ASME B133.16-2000

[Revision of ANSI B133.16-1978 (R1997)]

PROCUREMENT STANDARD FOR GAS TURBINE MARINE APPLICATIONS

AN AMERICAN NATIONAL STANDARD



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FOREWORD

The purpose of the B133 standards is to provide criteria for the preparation of gas turbine procurement specifications. These standards will also be useful for response to such specifications.

The B133 standards provide essential information for the procurement of gas turbine power plants. They apply to open cycle, closed cycle, and semiclosed cycle gas turbines with conventional combustion systems for industrial, marine, and electric power applications. Auxiliaries needed for proper operation are covered. Not included are gas turbines applied to earth-moving machines, agricultural and industrial type tractors, automobiles, trucks, buses, and aero-propulsion units.

For gas turbines using unconventional or special heat sources (such as chemical processes, nuclear reactors, or furnaces for supercharged boilers), these standards may be used as a basis, but appropriate modifications may be necessary.

ASME B133.16 is intended to aid the equipment builder, purchaser, and operator in coordinating efforts toward satisfactory performance of gas turbine prime movers used in marine applications. This Standard summarizes needs that have been demonstrated in practice of necessity; they are generalized because of variations in equipment, practices, and local conditions.

ASME B133.16-2000 was approved by the B133 Standards Committee, and final approval by the American National Standards Institute was granted on June 22, 2000.

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Subject:	Cite the applicable paragraph number(s) and the topic of the inquiry.
Edition:	Cite the applicable edition of the Standard for which the interpretation is being requested.
Question:	Phrase the question as a request for an interpretation of a specific requirement suitable for general understanding and use, not as a request for an approval of a proprietary design or situation. The inquirer may also include any plans or drawings which are necessary to explain the question; however, they should not contain proprietary names or information.

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Gas Turbine Procurement

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PROCUREMENT STANDARD FOR GAS TURBINE MARINE APPLICATIONS

1 GENERAL

1.1 Scope

(a) This procurement standard provides guidance and criteria for gas turbine systems used in marine applications. It supplements the general gas turbine procurement standards presented in ASME's B133 series.

(b) In utilizing this procurement standard, the user should ensure that only those requirements considered necessary for his/her application are utilized. This is a general document and its intent is to cover most marine applications. Therefore, there is an inclusion of data for most varied applications, which may not be applicable to a specific application.

(c) Marine applications are defined as gas turbines serving as prime movers for:

(1) propulsion
(2) electric power generation
(3) gas transmission or compression
(4) cargo pumps
(5) water flood pumps

(d) Emphasis should be made for machinery to be classed by International Maritime Organization (IMO) codes in the following areas of service:

(1) emergency duty
(2) essential service
(3) nonessential service
(4) process service
(5) above or below decks

1.2 Requirements

The unique considerations of a marine gas turbine system include the engine room and above deck environment. Additional considerations are foundations and mounting, sea salt in the inlet air, ship motions and accelerations, load characteristics, wide range of control, noise isolation, and safety.

Marine power plants are also subject to requirements specified by regulatory bodies that review and approve power plant design. In the United States, the regulatory body and classification agencies include the U.S. Coast Guard (USCG) and the American Bureau of Shipping (ABS). Other agencies, representing the international community, are Det Norske Veritas (DNV), Lloyd's Register, and Bureau Veritas (BV). Other bodies may also be taken into consideration.

Marine applications often require that the prime mover drive a hydrodynamic load over a range of speeds, and in both thrust and rotational directions. For electric drive or for an auxiliary power application, the gas turbine may drive a constant speed generator. In some cases, the prime mover may power a propulsor and a generator. In general, the propulsor rotates at a speed much lower than the power turbine speed, so a reduction gear is commonly located between the gas turbine and propulsion load.

To accommodate the range of ship speeds and power requirements, combination plants may be used to improve the power plant performance. The power plant may be configured with two significantly different power levels of available prime movers, such as a lower power base plant and a higher power boost plant. Sometimes a diesel or steam turbine will complement a gas turbine to provide a base/boost combination. Figure 1 illustrates some of these combinations, which have been designated by terms such as COGAG, CODAG, and CODOG. These terms are explained in Fig. 1. The steam turbines shown may utilize steam from heat recovery boilers within the engine exhaust system or separate oil-fired boilers.

For ship service electrical power applications, the configuration is generally similar to shoreside installations wherein the gas turbine is in line with the generator and may be separated by a reduction gear box.

1.3 Configuration

Gas turbines selected for marine uses are often procured with an enclosure and base. The base includes gas turbine mounting provisions that are designed to support the gas turbine, allow for differential thermal movement, and withstand the loads coming from ship motions. The base also serves to mount auxiliary components.

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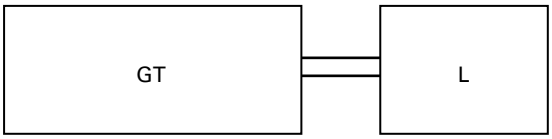
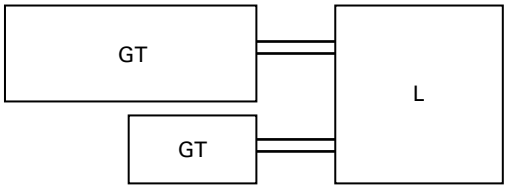
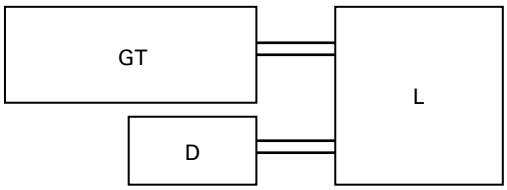


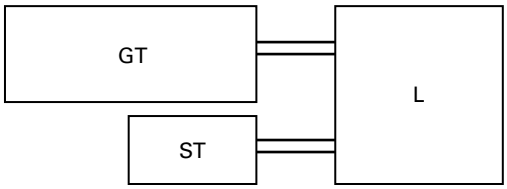
(a) Simple: Gas Turbine or Turbines



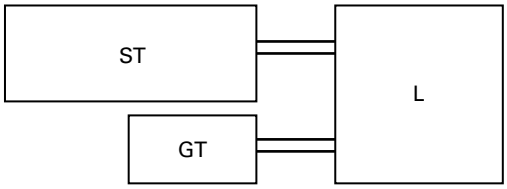
(b) COGAG and COGOG: Gas Turbine and/or Gas Turbine



(c) CODOG and CODAG: Diesel and/or Gas Turbine



(d) COSAG: Steam Turbine and Gas Turbine



(e) COGAS: Gas Turbine and Steam Turbine

D = diesel
GT = gas turbine
L = load
ST = steam

GENERAL NOTE: Size of square indicates relative horsepower.

FIG. 1 PLANT CONFIGURATIONS

The enclosure often serves to channel cooling air around the gas turbine, suppress airborne noise, isolate the gas turbine for safety purposes, and protect the gas turbine from external damage. Its use is optional, depending upon classification codes for unmanned or manned engine rooms. In most cases, an enclosure is recommended for engine room and personnel safety.

A marine gas turbine unit may include modules that are separate from the gas turbine itself, such as lubricating oil modules, a control module, and a maintenance monitoring console. All of these separate units are considered to be a part of the gas turbine system for the purposes of this Standard.

Opposite hand rotation output shaft may be required by the purchaser to provide inboard and outboard shaft rotation for twin screw vessels.

1.4 Scope of Included Equipment

Equipment for which procurement guidance and criteria are provided in this Standard include the following:

(a) gas generator
(b) power turbine
(c) compressor inlet fairing
(d) main fuel control system
(e) monitoring and alarm systems
(f) starter and start system
(g) fuel service and conditioning system
(h) lubrication system
(i) output shaft
(j) exhaust collector and ducting, including flexible joints, silencer, and dampers
(k) inlet barrier screen, silencer, and moisture separator flexible joints and dampers
(l) maintenance monitoring systems
(m) acoustic enclosure
(n) interconnecting piping
(o) interconnecting wiring
(p) base and mount system
(q) fire detection and extinguishing system
(r) icing protective system
(s) air cooling system
(t) regenerator and connecting piping

2 RATING POINTS AND PERFORMANCE GUARANTEES

NOTE: *TBD* means to be defined by mutual agreement of the user and manufacturer.

