 mils, whichever is greater.

NEMA Standard 6-21-1979.

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

Authorized Engineering Information 6-21-1979.

3.10 CRITICAL SPEEDS, LATERAL

The turbine shall be designed so that its critical speeds, including the effect of the half coupling, will not be detrimental to its satisfactory operation and so that it will be free of harmful or objectionable vibration at speeds within the specified operating range.

The calculated first critical speed of a stiff shaft turbine rotor shall be a minimum of 10 percent over the trip speed. The calculated first critical speed of a flexible shaft turbine rotor shall be not more than 60 percent of the maximum continuous speed nor closer than 10 percent to any operating speed.

The actual first critical speed of a flexible shaft turbine rotor shall be determined during the no-load running test when practical and shall be stamped on the nameplate followed by the word "test." Where it is impractical to determine critical speeds during the running test, the calculated critical speed shall be stamped on the nameplate followed by the abbreviation "approx."

NEMA Standard 6-21-1979.

Due to the practical limits imposed by the speed range or the complexity of the turbine assembly, the turbine may not have the specified margins between the operating speeds and critical speeds.

Authorized Engineering Information 6-21-1979.

3.11 LUBRICATION

3.11.1 Nonpressure-Type Oil Lubrication (Single-Stage Turbines)

3.11.1.1 SLEEVE BEARINGS—HORIZONTAL TURBINES

a. Lubrication should be provide by oil rings.
b. 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.
c. Facilities for cooling should be provided when necessary to assure the proper oil temperature. The cooling water should be supplied at a temperature not exceeding 90°F (32°C).

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A	B	C	D	E	F	G	H	J	K	L	M	N	P	R	S	T	V	Keyway AA	Keyway AB	Keyway AC	Keyway AD	Keyway AE	Keyway AF	Key AH	Key AK	Key AL	Key AM
Shaft Diameter +0.0000, −0.0005	Taper Diameter +0.0000, −0.0005	Coupling Bore +0.0000, −0.0005	Coupling Taper Bore +0.0000, −0.0005	Coupling Bore Length	+0.0, −1/64										+1/64, −0.0		+0.005, −0.000	+0.000, +0.002	+0.000, −0.002		+0.005, −0.000			Number	±0.001	+1/64, −0.0		
2.0000	1.8770	1.9965	1.8676	2 1/16	3/8	1/4	2 3/4	2 1/4	1 5/8	9/32	2 7/16	1/16	1 31/32	1/2	2 15/16	1 1/4–12	1.193	0.500	0.496	1 31/32	0.312	1/16	1/16	1	0.500	1 31/32	1/4–20	2 1/2
2.5000	2.3438	2.4965	2.3344	2 19/32	7/16	1/4	3 1/2	2 1/4	2	9/32	3 1/32	3/32	2 1/2	9/16	3 9/16	1 1/2–12	1.489	0.625	0.621	2 1/2	0.391	1/16	1/16	1	0.625	2 1/2	1/4–20	3 1/8
3.0000	2.8125	2.9965	2.8031	3 3/32	1/2	1/4	4 1/4	3 1/2	2 1/2	11/32	3 19/32	3/32	3	5/8	4 5/16	2–12	1.786	0.752	0.746	3	0.469	1/8	1/16	1	0.750	3	1/2–13	3 3/4
3.5000	3.2793	3.4965	3.2699	3 5/8	9/16	3/8	4 7/8	3 1/2	2 7/8	11/32	4 3/16	1/8	3 17/32	11/16	4 15/16	2 1/4–12	2.083	0.877	0.871	3 17/32	0.547	1/8	1/16	1	0.875	3 17/32	1/2–13	4 3/8
4.0000	3.7480	3.9965	3.7387	4 1/8	5/8	3/8	6 1/4	4	3 1/4	13/32	4 3/4	1/8	4 1/32	3/4	6 5/16	2 1/2–12	2.380	1.002	0.996	4 1/32	0.625	1/8	1/16	1	1.000	4 1/32	3/4–10	5 1/2
4.5000	4.2168	4.4965	4.2074	4 5/8	11/16	1/2	6 3/4	4	3 5/8	13/32	5 5/16	5/32	4 17/32	13/16	6 13/16	2 3/4–12	2.614	1.002	0.996	4 17/32	0.641	1/8	1/16	1	1.000	4 17/32	3/4–10	6
5.0000	4.6758	4.9965	4.6664	5 9/32	3/4	1/2	7 1/4	4	4	13/32	6 1/32	5/32	5 3/16	7/8	7 5/16	3–12	2.968	1.252	1.246	5 3/16	0.787	1/8	3/32	1	1.250	5 3/16	3/4–10	6 1/2

All dimensions in inches.

NOTE I All diametric tapers are 0.75 inch / foot.

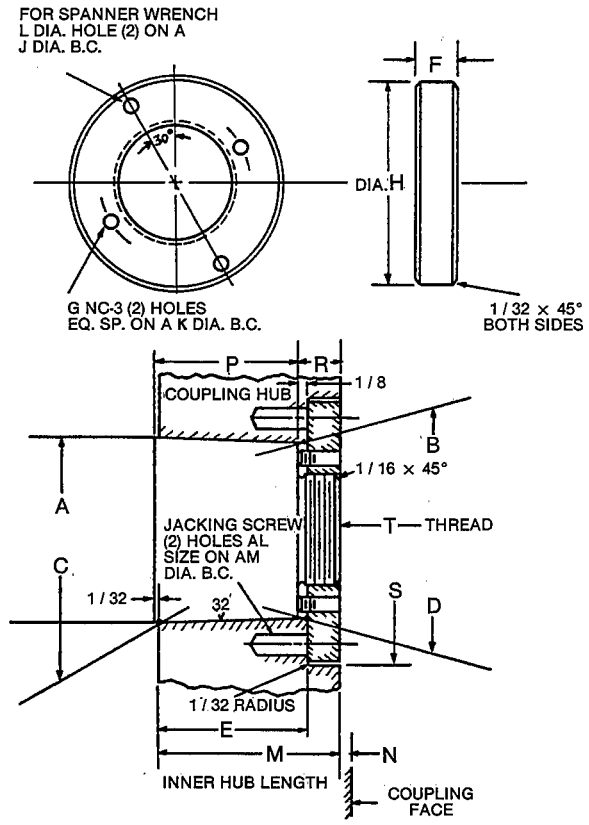
NOTE II Minimum of one key is required.

NOTE III When two keys are used, they shall be located 180 degrees apart.

NOTE IV Three set screws are suggested with two keys.*

NOTE V Key to be fitted to shaft and coupling hub at assembly. Fit in shaft to be 0.000 to 0.0015 tight. Corners shall be chamfered to suit.

*Note IV has been approved as Authorized Engineering Information.