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2.1 Power Rating

The user shall define the power required from the gas turbine system at a defined output speed under the conditions of para. 2.3.

2.2 Available Power and Specific Fuel Consumption

The manufacturer shall define the specific fuel consumption of the gas turbine system at the power rating in para. 2.1 and the conditions in para. 2.3. If the gas turbine system cannot achieve the power in para. 2.1, the manufacturer shall state the maximum power and the fuel consumption at the conditions in para. 2.3. The specific fuel consumption is defined as fuel mass flow/(power × time) for an engine in new and clean condition.

2.3 Performance Conditions

The performance requirements of paras. 2.1 and 2.2 are based on the following standard conditions set forth by the Society of Naval Architects and Marine Engineers (SNAME) for standard diesel and steam turbine power plants or by the International Organization for Standardization (ISO) for gas turbines.

(a) outside air temperature: 24°C (75°F)
(b) relative humidity: 85%
(c) barometric pressure: 101.32 kPa (760 mm Hg)
(d) customer air bleed: none
(e) inlet total pressure drop: none (measured at the compressor inlet)
(f) exhaust total pressure drop: none (measured at the exhaust collector exit, except regenerative or combined cycle measured at the exhaust gas exit of the regenerator or waste heat recovery boiler)
(g) fuel lower heating value: 42.1 MJ/kg (18,130 Btu/lb)

Other standards can be used if mutually agreed upon by the user and manufacturer.

2.4 Performance Capability

The manufacturer shall state the maximum power capability and the maximum torque capability of the gas turbine system.

2.5 Bleed Air Capability

The user shall define the required mass flow of bleed air from the engine compressor discharge corresponding to a power rating point and a specified engine compressor inlet temperature. The manufacturer shall provide the information in para. 2.2 for the case with and without the defined bleed air.

3 PERFORMANCE

3.1 Duty Cycle

The gas turbine should not require major overhaul at intervals of less than TBD operating hours when operated to the following duty cycle at the performance conditions given in para. 2.3 (or other TBD conditions):

(a) operating hours per year: TBD
(b) starts per 100 hr: TBD
(c) time at maximum installed power (MIP): TBD%
(d) time at TBD% MIP: TBD%
(e) other times at TBD% MIP levels: TBD%

NOTE: Refer to para. 9.2 for overhauls.

3.2 Off-Design Performance

The estimated performance of the gas turbine shall be shown in the manufacturer's curve No. TBD.

3.3 Load Application Rate

The gas turbine system shall be capable of accelerating from idle speed at no load to full speed at rated load in not more than TBD time interval under normal conditions.

3.4 Load Removal Rate

The gas turbine system shall be capable of decelerating from full speed at load to idle speed at no load in not more than TBD time interval under normal conditions and maintain combustion stability.

3.5 Stalled Torque and Idle Power

The estimated maximum stalled torque and horsepower at the idle condition shall be determined by the manufacturer and provided to the user.

3.6 Starting

The gas turbine shall be capable of accelerating from starter actuation to idle speed within TBD time interval.

3.7 Restart

The gas turbine system shall be capable of restarting within TBD time interval following any shutdown from any power level within the performance capability of

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the gas turbine system. An appropriate cool-down time interval shall be determined by the manufacturer. The start system and fuel purge system shall be capable of six consecutive failed start attempts without rejuvenation of the systems or purge system.

3.8 Motoring Period

The gas turbine may be motored on the starter for a period recommended by the manufacturer to purge the turbine and exhaust ducting of explosive vapors prior to starting and to prevent hot rotor bow.

3.9 Smoke

The gas turbine should operate with a smoke-free exhaust to a standard agreed upon by the manufacturer and user, or international rules for entering and leaving port.

4 FOUNDATION AND MECHANICAL INTERFACES

4.1 Foundation

If supplied, the foundation for a gas turbine in a ship shall be designed to:

(a) transmit the loads from the gas turbine base into the ship's structure;

(b) support the weight of the gas turbine;

(c) alleviate, where possible, through the use of three-point mounting and resilient mounts, excessive hull stiffness requirements to maintain power train alignment (on deck-mounted equipment, three-point mounting is desirable with all metallic, nonflammable anti-vibration pads located between the turbomachinery structure and the deck);

(d) accommodate thermal deflection due to heat from the gas turbine;

(e) maintain forces on interfacing piping and duct connections below the maximums specified by the gas turbine manufacturer under all conditions of gas turbine movement due to thermal growth, ship motions, etc.;

(f) avoid undesirable vibratory resonances involving the ship's structure;

(g) when required, provide for convenient removal of the gas turbine or major components for maintenance and repair. The removal tooling must be certified for use when the vessel is pitching and rolling or when maintenance is required when the vessel is either out of trim or is listing. The tooling must be equipped with suitable parking attachments to prevent machinery damage when the tool is in the stowed position;

(h) minimize noise transmission into adjacent compartments.

4.2 Gas Turbine Mounting

Gas turbines shall be provided with a suitable base that may be mounted solidly to the ship. If required, the gas turbine may be soft-mounted utilizing a distributed isolation material unit of low natural frequency capable of attenuating high frequency gas turbine structure-borne vibration. The selected natural frequency of the isolation material must take into account the frequencies noted in para. 4.3. In the case of military vessels, MIL-C-901 must be accounted for. In commercial fast vessels, the class society minimums are to be taken into account.

4.3 Structural Design

(a) Wherever possible, foundations shall be designed to take advantage of support points in the ship structure, such as bulkheads, floors, longitudinals, and stanchions. The foundation should not be directly attached to any adjacent ship structure that might transmit external forces into the foundation. Accommodation for hull distortion should be made in the design. Foundation member sizes should be sufficient to maintain stresses below allowable levels under both maximum static and inertia loads. The manufacturer shall provide the following information:

(1) accurate weight and center-of-gravity data;

(2) moment of inertia and product of inertia for gas turbine on its bedplate in three mutually perpendicular directions.

(b) Foundations shall be designed to avoid resonances between parts of the gas turbine foundation system and any of the following forcing frequencies:

(1) hull natural frequencies;

(2) propeller shaft natural frequencies:

(a) lateral;

(b) longitudinal;

(c) torsional;

(3) propeller blade passing frequencies;

(4) dominant frequencies of the gas turbine;

(5) dominant frequencies of adjacent equipment including reduction gear assembly. A comprehensive vibration analysis is recommended;

(6) wind wave frequencies, taking into account the vessel's maximum speed into oncoming seas.

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4.4 Alignment and Chocking

The criteria for aligning the gas turbine to the driven equipment shall be developed by the ship designer in cooperation with the gas turbine and driven equipment manufacturer. The location of the ship (on dock, in water) and status of the construction when alignment is carried out should be defined. Consideration must be given to allowable forces and moments at the intake duct, the exhaust duct, as well as piping and electrical connections. Foundation and equipment thermal growths must be considered. The alignment criteria to be utilized at the duct connections must be developed with the cooperation of the duct designer and the manufacturer.

The foundation mounting surface should be large enough to accommodate tolerance buildup that occurs between the gas turbine, power turbine output shaft centerline, and the bedplate mounting surfaces, as well as the shipbuilder's tolerances necessary in the manufacture and installation of the foundation.

Where alignment must be maintained by the foundation bolting, fitted foundation hold-down bolting must be used and the holes reamed with the coupled parts in position. Sufficient fitted bolts should be utilized in the foundation in order to assure maintenance of alignment. Collision chocks are to be installed fore and aft of the machinery mountings, taking into account the vessel builder's maximum shock value.