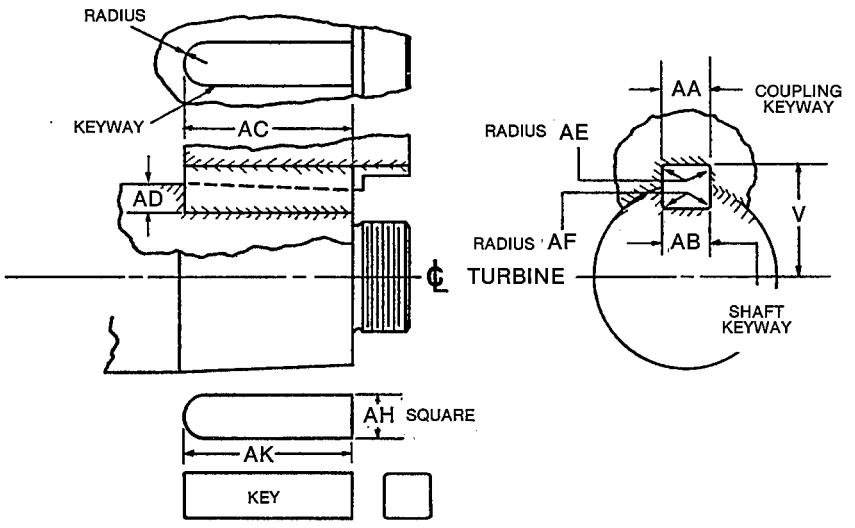


Figure 3-1
OUTPUT SHAFT EXTENSIONS

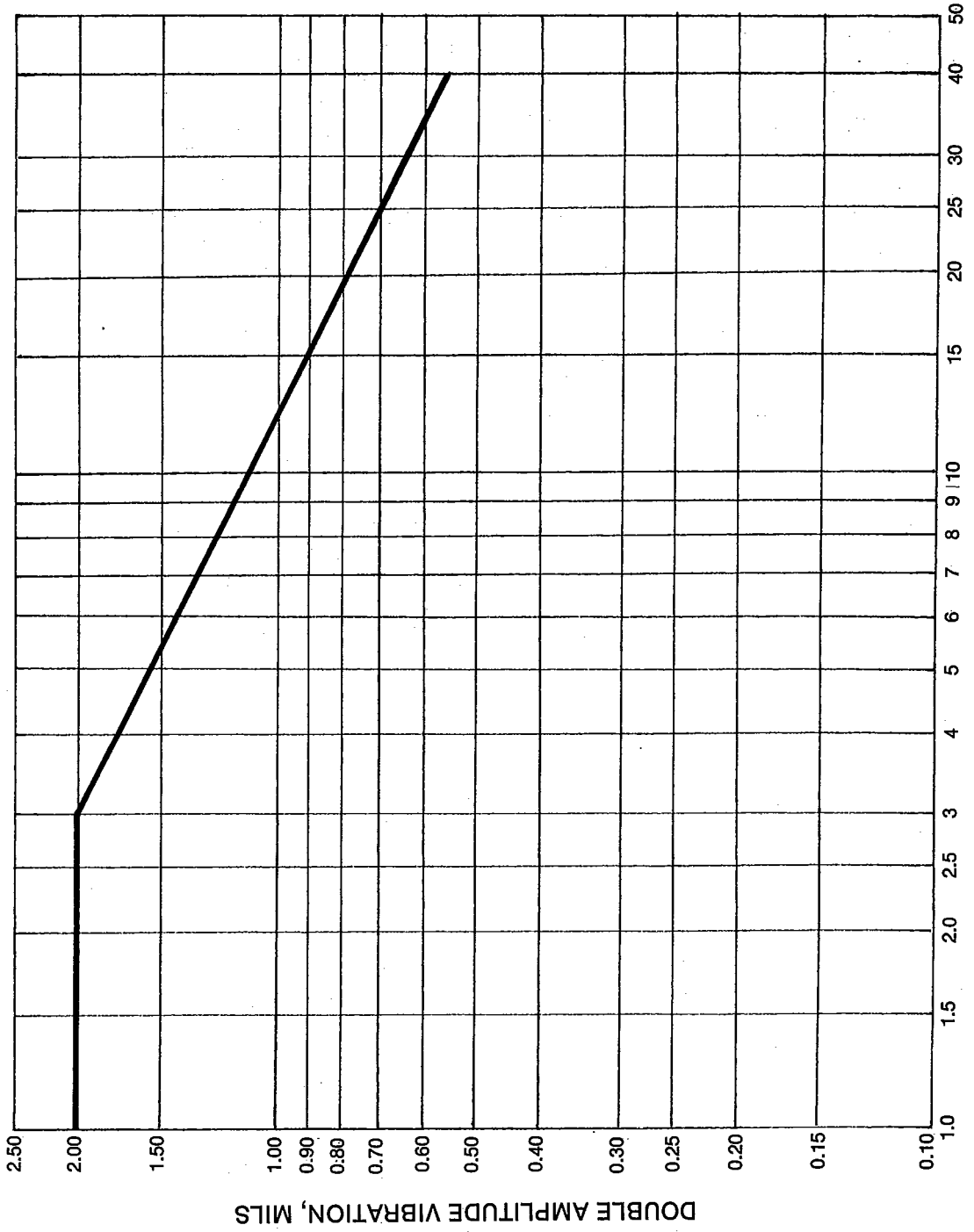


Figure 3-2
MAXIMUM PERMISSIBLE SHAFT VIBRATION

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3.11.1.2 ANTIFRICTION BEARINGS—HORIZONTAL AND VERTICAL TURBINES

a. Bearings should be oil- or grease-lubricated.
b. Means should be provided for venting the grease-lubricated bearings to prevent the buildup of pressure within the housing.
c. Facilities for cooling should be provided when necessary to assure the proper lubricant temperature. The cooling water should be supplied at a temperature not exceeding 90°F (32°C).

Authorized Engineering Information 11-14-1985.

3.11.2 Pressure-Type Oil Lubrication

It is recognized that there is a wide variation in turbine 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:

3.11.2.1 A main oil pump driven from the turbine shaft or a separately driven pump to provide oil for lubrication and governing should be provided.

3.11.2.2 A full-capacity 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 these standards, except that it may be provided with either:

a. A constant-speed governor and overspeed trip system, or
b. A wheel housing (casing and cover) of steel, and a rotor which is safe under runaway conditions.

3.11.2.3 OIL RESERVOIR—a separate oil reservoir should have:

a. Sufficient capacity to provide for the defoaming and settling of foreign material and for the contents of the system when drained.
b. Interiors cleaned.
c. Fill connection, level indicator, and breather suitable for outdoor use.
d. Sloped bottom and connection for complete drainage when the design permits.
e. Clean-out opening as large as possible.
f. Reservoir and fittings applicable for outdoor service.

3.11.2.4 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 than 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 operation at a pressure equal to or greater than the relief valve setting of positive displacement oil pumps or of the maximum shutoff discharge pressure of centrifugal oil pumps.

3.11.2.5 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 valve setting of the positive-displacement oil pumps or at the maximum shut off discharge pressure of centrifugal oil pumps.

3.11.2.6 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).

3.11.2.7 Thermometers 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.

3.11.2.8 An oil sight flow indicator in the oil return from each bearing housing where the design permits.

3.11.2.9 A pressure regulator or relief valve to maintain the oil pressure level(s) should be provided.

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

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3.12 ENVIRONMENTAL PROTECTION

Steam turbines 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 3.12.1 and 3.12.2.

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3.12.1 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, such as governor, governor linkage, fulcrum points, valve stems, and similar elements should be protected against rusting by the use of corrosion-resistant materials.

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

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

3.12.1.1 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.

3.12.1.2 In addition to the foregoing protective measures, the following should be included when ambient temperatures will be less than 40 °F (4.4 °C):

1. 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.
2. 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.
3. 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.
4. Protection against freezing for instruments and small piping.

Authorized Engineering Information 11-14-1985.

3.12.2 Exposure to Abnormal Atmospheric Conditions

If possible, the turbine 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 effects of the fumes or dust. When necessary, purge air connections on bearing housings, gland cases, and governors should be provided.

Authorized Engineering Information 11-14-1985.

3.13 NAMEPLATE DATA

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

1. Manufacturer's name and location
2. Serial number*
3. Model/type
4. Rated horsepower
5. Rated speed
6. Maximum inlet steam pressure
7. Maximum inlet steam temperature
8. Maximum exhaust steam pressure
9. Trip speed
10. Maximum continuous speed (if different from rated speed)
11. First lateral critical speed
12. Purchaser's equipment item number (when specified).

*In addition, the serial number shall be stamped on the turbine casing where readily visible.

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Section 4

GOVERNING SYSTEM

4.1 GENERAL

The governing system of a mechanical drive steam turbine controls the turbine speed. In addition, the governing system may control other variables such as extraction pressure, induction pressure, acceleration rate, start sequence, safety device, and so forth. These systems include mechanical, electrical, hydraulic, and pneumatic components.

Authorized Engineering Information 11-14-1985.

4.2 GOVERNING SYSTEM

The governing system includes the governor, the control mechanism, the governor-controlled valve(s), the speed changer, and any other control devices which are specified by the user.

NEMA Standard 11-14-1985.

4.3 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 Table 4-1.

NEMA Standard 11-14-1985.

4.4 MULTIVARIABLE GOVERNOR

The multivariable governor shall have the capability to control two or more control parameters in a simultaneous manner. In the event of conflicting parameters, the multivariable governor shall respond first to the highest priority parameter.

NEMA Standard 11-14-1985.

4.5 CONTROL MECHANISM

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

NEMA Standard 11-13-1969.

4.6 GOVERNOR-CONTROLLED VALVE(S)

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

There are two methods of controlling the admission of steam:

1. By single throttling valve(s)
2. By multiple automatic valves to reduce throttling losses.

NEMA Standard 11-13-1969.

4.7 SERVOMOTOR SYSTEM

A servomotor system includes a pilot valve actuated by the 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 governor or control mechanism.

NEMA Standard 6-21-1979.

4.8 SPEED CHANGER

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

NEMA Standard 11-14-1985.

4.9 EXTERNAL CONTROL DEVICES

External control devices shall be one of three types:

4.9.1 Speed-Changer Type

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

NEMA Standard 11-14-1985.

4.9.2 Remote Set Point Type

The remote set point type is incorporated directly into the governing system which in turn positions the governor-controlled valve(s). The governor shall be selected to provided the specified adjustable ranges for all controlling parameters.

NEMA Standard 11-14-1985.

4.9.3 Valve-Actuating Type

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

NEMA Standard 11-14-1985.

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4.10 SPEED GOVERNING SYSTEM CLASSIFICATION

Speed-governing systems shall be classified as shown in Table 4-1.