5 AIR INTAKES

5.1 General

The user is generally responsible for the design of the air intake system. The gas turbine intake system shall be designed to draw compressor inlet and cooling air from the atmosphere and direct it to the intake point at the compressor or gas turbine module. The system shall provide air to the gas turbine relatively free of sea salt, dust, and/or seawater particles larger than TBD micron at the required performance and at the intake system flow conditions agreed upon with the manufacturer. The system must also attenuate gas turbine noise to an acceptable level. The inlet system should protect the gas turbine and ducting in icing conditions.

5.2 Separate Ducts

When required, a separate intake system should be provided for each gas turbine.

5.3 Location of Intakes

The entrance to the intake system should be located such that gases exiting from exhaust ducts are not drawn into the intake under most expected conditions of stack velocity, wind velocity and direction, or ship speed. Oil vents, incinerator exhausts, and similar discharges should be located so that their discharges cannot be drawn into the intake system under expected conditions. If anti-icing requires mixing of the exhaust flow with the inlet air flow, this should be done with care. Provision should be made to protect the intake duct from implosion in case the upstream portion of the intake becomes clogged.

5.4 Duct Design

The duct size will generally be determined by the maximum allowable pressure loss in the intake system. The manufacturer shall provide information relative to the loss of gas turbine efficiency due to pressure drop. The inlet duct should be designed, where required, to permit gas turbine removal. Removal may take place in separate units, i.e., gas generator and power turbine.

Pressure variations across the face of the compressor must be minimized to provide satisfactory gas turbine performance and to reduce the possibility of induced vibration of the compressor blading. Limitations on pressure and velocity distribution across the face of the compressor can be obtained from the manufacturer.

Necessary characteristics of inlet ducts are:

(a) adequate drainage
(b) no shelves to collect foreign matter
(c) access for inspection
(d) corrosion resistant
(e) pressure tight
(f) no internal fasteners that can come loose

When required, acoustic treatment should be installed on the outside of the duct. Protected lighting fixtures may also be desirable additional features.

Provision should be made to protect the gas turbine from damage by foreign objects. Depending on the design of the inlet system, a screen at the compressor inlet can be considered. The acoustic lining of the duct and its fasteners should also be designed to minimize the possibility of any part coming adrift. Any possibility of peeling or flaking of the interior coatings should be avoided.

5.5 Sea Salt and/or Dust Separators

Sea salt separators should be provided in the gas turbine inlet system to reduce salt/dust ingestion to a

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minimum. A multistage separator system may be required to first take out the large droplets, then the fine particles, and finally to take out any possible reentrainment for coalesced droplets.

5.6 Cooling Air Ducts

Cooling air ducts that supply cooling air to gas turbine components within the gas turbine enclosure should contain sea salt separators and measures for noise attenuation treatment. The noise attenuation treatment may be different from the combustion air intake duct, since the noise to be attenuated is radiating from the gas turbine casing rather than the compressor inlet. The cooling of the gas turbine may be by fans forcing air into a module, by fans drawing air from the module, or by exhaust-driven eductor drawing air from the module. The cooling fans may be required to operate during the cool-down cycle of the gas turbine.

5.7 Anti-Icing

For vessels designed to operate in an environment in which icing could occur, it is desirable that the intake system include provisions for anti-icing. Anti-icing provisions shall include consideration of icing fog, sleet, snow, and freezing spray or rain environments that may be expected in the particular marine application.

5.8 Emergency Air Inlets

When required, provision shall be made for automatic-opening emergency air inlets to the gas turbine in case of blockage of the regular inlet ducts.

5.9 Silencers

Silencers may be required in the inlet duct to reduce the airborne noise level on deck to an acceptable sound level at the nearest manned position. When required, the silencers should be removable to permit gas turbine removal.

5.10 Flexibility and Support

Provision shall be included in the duct design to accommodate thermal expansion growth. The ducting must also provide for relative movement between turbine and deck, and whether the turbine is mounted on resilient mounts that will cause further relative movement. The duct support immediately upstream of the gas turbine should be arranged so that loading imposed by the ducting on the gas turbine is within the limits specified by the manufacturer, taking into account all forces as noted herein.

Supports for the ducting should be provided as required to maintain the integrity of the intake system and positioned to provide the required system flexibility.

5.11 Testing

Tests may be performed to prove that the inlet velocity and pressure distribution at the compressor are acceptable, and also that pressure losses and flows at various points in the system are as expected and acceptable to the manufacturer. A model test for the above, as well as to measure inlet salt spray ingestion, may be required.

Pressure tests may be required on the ducting after installation in the ship to determine that tightness is adequate.

6 EXHAUST

6.1 General

The user is generally responsible for the design of the exhaust system. The gas turbine exhaust system shall accept high-temperature exhaust gas from the gas turbine and direct it safely to atmosphere. The system must be designed for the temperatures involved and to a pressure loss at the design point agreed upon by the manufacturer. The system should attenuate noise to the extent required for the installation, and direct the discharge of the high-temperature gas to a safe location and direction for mixing with and cooling by the atmosphere.

6.2 Separate Ducts

When required, a separate uptake system should be provided for each gas turbine.

6.3 Location of Exhaust

Exhaust ducts should be located and designed so that the exhaust gases do not overheat adjacent equipment or nearby structure. The maximum stack exhaust temperature may be specified by the user. This is subject to agreement between the user and the manufacturer.

The dimensions of the ship stack, sufficient exhaust velocity, and the stack configuration should, with the ship superstructure involved, keep exhaust gas off the deck and away from ship ventilation intakes and gas turbine intakes.

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6.4 Duct Design

The duct should be sized to meet the pressure drop agreed upon with the manufacturer, and configured to provide desirable flow conditions at the gas turbine exhaust connection and an exhaust velocity consistent with avoidance of impingement of the gas on ship's equipment or personnel.

An exhaust silencer, if required to meet the noise limitation of the installation, must be designed for the high temperatures involved. Where required, acoustic and thermal insulation should be installed on the outside of the duct.

Necessary characteristics of exhaust ducts are:

(a) adequate drainage;

(b) no shelves to collect foreign matter;

(c) access for inspection;

(d) corrosion resistant;

(e) pressure tight;

(f) no internal fasteners that can come loose.

Exhaust covers may be required for long periods of shutdown. Suitable provisions must be made to prevent personnel from getting into contact with hot surfaces.

6.5 Flexibility and Support

The high temperatures involved in the exhaust ducting require careful consideration of duct flexibility and support. Suitable provision must be made to allow for movements between the uptake system and the ship structure arising from thermal expansion or ship movement in a seaway.

The supports for the ducts and its components must be designed to minimize the transmission of heat and noise from the duct to the ship structure.

6.6 Stack Gas Cooling

In some applications, it may be required that the stack gas temperature be controlled.

6.7 Testing

Model tests may be required on the stack/ship structure arrangement to ensure exhaust gas mixing does not impinge on the deck, ship's equipment, or personnel locations. The gas turbine air intakes and ship ventilation intakes may be simulated. This test should also simulate winds of varying velocities and directions. After construction, the exhaust system may be pressure tested to obtain assurance of tightness.

7 HEAT RECOVERY DEVICES

Marine gas turbine installations can include waste heat recovery devices. Regenerators are commonly utilized to improve gas turbine fuel rate by preheating the combustion gas. Waste heat hot water heaters or steam generators (boilers) are also utilized. The energy in the waste heat of the exhaust gas in some cases is sufficient to make it desirable as a secondary energy source (for example, a plant using a steam turbine in combination with the gas turbine). Waste heat recovery devices, except regenerators, require control to maintain design output characteristics under conditions of variable demand and variable heat input from the gas turbine. This can involve the bypassing of exhaust gas around the heat exchanger in ducts equipped with dampers or by dumping unused steam into an oversized condenser. The controls are usually provided by the manufacturer of the waste heat recovery device. The effects of the waste heat system on the gas turbine performance require careful consideration, especially exhaust system pressure loss. The allowable pressure loss shall be specified by mutual agreement of the user and manufacturer.