NEMA Standard 11-14-1985.

Table 4-1
SPEED-GOVERNING SYSTEM CLASSIFICATION

Class of Governing System	Percent of Rated Speed		
	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

4.11 SPEED RANGE

Speed range is the specified range of operating speeds when the turbine is operating under the control of the speed governor.

NEMA Standard 11-14-1985.

4.12 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 steady-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).

$$\text{Speed Regulation (\%)} = \frac{\left(\begin{array}{c}\text{Speed at}\\ \text{zero power}\\ \text{output}\end{array}\right) - \left(\begin{array}{c}\text{Speed at}\\ \text{rated power}\\ \text{output}\end{array}\right)}{\text{Speed at rated power output}} \times 100$$

(See Figure 4-1 for graphic representation of characteristics of a Class D Governor.)

NEMA Standard 6-21-1979.

4.13 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 4.12. 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.

$$\text{Speed variation (± \%)} = \frac{\left(\begin{array}{c}\text{Change in}\\ \text{r/min above}\\ \text{set speed}\end{array}\right) + \left(\begin{array}{c}\text{Change in}\\ \text{r/min below}\\ \text{set speed}\end{array}\right)}{2 \times \text{Rated speed}} \times 100$$

NEMA Standard 6-21-1979.

4.13.1 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.

NEMA Standard 6-21-1979.

4.13.2 Stability

Stability is the ability of the speed-governing system to position the governor-controlled valve(s) so that a sustained oscillation in speed is not produced by the speed-governing system during operation under a steady-state load demand or following a change to a new steady-state load demand.

NEMA Standard 6-21-1979.

4.13.3 Oscillations

Oscillations are the alternate increase and decrease in speed with respect to time under steady-state or normal operating conditions, or both. (See Figure 4-2 for graphic representation of characteristics of a Class D governor.)

NEMA Standard 6-21-1979.

4.14 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.

$$\text{Maximum speed rise (\%)} = \frac{\left(\begin{array}{c}\text{Maximum speed}\\ \text{at zero power}\\ \text{output}\end{array}\right) - \left(\begin{array}{c}\text{Rated}\\ \text{speed}\end{array}\right)}{\text{Rated speed}} \times 100$$

(See Figure 4-3 for graphic representation of characteristics of a Class D governor.)

NEMA Standard 6-21-1979.

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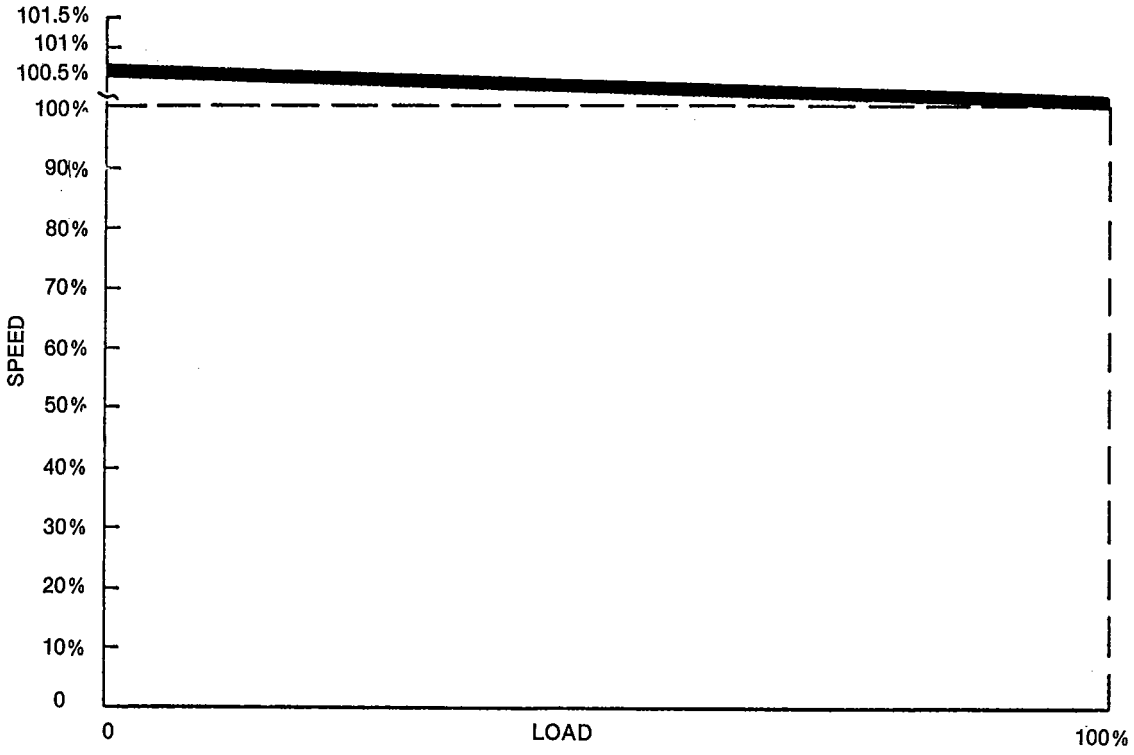