8 ENVIRONMENT

8.1 General

The gas turbine must be designed and constructed to operate satisfactorily in a marine environment as defined by the following paragraphs. The operating environment must be specified in the data sheets in Appendices 1 and 2.

8.2 Temperature, Pressure, Humidity, and Sea Salt

The following paragraphs present expected marine environment parameters. The latest revision of the IMO codes shall prevail where local codes as defined below are deficient.

8.2.1 Temperature. Depending on where a vessel might be routed, the marine gas turbine may be designed for inlet compressor and cooling air temperature extremes of −40°F (−40°C) to 114°F (46°C) as agreed with the user. Equipment associated with gas turbine operation, such as fuel controls, torque limiters, and other control and monitoring equipment not located inside the gas turbine or gas turbine module, and not subjected to cooling air flow may be designed for a temperature range of 32°F (0°C) to 120°F (49°C) in

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operation as agreed with the user. These types of equipment should also be designed for the full range of air temperature in the secured state.

8.2.2 Pressure. The manufacturer and the shipbuilder must agree upon the pressures and the range of pressures to be used as the design point.

8.2.3 Humidity. The gas turbine should operate satisfactorily when subjected to relative humidity of 0–100%. Some control systems cannot meet the 0% relative humidity requirements. In such cases, specific relative humidity limits should be agreed upon between the manufacturer and the user.

8.2.4 Sea Salt in the Atmosphere. The marine atmosphere will contain sea salts. The manufacturer and the user shall agree on the limits of sea salt acceptable to the gas turbine, and that an intake system and cooling system are designed to meet these requirements.

8.3 Seawater Cooling

Seawater cooling is generally utilized for cooling the gas turbine lubricating oil systems. Where required, this may be accomplished through the use of secondary cooling loops to avoid high metal temperatures on the seawater side of the heat exchangers. The materials in all components of the cooling systems should be designed for the use of seawater to avoid corrosion.

8.4 Steady-State Attitudes

The following steady-state attitudes should be specified by the user and agreed to by the manufacturer:

(a) rake
(b) list and trim

8.5 Motions and Accelerations

The following maximum and normal motion and acceleration values and natural periods should be defined by the user and agreed to by the manufacturer:

(a) pitch
(b) roll
(c) heave

The gas turbine and its associated equipment shall be designed to withstand these accelerations in any combination, including simultaneous imposition of all three.

Depending upon the service class of the machinery, i.e., for essential service and emergency service, the IMO code defines the minimum requirements.

For high speed and light craft, the minimum shock values and periods per Appendix 1 should be taken into account. The cyclic events of the shock should be agreed upon with the supplier and the builder, together with the class society.

8.6 Vibration

The following forcing frequencies exist in gas turbine ship applications:

(a) hull natural frequencies
(b) propeller shaft natural frequencies
  (1) lateral
  (2) longitudinal
  (3) torsional
(c) propeller blade passing frequency
(d) gear frequencies
(e) other uncommon conditions, such as those caused by ice milling and grounding

The gas turbine and associated mounting system (including resilient mounts if provided) and associated equipment must withstand the environmental vibration amplitudes and frequencies to be expected. The expected amplitudes and frequencies shall be provided by the user or his/her agent. See para. 4.3.

9 LIFE AND RELIABILITY

9.1 Availability

The manufacturer shall provide data to demonstrate the expected operational availability goal of TBD when operated to the duty cycle of para. 3.1. *Operational availability* is defined as time the gas turbine was available divided by the desired usage time in the same period.

9.2 Overhauls

The gas turbine shall be designed to achieve TBD hours of operation between overhauls, when operated to the duty cycle set forth in para. 3.1. Since gas turbine designs vary considerably, some may require their maintenance work to be done on board while others may require their work to be done in a shoreside facility. The scope of work covered under the definition of overhaul varies considerably from manufacturer to manufacturer. Therefore, the user should investigate this area thoroughly with the manufacturer.

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10 MAINTENANCE

10.1 Scheduled (Preventive) Maintenance

Whenever possible, the major overhaul period shall coincide with the normal ship inspection or as required by the classification agency or regulatory body. The average elapsed times and frequency of scheduled maintenance should be stated by the manufacturer.

10.2 Maintenance Access

Wherever practical, the arrangement of components should be such that inspection, replacement, or adjustment is possible without removal of or damage to adjacent parts. All parts or components should be readily accessible for replacement or repair.

10.3 Gas Path Cleaning

The gas turbine should have provisions for gas path inspection and cleaning for removing contamination. Design should be such that it will not be necessary to remove any components or accessories during the cleaning operation. A low-speed shaft-turning system should be capable of rotating the turbine above a specified RPM for a minimum period to be determined by the manufacturer. The manufacturer should specify cleaning materials, quantities, and guidelines for frequency of cleaning, and supply definitive instructions.

10.4 Gas Turbine

If the gas turbine's maintenance program includes gas turbine change out, then the gas turbine shall be designed for gas turbine removal from the ship's engine room in total or by major assemblies as required. The engine room should be designed for removal of the gas turbines in a period of not less than TBD hours.

10.5 Maintenance Monitoring

An instrumentation/data system to measure key gas turbine performance and vibration parameters, and provide diagnosis of the gas turbine's maintenance needs, should be considered as an option by the user, if available (see also para. 12.3).

If included in the purchase, the maintenance monitoring system can be specified to base its diagnosis on:

(a) vibration measurements made at key points within the gas turbine system by comparing current measurements with baseline data established for the gas turbine and its components;

(b) pressure, temperature, torque, and speed measurements made at key points within the gas turbine and processed for the purpose of determining significant changes in component performance within the gas turbine;

(c) correlation of other gas turbine parameters.

The output of the system shall be performance and vibration trends that can be correlated to maintenance needs.

The makeup of the instrumentation and data processing program should be agreed upon by the user and manufacturer.

10.6 Spare Parts

Spare parts shall be provisioned according to classification society rules for shipboard power plants. Components of the controls, accessories, and gas turbine itself may be included in provisioning.

10.7 Technical Manuals

Technical manuals shall be provided to guide the scheduled and unscheduled maintenance activities for the gas turbine (see para. 18.1).

10.8 Training

The manufacturer may provide training for the use and maintenance of the gas turbine, associated controls, and accessory system at the option of the user.

10.9 Field Support

The manufacturer shall provide field support for the gas turbine during trials and tests according to para. 17.8. Any additional field support shall be at the option of the user over and above support required under the warranty and guarantee provisions of the contract.

11 PLANT PROTECTION AND SAFETY

11.1 Controls and Alarms

The gas turbine and its controls should include additional plant protection and safety features for the marine application over and above the normal protective features used in shore-based installations. In addition, both ABS and USCG have very specific rules and regulations regarding plant protection and safety that must be met. It is recommended that the gas turbine be shut down if set points are exceeded on the following parameters:

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(a) turbine inlet or exhaust temperatures[1]
(b) gas generator RPM
(c) power turbine RPM
(d) engine vibration level measured at either the gas generator or at the power turbine[1]
(e) torque over the maximum allowable, if required[1]
(f) excessive lube oil temperatures, if required[1]
(g) insufficient fuel oil pressure, if required[1]
(h) insufficient lube oil pressure
(i) insufficient cooling air, if required[1]
(j) loss of flame, if required
(k) enclosure fire, if required

The selection of alarms and shutdown criteria set points on all of these parameters should be determined by mutual agreement of the manufacturer and user.

Specific turbine designs may require additions or deletions from the above listings. The IMO code defines the minimum and maximum alarms and shutdowns permitted for high speed and light craft for propulsion machinery.

11.2 Fire Protection

Where the gas turbine is supplied with an enclosure, provision shall be made for fire detection and control within the enclosure. The manufacturer shall provide details of the design consistent with specified regulations.

11.3 Mechanical Safety

The enclosure should be designed to contain any blade failure fragments so that fragments do not penetrate into the engine room spaces in the event that the gas turbine casings are not so designed.

It is recommended that a comprehensive hazard analysis be undertaken for each marine installation so that hazards may be identified and addressed on a case-by-case basis.

12 CONTROLS/INSTRUMENTATION

The marine gas turbine application is unique compared to industrial and utility applications in that the speed and load requirements may vary over a wide range of operation. The engine may be started and stopped on short notice, the plant accelerated and decelerated upon demand, and the unit held at constant RPM for a generator drive or while the plant propulsor is stopped and reversed. If so specified by the user, the gas turbine controls shall be compatible and integrated with the ship controls systems. The plant shall be controlled to ensure safe operation during all of these maneuvers and operations. Means should also be provided to prevent loss of power due to auxiliary failures or malfunctions, or to operate through with a temporary power loss.

In general, the operator interface is located at two or more stations so that extra complexity may exist in the total control system. Users prefer to operate with a minimum crew size, making automation a necessity in the control system. Regulatory body and classification societies (ABS and USCG) have established rules and control requirements for unmanned machinery space operations that shall be complied with.

12.1 Control Location

The marine prime mover gas turbine may be controlled from the ship's bridge (pilothouse) or a central control station or engineering operating station (EOS).

At the option of the user, an additional local control station may be located in the engine room. The EOS is the location for the data recording (data logged) if supplied. Bridge wing control of the power plant speed and direction is available at the option of the user. The EOS may also be the control center for the ship service generators.

12.2 Control Functions and Equipment

(a) The control system shall include the following functions in a manner that is compatible with the ship control system:

(1) automatic sequencing for start and shutdown of turbine;

(2) power control or shaft speed control as commanded by the control lever or power demand. Load control may be integrated with the gas turbine control;

(3) clutch and brake control, if required;

(4) optional bleed airflow control (on/off, regulation);

(5) plant protection;

(6) maintenance functions (such as water washing);

(7) selection of fuel (if required);

(8) provisions for integration with other propulsion or power system components (such as CP propeller, clutches, brakes, etc.);

(9) speed limiting;

(10) torque limiting;

(11) temperature limiting.

[1] It may be more desirable to automatically sound an alarm or reduce or limit power, rather than shut down.

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(b) The gas turbine system propulsion load may be varied in a preprogrammed schedule during maneuvering (including reversing and stopping).

(c) RPM control is often specified for propulsion systems as a method of establishing ship speed. Power control may be used in lieu of speed control to avoid gas turbine cycling (hunting) in sea states above TBD. The accuracy of the RPM control is TBD dependent upon sea state.

(d) The output shaft may be braked and stopped with the power turbine brake or an output shaft brake in a specified time period.

(e) The brake may also be used to hold one power turbine while other turbines are operating through the gear box.

(f) The gas turbine may be required to go through certain preprogrammed automatic and manual power level changes as the plant accomplishes the following status changes:

(1) standby to ready/ready to standby;

(2) ready to part or full ahead/part or full ahead to standby;

(3) ahead to astern (full or part);

(4) bring on line or drop off line additional gas turbines as required;

(5) ahead/astern to stop shaft.

(g) For power generation applications, the RPM is constant and power output is controlled.

12.3 Instrumentation and Data Acquisition

Adequate instrumentation to allow the operator to ascertain the operating condition of the gas turbine and its supporting auxiliary equipment shall be supplied. In addition, sufficient instrumentation shall be provided to allow the operator to rapidly diagnose equipment malfunctions. Gas turbine requirements will vary, depending on type, and the manufacturer should be consulted. Classification societies (ABS and USCG) have specific minimum requirements that shall be complied with in all cases.

At the option of the user, an automatic data and alarm logging system may be included.

12.4 Control Systems Integration

The shipbuilder has responsibility for integration of the propulsion system control. The manufacturer shall supply the builder with adequate and sufficient data and distributions of the equipment supplied so that the builder may properly discharge his/her responsibilities. With mutual agreement of the builder and manufacturer, the builder may delegate selected portions of this system design and manufacture to the equipment suppliers. A simulation analysis of the propulsion power plant together with the controls is recommended.

12.5 Manual Operation

At the user's option, manual controls of the gas turbine shall be provided at an engine room operating station. Local monitoring of the gas turbine parameters shall be provided as necessary. The manual controls shall include manual start–stop sequences and manual control of the fuel control.

12.6 Torque Limiter

A torque limiter shall be supplied to protect the transmission system at all control stations. The torque limiter shall limit the actual turbine output torque to TBD percent above the nominal maximum output shaft torque. The limit set points for the limiter may be adjustable only by the machinery's suppliers at their recommendation.

12.7 Manning

The number, types, and location of personnel for the control and operation of the propulsion and auxiliary power plant shall be specified by the owner as part of the requirements and background for the design. Applicable local and international regulations shall be followed as appropriate for the vessel's ownership and flag.

12.8 Human Engineering

The shipboard environment shall be accounted for in the human engineering aspects of the design of the control equipment consoles and their location within the control rooms. Flashing lamps and audible alarms shall be provided to indicate any equipment malfunctions.

13 FUEL AND FUEL SYSTEMS

13.1 General

The primary requirement for shipboard fuel systems is to provide clean fuel, at the appropriate pressure and temperature, to the gas turbine, free of seawater and contaminants. The type of fuel to be utilized shall be established by the user and approved by the manufacturer.

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13.2 Pumps

The fuel pumps should be constructed of materials compatible with the fuel to be utilized. They should be sized to meet the fuel requirements of the gas turbine and any ship auxiliary equipment driven by devices running on fuel oil. The capacity should include margins for wear, leakage, and gas turbine acceleration.

13.3 Transfer System

Fuel oil is usually stored in the storage tanks after being delivered to the ship. The fuel oil transfer system transfers oil from the storage tank and delivers it to the service tanks. The transfer system is commonly arranged, and equipment sized, so that oil can be delivered to the service tanks at a rate of two to four times the rate of the fuel being used by the ship at full power.

The system is arranged to draw oil from any storage tank through a strainer to the transfer pump, to a purifier or fuel treatment system, and then to the service tank. The strainer and purifier provide the first level of contaminant and seawater removal. The fuel should be tested at the purifier. A fuel treatment system is usually required for systems designed for heavy fuels.

13.4 Service System

The service system forwards fuel oil from the service tank and delivers it to the gas turbine at the required temperature (viscosity), pressure, and quality. Pumps, prefilters, filter separators, and thermostatically controlled heaters (if necessary) should be included in the system in accordance with classification society and regulatory body rules. The manufacturer should be consulted regarding specific requirements.

13.5 Tanks

The fuel storage tanks and the service tanks may be an integral part of the hull. They should be suitably coated internally to prevent corrosion. Tank heating should be provided if required.

13.6 Microbiological Contamination

The use of fuels having significant water content can result in microbiological growth at the water–fuel interface. This growth or slime plugs filters and can cause excessive tank corrosion. Frequent removal of accumulated water at the bottom of the fuel tank can significantly reduce the problems associated with microbial growth. Designing tanks with conical or sloping bottoms can facilitate the draw-off of accumulated water. Treatment of the fuel with chemical biocides will also reduce growth of microorganisms.

13.7 Controls and Valves

Valves with controls must be installed in transfers and service systems. If positive displacement pumps are used (as is customary), the discharge pressure should be controlled by unloading or relief valves. The piping should be arranged so that the oil from the unloading valves is returned to the tank from which fuel is being drawn. Fuel oil heaters should be controlled by throttling the heating medium.

13.8 Filters and Equipment

Equipment utilized in the fuel oil systems should be reliable standard marine-type hardware. The design characteristics for the system shall be established by limitations provided on fuel cleanliness, viscosity, pressure, temperature, etc., by the manufacturer.

13.9 Fuel Treatment

The use of scrubbing, additives, and other treatment to remove dirt and salts, or to inhibit contaminants, may be required to make fuel acceptable for gas turbine use. (A discussion of fuel treatment appears in ASME B133.7M, Gas Turbine Fuels.)