Figure 4-1
STEADY STATE SPEED REGULATION
NEMA CLASS D GOVERNOR

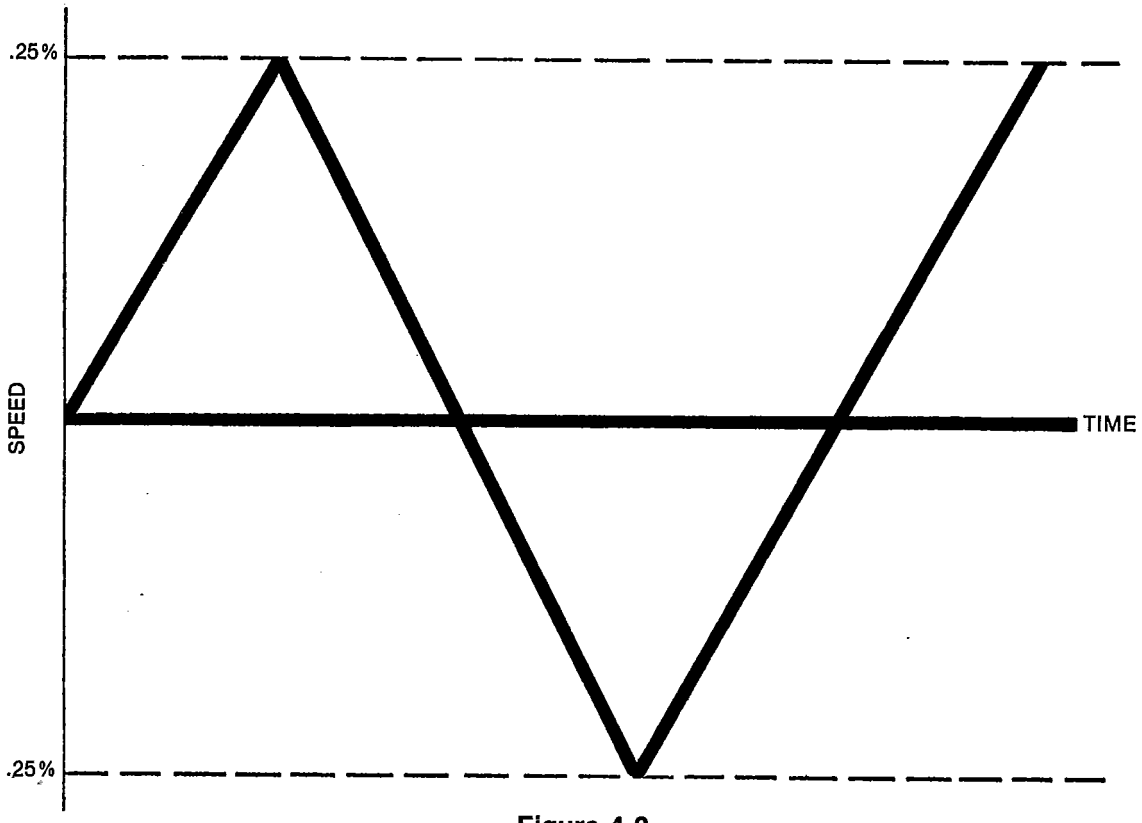

Figure 4-2
SPEED VARIATION
NEMA CLASS D GOVERNOR

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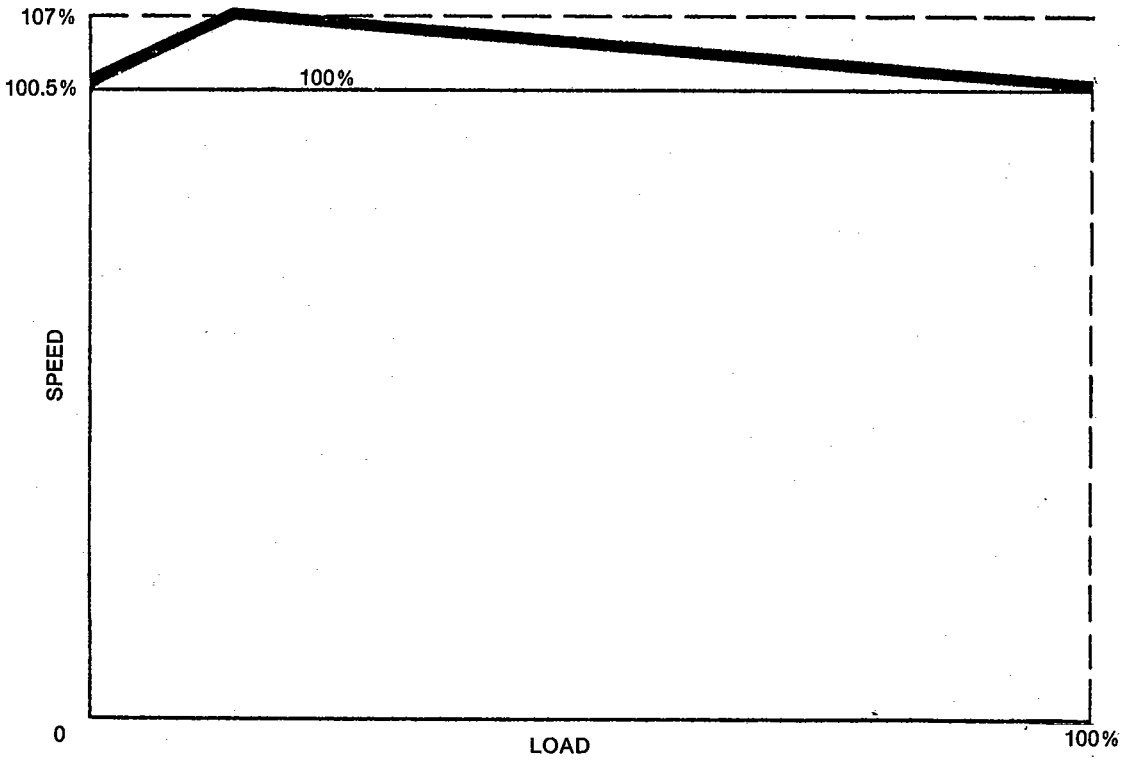

Figure 4-3
SPEED RISE
NEMA CLASS D GOVERNOR

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4.15 STEAM PRESSURE CONTROL

4.15.1 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 11-14-1985.

4.15.2. Pressure Regulator

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

NEMA Standard 11-14-1985.

4.15.3 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 11-14-1985.

4.15.4 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 11-14-1985.

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 11-14-1985.

4.15.5 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 11-14-1985.

4.15.6 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 power output of the steam turbine is gradually reduced from rated power output to zero power output.

NEMA Standard 11-14-1985.

4.15.7 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 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 purpose 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 11-14-1985.

4.16 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 11-14-1985.

4.17 PRESSURE CONTROL PERFORMANCE

A Class D governoring system (see 4.10) shall exhibit the following characteristics when utilized in a compensated control system:

4.17.1 Change in sustained speed shall be 1% maximum for any sustained change in flow within limits of 5% and 95% of maximum induction or extraction flow guaranteed for that load.

NEMA Standard 11-14-1985.

4.17.2 Steady state pressure regulation shall be 0.5 psig maximum or 4% of rated exhaust, extraction, or induction pressure expressed in PSIA; whichever is larger.

NEMA Standard 11-14-1985.

4.17.3 Sustained oscillations of controlled pressure, when operating at constant flow demand or following a change to another constant flow, shall not exceed 0.25 psig or 2% of the controlled pressure expressed in PSIA; whichever is larger.

NEMA Standard 11-14-1985.

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4.17.4 Sustained oscillations of controlled pressure, when operating at constant flow demand or following a change to another constant flow, shall not exceed 4% of rated power.

4.17.5 The range of adjustment for pressure change(s) shall permit adjustment of exhaust, extraction, or induction pressure between ±5 psig or ±10% of the controlled pressure expressed in PSIA; whichever is larger.

NEMA Standard 11-14-1985.

4.18 ELECTRONIC GOVERNING SYSTEM

4.18.1 Basic Features

An electronic governing system shall include the following basic components:

1. Sensors which measure an operating parameter of the turbine or system, and produce corresponding electric signals.
2. A governor which compares signal(s) from the sensor(s) with the selected set point(s) and produces a signal(s) to the value 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 following parameters shall be controlled by the governing system:

   a. Speed
   b. Each induction/extraction pressure
   c. Others for specific applications.

NEMA Standard 11-14-1985.

4.18.2 Accessories

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

1. A multifunctional control may be incorporated in the governor to allow the governor to receive signals from several sensors. The control will respond to the highest priority signal, which will result in the desired governor valve opening.
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 the controlled extraction or induction opening while simultaneously controlling speed, as long as no conflict in control requirements exist (see 4.4).
4. Sensor redundancy
5. Overspeed trip

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

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Section 5

OVERSPEED TRIP SYSTEM

5.1 OVERSPEED TRIP SYSTEM

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

NEMA Standard 11-14-1985.

5.2 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.

NEMA Standard 6-21-1979.

5.3 TRIP SPEED

The trip speed is the speed at which the overspeed sensing device is set.

NEMA Standard 6-21-1979.

5.4 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.

NEMA Standard 6-21-1979.

5.5 COMBINED TRIP-AND-THROTTLE VALVE

The combined trip-and-throttle valve is separate from the governor-controlled valve(s) and is closed (tripped) in response to the action of the overspeed sensing device or other safety devices or is manually tripped. This valve permits manual throttling of steam to the turbine.

NEMA Standard 6-21-1979.

5.6 OVERSPEED TRIP SYSTEM SETTINGS

The trip speed settings shown in Table 5-1 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 6-21-1979.

When design or application of driven equipment requires trip speeds other than those shown in Table 5-1, the trip speed should be specified.

Authorized Engineering Information 6-21-1979.

Table 5-1
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 maximum continuous speed.

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Section 6

FACTORY TESTING

6.1 HYDRO TEST

6.1.1 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 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.

NEMA Standard 11-14-1985.

6.1.2 Water jackets, coils, or coolers shall be hydro tested to 1½ times the specified cooling water pressure, but not less than 115 psig.

NEMA Standard 6-21-1979.

6.1.3 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.

NEMA Standard 6-21-1979.

6.1.4 Casings shall not be painted until hydro testing is completed.

NEMA Standard 6-21-1979.

6.2 NO-LOAD RUNNING TEST

The turbine shall be operated through the specified operating speed range 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 1 hour without an undue rise in oil temperature.

NEMA Standard 6-21-1979.

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Section 7

SOUND PRESSURE LEVELS

7.1 GENERAL

It is the turbine manufacturer's intention to design and manufacture turbines 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.

However, the turbine manufacturer does not have control over such factors as foundations, piping, and building configurations which emit, reflect, focus, or amplify the sound of the turbine 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. In order to achieve this, the user should suitably insulate the steam piping.

Furthermore, it is generally impractical to isolate the turbine from its environment sufficiently to separately measure its sound emission. The physical size of the turbine and the fact that it must be connected to piping as well as to drive equipment makes isolation for sound measurement difficult, if not impossible.

Sound pressure levels listed in 7.2 represent sound pressure levels of the turbine only when the turbine is 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 of turbines and adjacent auxiliary equipment.

Sound power 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 environments encountered. Each turbine should be evaluated as to its sound pressure levels, radiating surface areas, and directivity.

Authorized Engineering Information 6-21-1979.

7.2 SOUND PRESSURE LEVELS

Expected sound pressure levels for soleplate-mounted turbines operating with maximum steam flow, normally occurring at rated power and speed and maximum steam conditions, are as follows:

Frequency Band, Hertz	Mid-Band Frequency, Hertz	Maximum Sound Pressure Levels, Decibels	
		Single-Stage	Multistage
45-90	63	98	106
90-180	125	94	98
180-355	250	91	92
355-710	500	89	92
710-1400	1000	89	90
1400-2800	2000	89	90
2800-5600	4000	89	90
5600-11200	8000	89	90
Overall dBA.....		93	

For turbine mounted on a steel baseplate, add one additional decibel to tabulated values.

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.

Authorized Engineering Information 6-21-1979.

7.3 SOUND PRESSURE LEVEL MEASUREMENT PROCEDURE

Sound pressure levels shall be measured in accordance with American National Standard S5.1, 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 effect 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.