13.10 LNG/LPG Fuel System

Special provisions for utilization of boil-off from LNG/LPG tanks as fuel is required. The shipbuilder and manufacturer shall coordinate closely on gas handling and control equipment to ensure that the requirements of the regulatory bodies and classification societies are met.

14 LUBRICATION SYSTEM

14.1 General

The lubricant to be utilized in the gas turbine lubrication system for the gas turbine may be separate from or combined with the lubrication system for the driven load equipment. In certain cases, the lubrication system of the gas generator may be separate from the power turbine. In general, the lubrication system should be supplied by the gas turbine manufacturer.

The system(s) shall be consistent with ASME B133.3, Procurement Standard for Gas Turbine Auxiliary Equip-

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ment, but for marine applications special considerations should be given by the user and the manufacturer.

14.2 Reservoir

14.2.1 Storage. Lubricant for replenishment of the lubricating system is usually carried on board. It may be stored in bulk storage tanks. Short shelf-life fluids should be stored in cans or drums.

14.2.2 Supply and Sump. The main lube oil supply and sump tanks may be arranged as part of the gas turbine assembly or in the gas turbine foundation as part of the ship's hull or platform floor structure. For systems requiring small capacities, freestanding tanks may be used. In every case, they shall be constructed to meet the manufacturer's requirements for adequate size, materials compatibility, thermal isolation, cleanliness, deaeration systems, and pump suction considerations. They should also be arranged to minimize churning and foaming, and to allow for separation of entrained air.

14.2.3 Gravity. Gravity tanks may be supplied at the option of the user. They should be sized to provide adequate capacity for coast down of the gas turbine and the driven equipment where required.

14.2.4 Location. The various reservoirs (or tanks) and the lubricant storage should be located and configured in the ship to minimize condensation and the introduction of water into the lubricant and the reservoirs.

14.3 Pumps

The combinations of supply pumps and scavenger pumps (if required) shall be agreed upon by the user and the manufacturer where optional configurations are available. The appropriate redundancy shall be in accordance with classification society rules. Pump construction shall be compatible with the lubricant.

14.4 Coolers

Materials used in coolers shall be compatible with the coolant and the lubricant to be used. Normally seawater can be used, but when salting of the cooler is a problem (metal temperatures on the seawater side of 160 to 180°F), secondary freshwater or main reduction gear oil should be considered. Single or dual full-size coolers may be utilized.

14.5 Filters

The main filters should be of the dual type without automatic bypass.

14.6 Regulation

Suitable devices should be provided to maintain the lubricant at the required pressure and temperature.

The temperature may be controlled by a thermostatic three-way valve in a lubricant bypass around the cooler or by a thermostatically controlled throttle valve in the coolant discharge. The lubricant pressure should be at a higher pressure than the coolant pressure.

The pressure in the lubrication system should be controlled by relief valves, throttling control valves, or combinations of the two. Throttling valves shall be configured with a bypass so the flow of lubricant shall not be interrupted by a valve malfunction.

14.7 Purifiers

Normally it has not been necessary to include purifiers or coalescers with gas turbine lubricating systems. By mutual agreement, they can be supplied. When a transfer system is furnished to transport the lubricant from the storage to the supply or sump, a filter shall be included of the same type and rating as the main filter (see para. 14.5).

15 ELECTRICAL

15.1 Interfaces

The electrical interfaces to the gas turbine shall be mutually defined by the manufacturer and the shipbuilder.

15.2 Electromagnetic Radiation

Requirements pertaining to electromagnetic radiation are set forth in the following paragraphs.

15.2.1 Bonding and Grounding. Bonding and grounding of the gas turbine and its associated equipment shall be in accordance with appropriate standards.

15.2.2 Electromagnetic Interference (EMI). Components such as instrumentation, actuators, and electronics shall be self-compatible and compatible with associated peripheral equipment to the extent that switching functions and internally generated noise shall not cause inadvertent alarms, false signals, false data logging, or perturbations in the control system.

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15.3 Electrical Load Requirements

The electrical power requirements shall be compatible with industry standards for power sources. The electrical power requirements shall be specified as follows:

(a) component: TBD
(b) starting: TBD
(c) pre-start idle and above: TBD
(d) cool down: TBD
(e) shutdown: TBD

A backup power source may be desirable to keep the cooling fans operating if there is a ship power failure.

15.4 Electrical and Electronic Equipment

All electrical equipment and parts shall be built to industry standards and the requirements of IMO codes, IEC, and NEC as appropriate for the vessel's ownership and flag. The magnetic, insulation, and dielectric characteristics shall be to existing standards. The relays, semiconductors, integrated circuits, switches, and converters shall be to industry standards.

16 AIRBORNE AND STRUCTURE-BORNE NOISE

16.1 Airborne Noise

The gas turbine in marine applications is usually located in an engine room where people may be working on an intermittent basis. Engine room acceptable airborne noise levels for the gas turbine system are established by the user with consideration of crew time exposure (hearing loss criteria) and crew function (speech interference) within the space, and by noise requirements in adjacent spaces. Adjacent space requirements are based on crew comfort and speech intelligibility considerations that are much more severe. Three basic sources must be considered in setting the allowable component noise levels, including inlet, exhaust, and casing noise, in specifying airborne noise requirements for the gas turbine. Allocations to each of these sources take into account permissible turbine noise in the engine room, adjacent space requirements (in particular, spaces adjacent to inlet and exhaust duct work), insertion loss of inlet and exhaust duct work and/or silencers, and insertion loss of the gas turbine enclosure.

On deck, inlet and exhaust airborne noise levels are set primarily by speech interference criteria. A typical requirement would define the allowable noise level at a specified distance from the inlet or exhaust. The users should set these requirements. It is suggested that airborne noise levels be determined in accordance with MIL-STD-740B or ANSI S1.13-1995, Measurement of Sound Pressure Levels in Air.

16.2 Structure-Borne Noise

Structure-borne noise or vibration requirements are specified primarily to avoid premature gas turbine failure. As a secondary consideration, gas turbine vibration may be transmitted to hull plating in the engine room or adjacent spaces and radiated, resulting in excessive airborne noise levels. These problems can usually be eliminated by supporting the gas turbine on a massive, stiff (high impedance) foundation, or by resilient mounting. The user should set these requirements.

Structure-borne noise requirements to prevent the possible problems discussed above may consist of acceleration, velocity, or displacement levels in one octave, one-third octave, or other bandwidths. Due to the broadband vibration characteristics of gas turbines, the use of acceleration levels is recommended in determining these requirements. The specified levels shall normally be taken near the mounting points of the gas turbine.

17 QUALITY ASSURANCE

17.1 General

The manufacturer shall accomplish each quality assurance verification defined herein. These verifications shall be accomplished by test, inspection, or analysis employing the manufacturer's own facilities or any acceptable to the user. Most of the quality assurance provisions described herein would be the same as for other applications. However, most of the component tests (acceptance tests) would be accomplished in the manufacturer's facilities. The overall verification of the system is accomplished by sea and dockside trials.

17.2 Test Conformance by Similarity

In lieu of conducting the tests specified in the following paragraphs, the manufacturer can demonstrate compliance by submitting reports on tests conducted on similar components or units. This is subject to mutual agreement of the user and manufacturer.

17.3 Product Examination

The gas turbine system and its components shall be inspected for workmanship and conformance to

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TABLE 1 CROSS-REFERENCE INDEX

Subject	Paragraph No.	Verification Paragraph No.
Product examination	. . .	17.3
Full power rating	2.1	17.7.1
Fuel consumption	2.2	17.7.1
Bleed air	2.5	17.2
Acceleration	3.3	17.7.2
Start	3.6	17.7.3
Restart	3.7	17.7.4
Smoke	3.9	17.2
Vibration	8.6	17.7.5

applicable drawings, specifications, and identification requirements. This final inspection of the system is by the user's representatives and regulatory agencies on board ship.

17.4 Quality Assurance Verifications

The verifications listed in Table 1 shall be accomplished to demonstrate individual product requirements.