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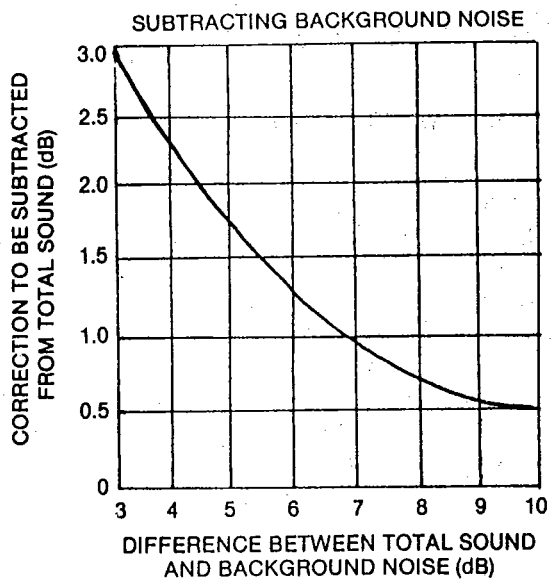

Figure 7-1
ADDING TWO SOUNDS

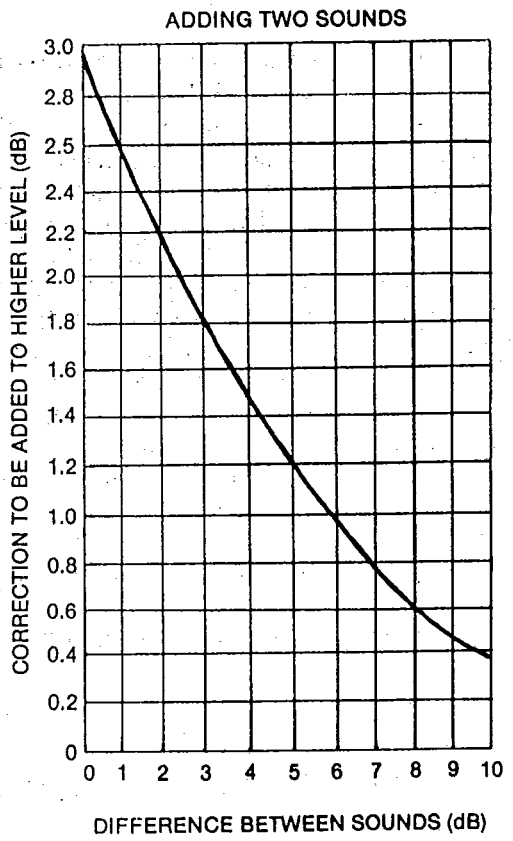

Figure 7-2
SUBTRACTING BACKGROUND NOISE

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 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 6-21-1979.

7.4 CORRECTION FOR AMBIENT BACKGROUND SOUND PRESSURE LEVEL

Measurements of turbine 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 following correction factor should be subtracted from the measured sound level:

Decibel correction factor =

(measured − background)dB			
3	4-5	6-9	10 and over
3	2	1	0

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

Authorized Engineering Information 6-21-1979.

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

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be combined with a correction number. The correction numbers obtained from Figures 7-1 and 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 Figure 7-1. 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 Figure 7-2. Thus the sound level without the background noise is 96 decibels.

Authorized Engineering Information 6-21-1979.

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.

A full-octave-band sound analyzer, meeting the requirements of American National Standard S1.11, should be used in conjunction with the sound level meter to measure sound.

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

Authorized Engineering Information 6-21-1979.

7.7 SOUND ATTENTUATION

It is recommended that acoustical treatment for turbines and similar machinery 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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Section 8

PREPARATION FOR SHIPMENT AND STORAGE

8.1 SHIPPING PREPARATION

The turbine and all separate parts shall be properly tagged and identified.

At the time of shipment, the turbine shall be protected by painting all exposed nonmachined surfaces with one coat of shop paint and coating or covering, or both, all exposed machined surfaces and oil reservoir interiors with a rust preventative. All openings shall be plugged or covered. The interior of the turbine shall be sprayed through available openings with a rust preventative.

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

NEMA Standard 11-14-1985.

The preparation assumes that storage will be so arranged that the equipment will be protected against loss, corrosion and weather damage.

Authorized Engineering Information 11-14-1985.

8.2 SHIPMENT

The user, since he has the most complete knowledge of local conditions, should specify the delivery point and provide information on the method of handling 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 user that installation will be delayed, the manufacturer should specify the additional preparation and protective coatings that should be provided to protect the equipment.

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

Authorized Engineering Information 11-14-1985.

8.3 RECEIPT AND STORAGE OF EQUIPMENT

Upon receipt, the user 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.

Before start-up, the oil or preservative used in the bearing housing 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 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 mechanical drive steam turbines. 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.

Authorized Engineering Information 11-13-1969.

9.2 SUPERVISION OF INSTALLATION

It is recommended that the manufacturer's representative supervise the installation of the turbine. 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.

Authorized Engineering Information 6-21-1979.

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 of 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, including the space for removing the rotor and setting down the upper half of the turbine casing.

Authorized Engineering Information 11-14-1985.

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 user 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 foundation. The natural frequency of the foundation should not correspond to any operating speed of the unit.

Authorized Engineering Information 11-14-1985.

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.

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.

Authorized Engineering Information 11-14-1985.

Table 9-1
MAXIMUM STEAM VELOCITY, IN PIPING

	Noncondensing Turbine Ft./Sec.	Condensing Turbine Ft./Sec.
Inlet	175	175
Exhaust	250	450
Induction	175	175
Extraction	250	250

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 mechanical drive steam turbines by piping. This information is presented as an aid to the user 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.

Authorized Engineering Information 6-21-1979.

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

Authorized Engineering Information 6-21-1979.

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 unrestricted expansion joint will cause an axial thrust equal to the effective area of the bellows times the internal pressure. The force necessary to compound 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 piping puts the expansion joint in shear instead of 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 the 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

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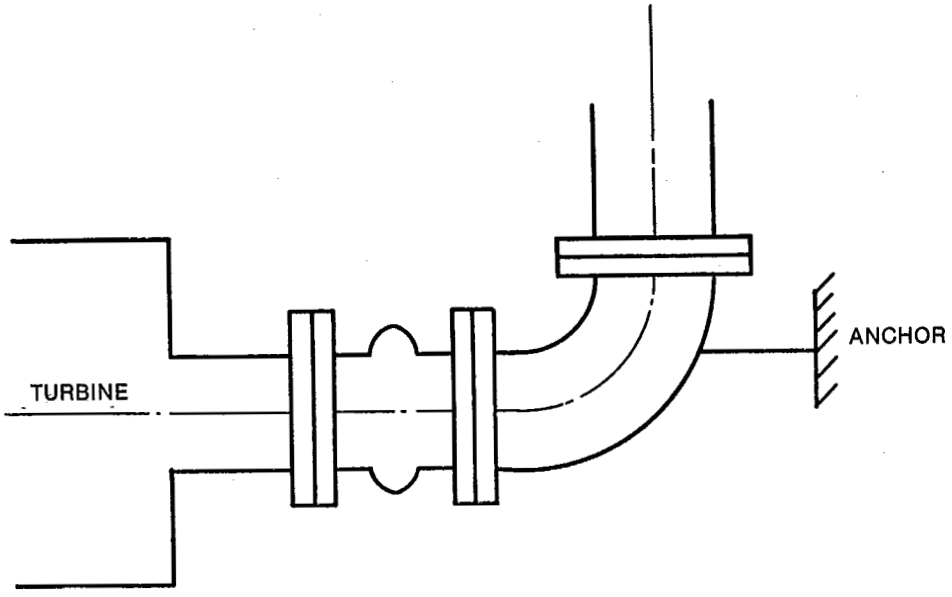