17.5 Test Conditions

All tests shall be conducted under existing test conditions and the results corrected to standard conditions. The tests shall be performed in accordance with an appropriate test code mutually agreed upon by the manufacturer and user.

17.6 Instrumentation

The following shall be applicable when calibrating instrumentation.

17.6.1 Calibration of Instruments. All instruments used to obtain physical measurements of subsystem parameters shall be calibrated and certified at periodic intervals to verify instrument accuracy. Standards used for calibration shall be certified and traceable to primary standards of the National Bureau of Standards.

17.6.2 Instrumentation Measurement Accuracy. Accuracy of instrumentation used for parameter measurement shall be within the limits established by mutual agreement of the user and manufacturer.

17.7 Acceptance Tests

The following tests shall be performed as requirements for acceptance.

17.7.1 Maximum Power Rating and Fuel Consumption. Maximum power rating and fuel consumption shall be tested in accordance with the following or by alternative procedures mutually agreed upon by user and manufacturer.

(a) The gas turbine system shall demonstrate capability to operate at various power turbine speeds and loadings per the test schedule established by mutual agreement of the user and manufacturer. Compliance with the required fuel consumption shall also be demonstrated as indicated therein.

(b) Alternatively, performance shall be demonstrated by measuring the isentropic gas horsepower and fuel flow of the gas generator alone using a conical nozzle or power turbine shaft lock instead of a load-absorbing device. Isentropic gas horsepower corresponding to the schedule shall be set. The power turbine shall be tested without load to assure absence of excessive vibration levels.

17.7.2 Acceleration. The gas turbine system shall demonstrate the capability to accelerate from idle speed, at no load, to full rated speed as required by para. 3.3.

17.7.3 Start Test. During the gas turbine testing defined herein, starts shall be demonstrated.

17.7.4 Restart Test. The gas turbine system shall be shut down using the normal shutdown procedure and restarted immediately after coming to rest or to an acceptable restart speed.

17.7.5 Vibration Test. The gas turbine system shall be run according to the schedule indicated, and the vibratory levels (self-generated) shall be determined and verified to be satisfactory.

17.8 Shipboard Trials

The manufacturer shall provide the services of a gas turbine technical representative for each gas turbine system as technical assistance during installation, start-up, and sea trials of the gas turbine system.

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18 DOCUMENTATION AND STANDARDS

18.1 Manuals

Manuals shall be prepared providing concise, accurate instructions for installation, checkout, testing, operation, and maintenance (repair). Manuals should be provided for all accessories and controls, as well as for the gas turbine. Manuals shall reflect the configuration of the hardware precisely and shall be prepared to the educational level and language capability of shipboard personnel who will actually install, check out, test, operate, and maintain the equipment. Copies shall be supplied to support shipboard use as well as dockside repair facilities.

18.2 Interchangeability

Interchangeability of components shall be provided to the greatest practical extent. All similar parts, including repair parts, shall be interchangeable without additional machining or selective assembly, and with a minimum of hand fitting. As far as practical, equipment that is functionally interchangeable shall be physically, electrically, and mechanically interchangeable.

18.3 Standardization

Wherever feasible, the gas turbine system shall include standardized components, parts, or units that are currently being used by the user or by a group of users.

19 SHIPMENT, STORAGE, AND INSTALLATION

19.1 Shipment

The following minimum requirements shall pertain in preparation of gas turbine and supporting subsystems and components for shipment. (See also ASME B133.11 for shipping and packing information.)

19.1.1 Receiving and Packaging. All equipment shall be preserved and packaged in a manner to assure that the equipment will reach the user in a satisfactory condition. The packaging should be compatible with a marine environment, since packages will be stored at a seaside dock site. The expected storage time should be 1 year or as determined by the shipbuilder.

The gas turbine may be sealed tight and may be provided with desiccant by the manufacturer. The gas turbine shall remain sealed unless the desiccant indicator reflects humidity of 40% or more.

Items that are easily damaged, installed late in the production cycle, or are easily pilferable should be separately packaged and/or identified.

19.1.2 Marking. All packages, crates, and cartons shall be marked to accurately identify equipment or components contained in the package. Spare parts shall be identified and marked or tagged with the manufacturer's service part number.

The outside of each module shall be marked as follows (or with other appropriate terminology):

MACHINERY — HANDLE CAREFULLY

19.1.3 Container Requirements. All containers and packaging shall be sufficiently strong to provide protection from damage in transit, storage, and handling until completion of delivery to the purchaser. Suitable handling arrangements (handles, pads, strongbacks, etc.) shall be provided to enable the containers to be handled with normal handling gear. Containers shall be provided with humidity control and indicators when required.

19.2 Storage Requirements

The following shall be minimum requirements when preparing gas turbines for storage and during storage.

19.2.1 Gas Turbine Unit. Proper protection from the environment shall be provided to the gas turbine for 1 year or as specified by the user. It must be stored, blocked, and supported in accordance with the manufacturer's instructions. All resilient mounts must be protected from oil, paint, solvents, etc. Regular inspections shall be provided for in the design of the storage container. A salt air environment should be expected during storage.

19.2.2 Other Mechanical Equipment. Other mechanical equipment shall be stored so as to ensure it is protected from damage, dust, other foreign matter, moisture, and salt air according to the manufacturer's instructions. Regular inspections shall be provided for in the storage containers.

19.2.3 Electrical Equipment. All electrical equipment shall be stored in a manner to protect it from damage, dust and other foreign matter, moisture, and salt air according to the manufacturer's instructions. Equipment shall not be subjected to temperatures above or below the designed limits for the equipment. Regular inspections shall be provided for in the storage containers.

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19.3 Instructions

Manuals and instructions providing required information for installing the equipment shall be furnished to the user at the time of delivery. Special requirements for handling, if required, shall be included in the instructions.

20 REGULATORY BODIES

20.1 General

Gas turbine systems for marine applications shall meet all applicable requirements of the U.S. Coast Guard and/or other specified regulatory bodies.

When ABS is the specified regulatory body, all machinery is to be constructed and installed to meet the requirements of that body and bear the stamp acceptable to the surveyor.

When another regulatory body (such as Lloyd's) is specified, all machinery is to be constructed and installed to meet the level of requirements of that body and bear the stamp acceptable to the surveyor.

Additional labels or markings should be specified by the user.

20.2 Material

All material used in gas turbines and auxiliaries shall be in accordance with applicable regulatory body requirements or as specifically approved by them.

20.3 Spare Parts

Spare parts shall be provided according to the standards set by the regulatory bodies for shipboard applications. Additional dockside spares shall be provided according to the requirements established by the user.

20.4 Tests and Trials

All tests and sea trials shall be performed in accordance with applicable regulatory body requirements and witnessed by their representatives. All sea trials shall be conducted in accordance with requirements specified by appropriate regulatory bodies and applicable SNAME trial code. Trials shall be witnessed by representatives of the U.S. Coast Guard and applicable regulatory bodies, as well as the user's representatives. All the results of the sea trials shall be reported in appropriate trial reports as prescribed by the regulatory bodies.