Figure 9-1
EXPANSION JOINT

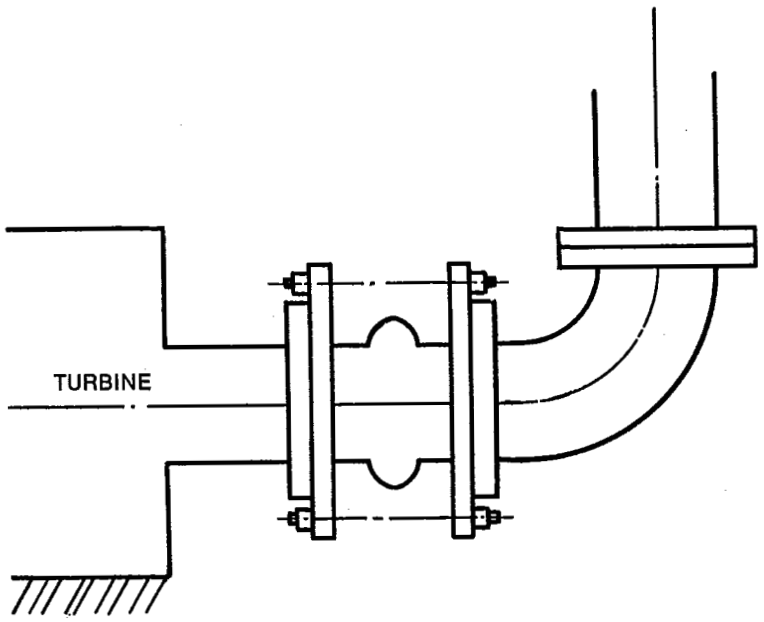

Figure 9-2
EXPANSION JOINT WITH TIE RODS

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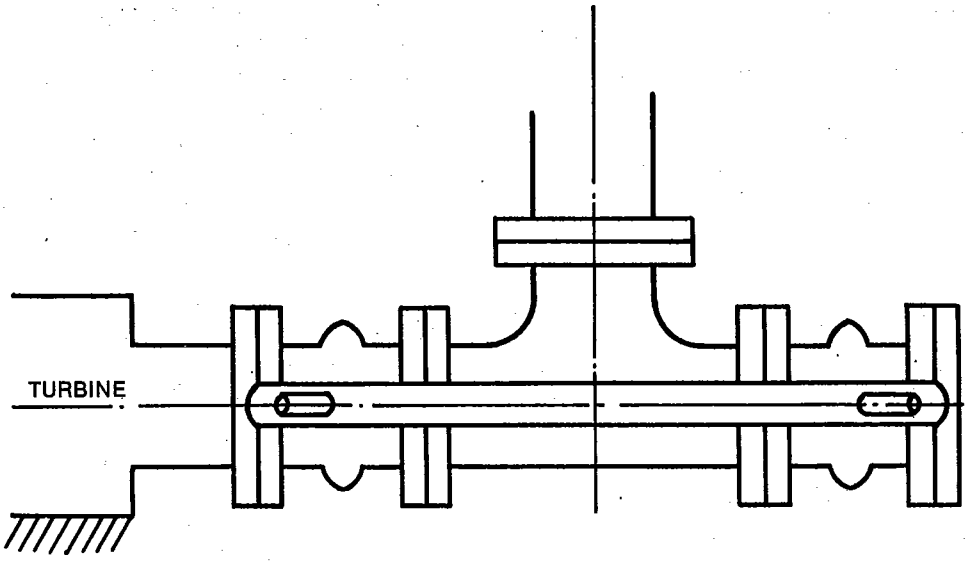

Figure 9-3
EXPANSION JOINT WITH TIE RODS FOR NONCONDENSING OPERATION

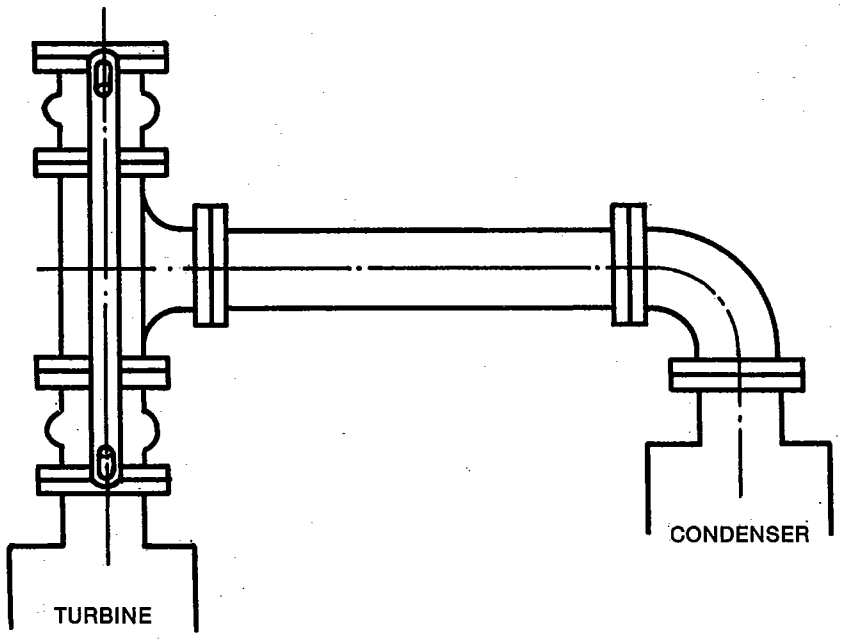

Figure 9-4
EXPANSION JOINT WITH TIE RODS FOR CONDENSING OPERATION WITH "UP" EXHAUST

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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 systems and ΔX and ΔY 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 arrangements 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.

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:

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

$$F_R + M_{R3} = 167\ D_e \qquad \text{(Equation 1)}$$

where:

F_R = Resultant force (pounds) including pressure forces where unrestrained expansion joints are used at the connection except on vertical exhausts. Full vacuum

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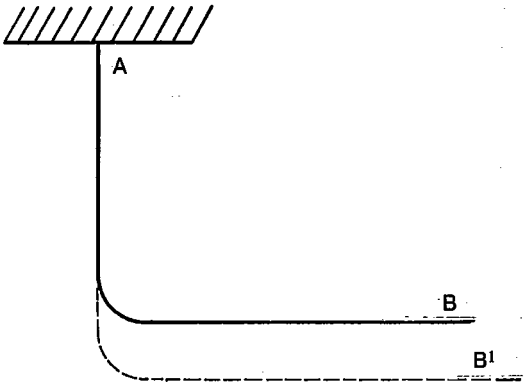

Figure 9-5
FREE EXPANSION

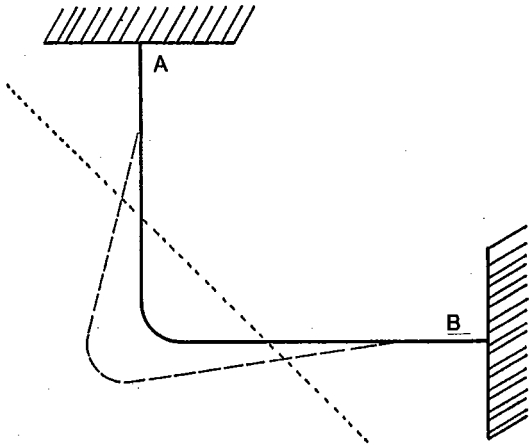

Figure 9-6
RESTRAINED EXPANSION

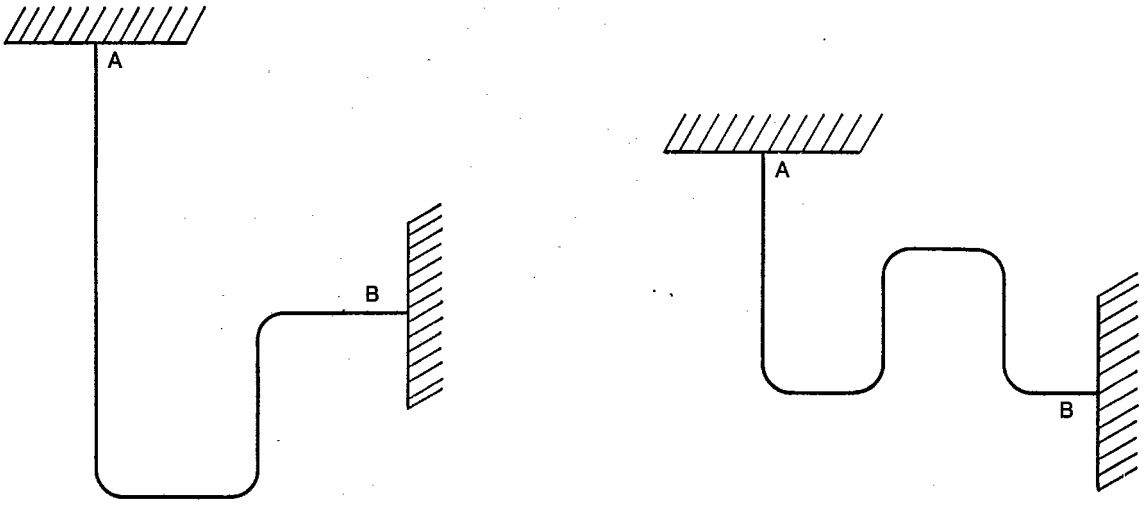

Figure 9-7
EXPANSION LOOPS

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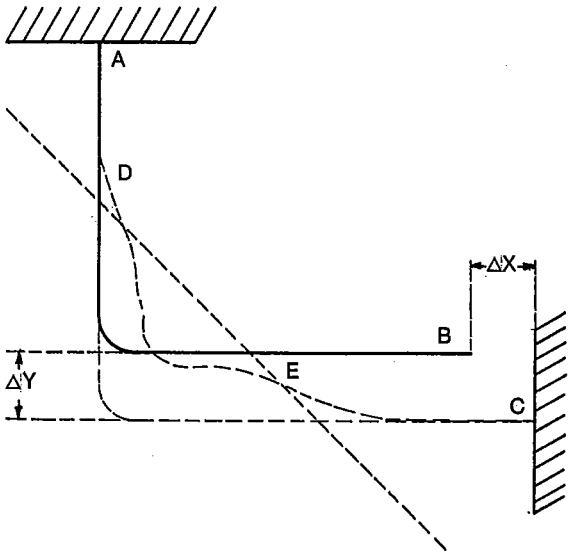

Figure 9-8
PRE-STRESSING (COLD SPRINGING)

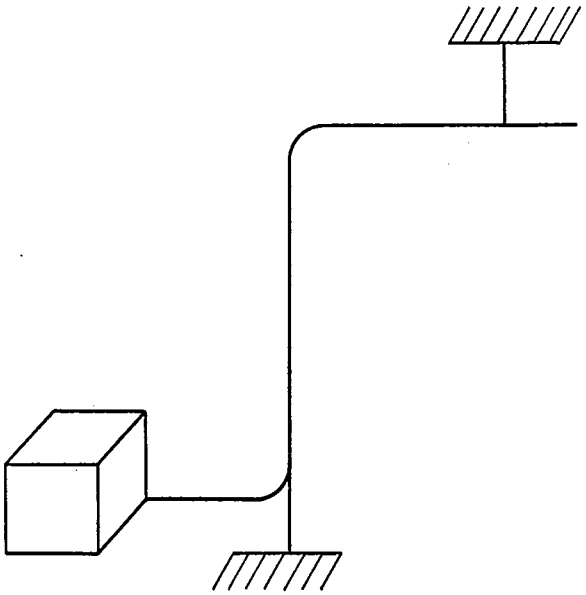

Figure 9-9
DEAD WEIGHT SUPPORT

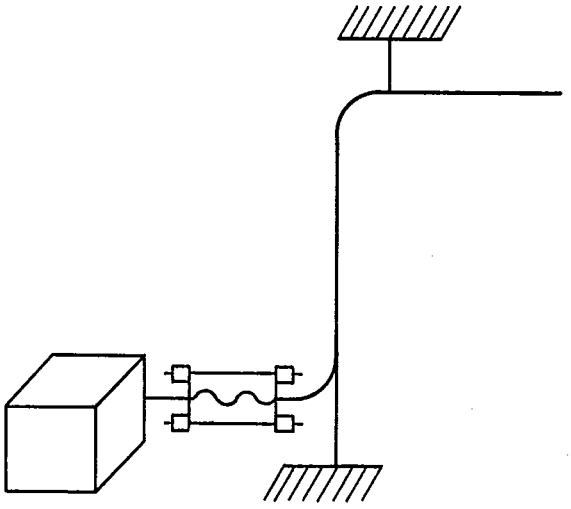

Figure 9-10
DEAD WEIGHT SUPPORT WITH RESTRAINED EXPANSION JOINT

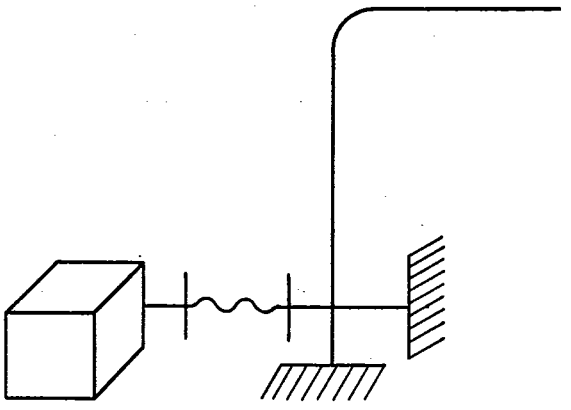

Figure 9-11
DEAD WEIGHT SUPPORT WITH UNRESTRAINED EXPANSION JOINT

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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

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

9.4.6.2 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 resultations 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 components 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.

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9.4.6.3 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 9.4.6.1 and 9.4.6.2.

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.

9.4.6.4 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 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.

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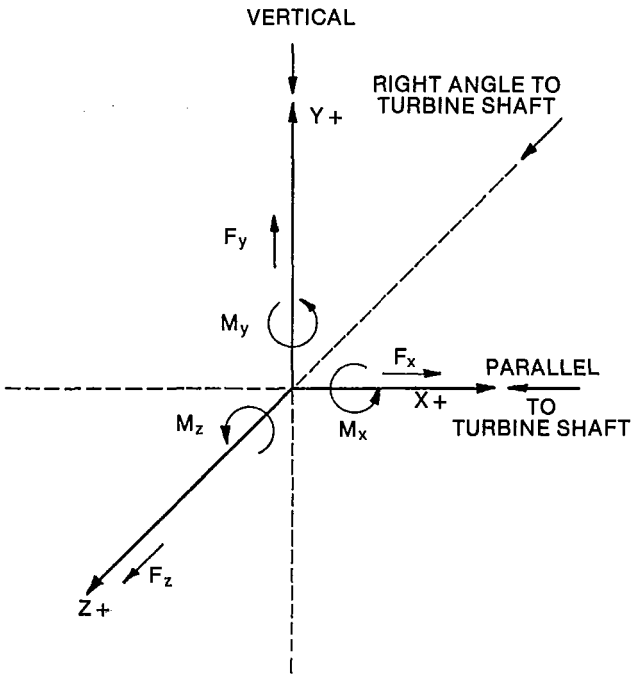

Figure 9-12
COMPONENTS OF FORCES AND MOMENTS ON TURBINE CONSTRUCTION

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The full-flow relief valve should be provided by the user as 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-flow 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 of 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 and driven equipment, 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 and driven equipment supports.

In the actual alignment of couplings, allowance 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 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 overexpand 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 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 manufacture's recommendations.

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9.10.1 Flushing oil should be compatible with the final turbine oil.

9.10.2 Oil should be circulated through the entire system as long as necessary to remove or to flush particulate 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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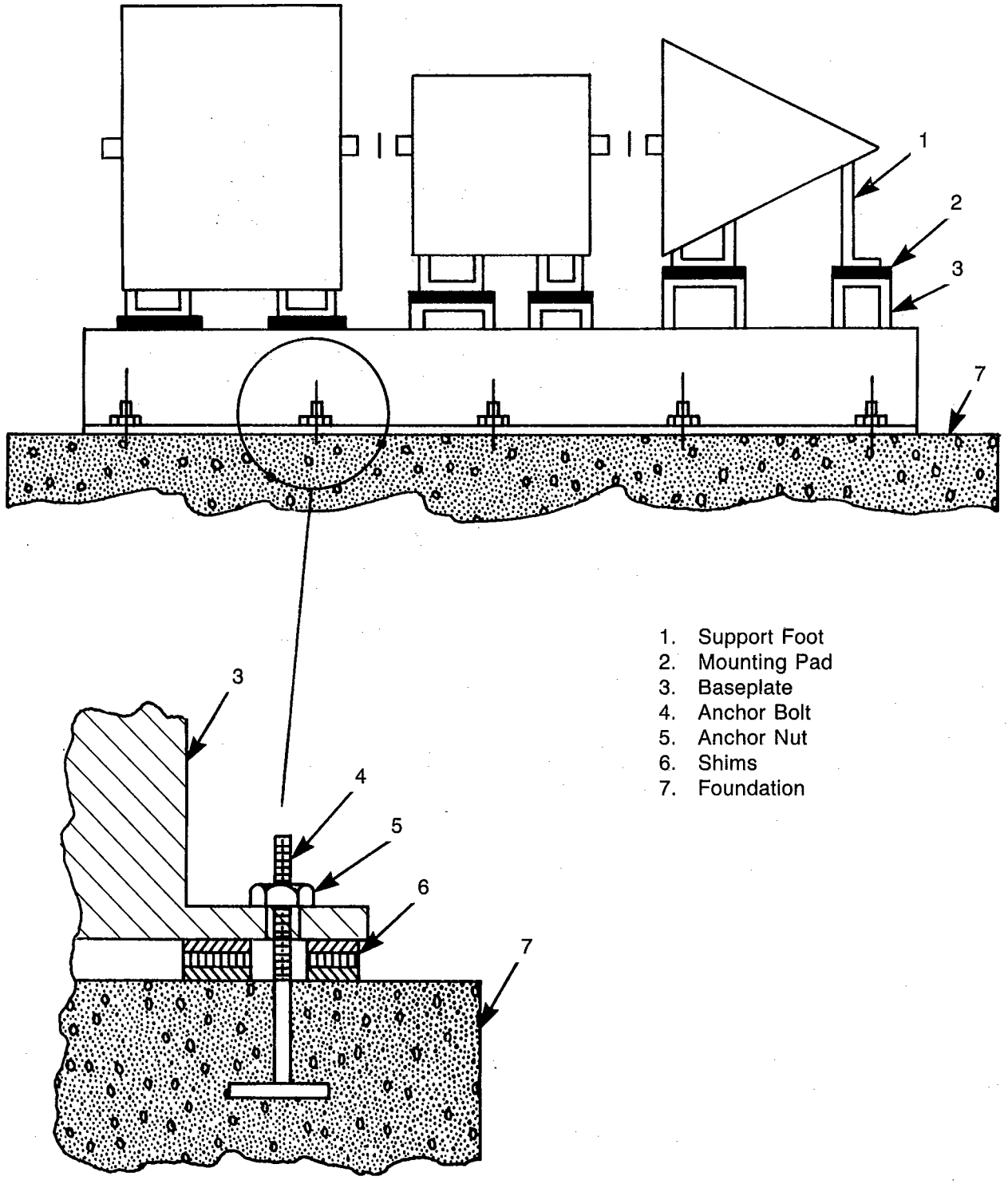

1. Support Foot
2. Mounting Pad
3. Baseplate
4. Anchor Bolt
5. Anchor Nut
6. Shims
7. Foundation

Figure 9-13
BASEPLATE MOUNTED TURBINE GENERATOR SET

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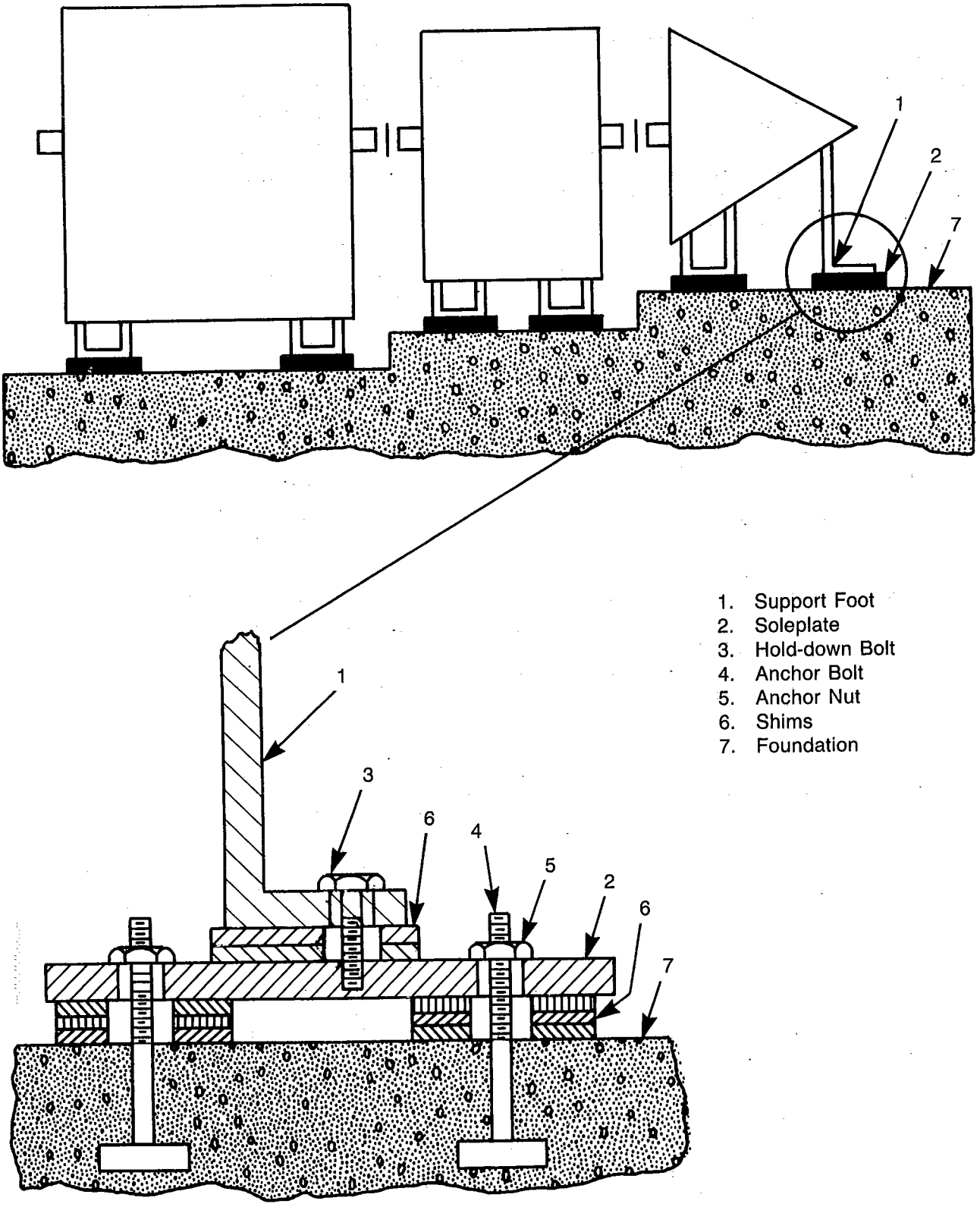

1. Support Foot
2. Soleplate
3. Hold-down Bolt
4. Anchor Bolt
5. Anchor Nut
6. Shims
7. Foundation

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 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 turbine.

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10.2 OPERATION

The following should be given careful consideration by the operator:

1. The steam supplied to the turbine 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, 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

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. Monitor turbine 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 personnel.

The following is a typical maintenance program:

Daily

1. Visually inspect turbine 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.

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.

Monthly

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

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Annually

Shut down the turbine and perform the following:

1. Remove and clean steam strainer.
2. Check shaft seals 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 foundation.
12. Check alignment.
13. Check and recalibrate gauges.

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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 THAN 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 applications, turbines may operate satisfactorily on steam having purity limits set by the American Boiler Manufacturers Association. See Table 10-1.

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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.

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— Micromhos/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

STEAM TURBINE INQUIRY GUIDE

(Authorized Engineering Information)

Job No._____ Item No._____
Inquiry Order No._____
Purchase Order No._____
Page No._____ By_____
Date_____ Revision_____

Purchaser
Contractor
User
Applicable To: Proposal_____
For: _____

Site:_____ No. Required:_____
Service_____ Driven Equip._____ Gear Yes/No
Manufacturer_____ Model_____

List and/or attach additional applicable standards or specifications.

_____
_____
_____
_____

Turbine Rating

	Guar.	Rated	Normal	Max.	Min.	Other	Units
Power							
Speed							
Steam Conditions							
Inlet pressure							
Inlet temperature							
Exhaust pressure							
Extraction/induction pressure							
Extraction/induction temperature							
Inlet flow							
Extraction/induction flow							
Other performance requirements							

Maximum Continuous Speed _____

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Duty
Continuous_____ Intermittent_____ Standby_____
Emergency _____ Auto start _____ Manual start _____
Other _____

Evaluation
Approximate steam rate (normal) desired _____
Steam rate measured at output of turbine _____ gear _____
Steam cost $_____ per unit flow _____
Payout period: No. of years _____
Hours per year of operation _____

Construction Single Valve_____ Multivalve_____
Horizontal shaft_____ Vertical shaft_____
Thrust_____ _____(Upward/downward)
Automatic extraction or induction _____
Nonautomatic extraction or induction_____
Induction/extraction _____

Governing System
NEMA Class _____
Min. speed_____rpm, Max speed_____rpm
Additional features_____

Speed Changer Type
Manual_____ Pneumatic_____ Electric_____

Lubrication
Supplied by: Manufacturer_____ Other_____
For turbine_____
For turbine gear_____
For driven equipment (type)_____
Flow_____ Heat load_____ Pressure_____

Mounting
Baseplate_____ Soleplate(s)_____
Supplied by _____
Extended for _____

Accessories
_____
_____
_____
_____
_____

Paint
Manufacturer's standard_____ Other_____

Shipping Preparation
Manufacturer's standard_____ Other_____

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Factory Tests

	Required	Witnessed
Hydo test	Yes	Yes/No
No-load running test	Yes	Yes/No
Dynamic balance rotor	Yes/No	Yes/No

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 _____

Air Supply _____ Pressure _____

Site Environment

Ambient temperature Maximum _____ Minimum _____
Elevation _____

Area classification: Class _____ Group _____ Div. _____
Control(s)
Explosion proof _____
Weatherproof _____
General purpose _____
Motor(s)
TEFC _____
Explosion proof _____
General purpose _____
Other _____

Environment Protection at Site (S or I)
Enclosed _____ Sheltered _____ Outdoor _____
Other _____
For _____ months storage prior to startup
S = Storage
I = Installation

Remarks

_____
_____
_____
_____
_____
_____

Drawings and Data to be Supplied

Certified outline drawings _____
Recommended spare parts list _____
Instruction books _____ No. _____
Other _____
_____
_____

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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
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