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MANDATORY APPENDIX 1
DATA SHEET FOR GAS TURBINE APPLICATIONS AS PRIME MOVERS FOR PROPULSION ON CRAFTS AND VESSELS

1. High speed and light craft _____

(a) Military _____

(b) Crew/cargo _____

(c) Passenger _____

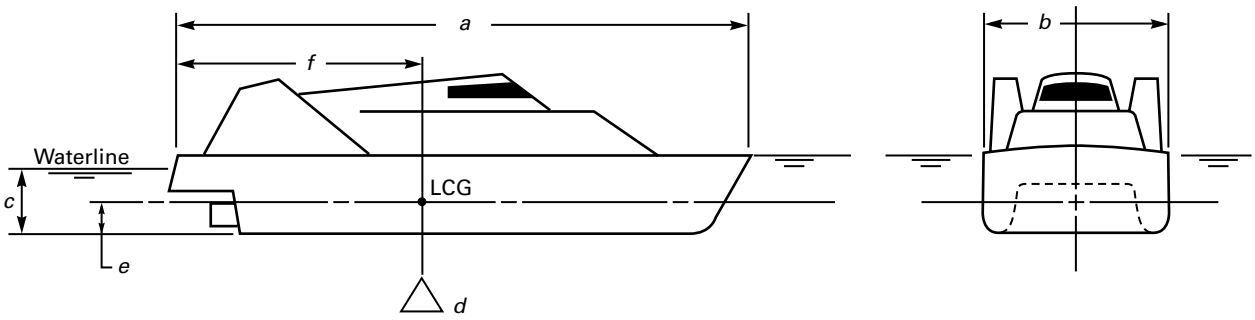
(d) Pilot _____

(e) Monohull _____

(f) Multihull _____

(g) Vessel type (i.e., SES, hydrofoil) _____

2. Vessel specifications:



(a) Length *a* _____ (m or ft)

(b) Breadth *b* _____ (m or ft)

(c) Draught *c* _____ (m or ft)

(d) Displacement *d* _____ max., _____ min. (tonnes or tons)

(e) Distance *e* of axis of roll to keel _____ (m or ft)

(f) Distance *f* of longitudinal position of center of gravity (LCG) from stern _____ (m or ft)

(g) Distance to package from LCG:

X direction _____ (m or ft)

Y direction _____ (m or ft)

Z direction _____ (m or ft)

(h) Maximum speed of vessel _____ knots

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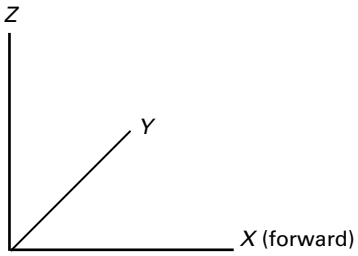
3. Accelerations (m/s^2 or ft/sec^2):



(a) *X* direction _____

(b) *Y* direction _____

(c) *Z* direction _____

(d) Surge _____

(e) Sway _____

4. Design vector combination of accelerations in item 3:

$$= \sqrt{\_\_\_\_^2 + \_\_\_\_^2 + \_\_\_\_^2 + \_\_\_\_^2 + \_\_\_\_^2}$$

5. Is the proposed machinery to be classified as:

(a) Essential service? _____ (yes or no)

(b) Nonessential service? _____ (yes or no)

6. If classified as nonessential service, what is the maximum angle the machinery will be guaranteed to be operated at?

(a) Pitch _____ (deg)

(b) Roll _____ (deg)

(c) Trim _____ (deg)

(d) List _____ (deg)

(e) Is the operation to include simultaneous addition of (a)+(c) and (b)+(d)? _____ (yes or no)

7. What are the dynamic time periods for pitch, roll, sway, and heave for:

	Pitch	Roll	Sway	Heave	
(a) 100 year storm?	_____	_____	_____	_____	(s or sec)
(b) Nonessential service?	_____	_____	_____	_____	(s or sec)

8. What is the angle of twist of the machinery deck in the:

(a) *X* direction for 100 year storm? _____ (deg/m or deg/ft)

(b) *X* direction for nonessential service? _____ (deg/m or deg/ft)

(c) *Y* direction for 100 year storm? _____ (deg/m or deg/ft)

(d) *Y* direction for nonessential service? _____ (deg/m or deg/ft)

9. Customer's desired package axis orientation with respect to vessel longitudinal axis:

(a) Fore and aft _____

(b) Thwart ships _____

10. Additional required information:

(a) General arrangement drawings clearly showing dimensional proposed installation area and restrictions

(b) Name of classification society

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MANDATORY APPENDIX 2
DATA SHEET FOR GAS TURBINE APPLICATIONS FOR POWER GENERATION OR MECHANICAL DRIVE APPLICATIONS ON VESSELS AND PLATFORMS

1. Application:

   (a) Floater/tanker _____

   (b) Semi-submersible platform _____ Type _____

   (c) Barge _____

   (d) Stationary platform (i.e., fixed leg, pitch, and roll = 0 deg) (go directly to item 14) _____

2. Vessel specifications:

   (a) Length _____ (m or ft)

   (b) Breadth _____ (m or ft)

   (c) Draught _____ (m or ft)

   (d) Displacement _____ max., _____ min. (tonnes or tons)

   (e) Distance of axis of roll to keel _____ (m or ft)

   (f) Distance of longitudinal position of center of gravity (LCG) from stern _____ (m or ft)

   (g) Distance to location of equipment from LCG:

      X direction _____ (m or ft)

      Y direction _____ (m or ft)

      Z direction _____ (m or ft)

   (h) Maximum speed of vessel _____ knots

3. Accelerations (m/s^2 or ft/sec^2):

   (a) *X* direction _____

   (b) *Y* direction _____

   (c) *Z* direction _____

   (d) Surge _____

   (e) Sway _____

4. Slamming load (m/s^2 or ft/sec^2):

   (a) *X* direction _____

   (b) *Y* direction _____

   (c) *Z* direction _____

5. Design vector combination of accelerations in item 3: _____

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6. Who will be the classification society for the vessel?

   (a) Lloyd's _____

   (b) DNV _____

   (c) ABS _____

   (d) U.S. Coast Guard _____

   (e) Other _____

7. What will the gas turbine equipment be used for?

   (a) Essential service (equipment that is used to power fire fighting, emergency power, propulsion, steerage, anchorage, and any other services needed for safe operation of the ship) _____

   (b) Nonessential service (equipment that is used to power other shipboard requirements that are part of the shipboard systems but are not essential to the safe operation of the ship) _____

   (c) Process equipment (equipment that is used to power process equipment that is not part of the ship's systems; e.g., CS/MDs and GSs that are used as process equipment) _____

8. What will the equipment need to be certified to?

   (a) DNV classification of ships, main class: essential service

   (b) DNV classification of ships, main class: nonessential service

   (c) DNV classification of ships, additional class: _____

   (d) DNV certified process equipment

   (e) DNV other

   (f) Lloyd's classification of ships, main class: essential service

   (g) Lloyd's classification of ships, main class: nonessential service

   (h) Lloyd's classification of ships, additional class: _____

   (i) Lloyd's certified process equipment

   (j) Lloyd's other

   (k) ABS classification of ships, main class: essential service

   (l) ABS classification of ships, main class: nonessential service

   (m) ABS classification of ships, additional class: _____

   (n) ABS certified process equipment

   (o) ABS other

   (p) Other

   Answer: _____

9. What is the maximum angle that the vessel will see (gas turbine equipment must survive but not operate) if different from the society's minimum requirements?

   (a) Pitch _____ deg; time period _____

   (b) Roll _____ deg; time period _____

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(c) Trim _____ deg (up at bow or up at stern)

(d) List _____ deg

(e) Is the operation to include simultaneous addition of (a)+(c) and (b)+(d)? _____ (yes or no)

10. What is the maximum angle that the gas turbine equipment will be required to operate up to?

(a) Pitch _____ deg; time period _____

(b) Roll _____ deg; time period _____

(c) Trim _____ deg (up at bow or up at stern)

(d) List _____ deg

(e) Is the operation to include simultaneous addition of (a)+(c) and (b)+(d)? _____ (yes or no)

11. Design natural frequency range for the equipment mounting structure _____ Hz

12. Customer's desired package axis orientation with respect to vessel longitudinal axis (recommendation is parallel to ship's axis)?

(a) Parallel to ship's axis _____

(b) Perpendicular to ship's axis _____

13. Additional required information: General arrangement drawings clearly showing dimensions of proposed installation area and restrictions.

14. What is the angle of twist of the machinery deck in the:

(a) *X* direction for 9(a)? _____ (deg/m or deg/ft)

(b) *X* direction for 10(a)? _____ (deg/m or deg/ft)

(c) *Y* direction for 9(a)? _____ (deg/m or deg/ft)

(d) *Y* direction for 10(a)? _____ (deg/m or deg/ft)

15. Who can be contacted for additional information and/or clarification of information provided in this data sheet?

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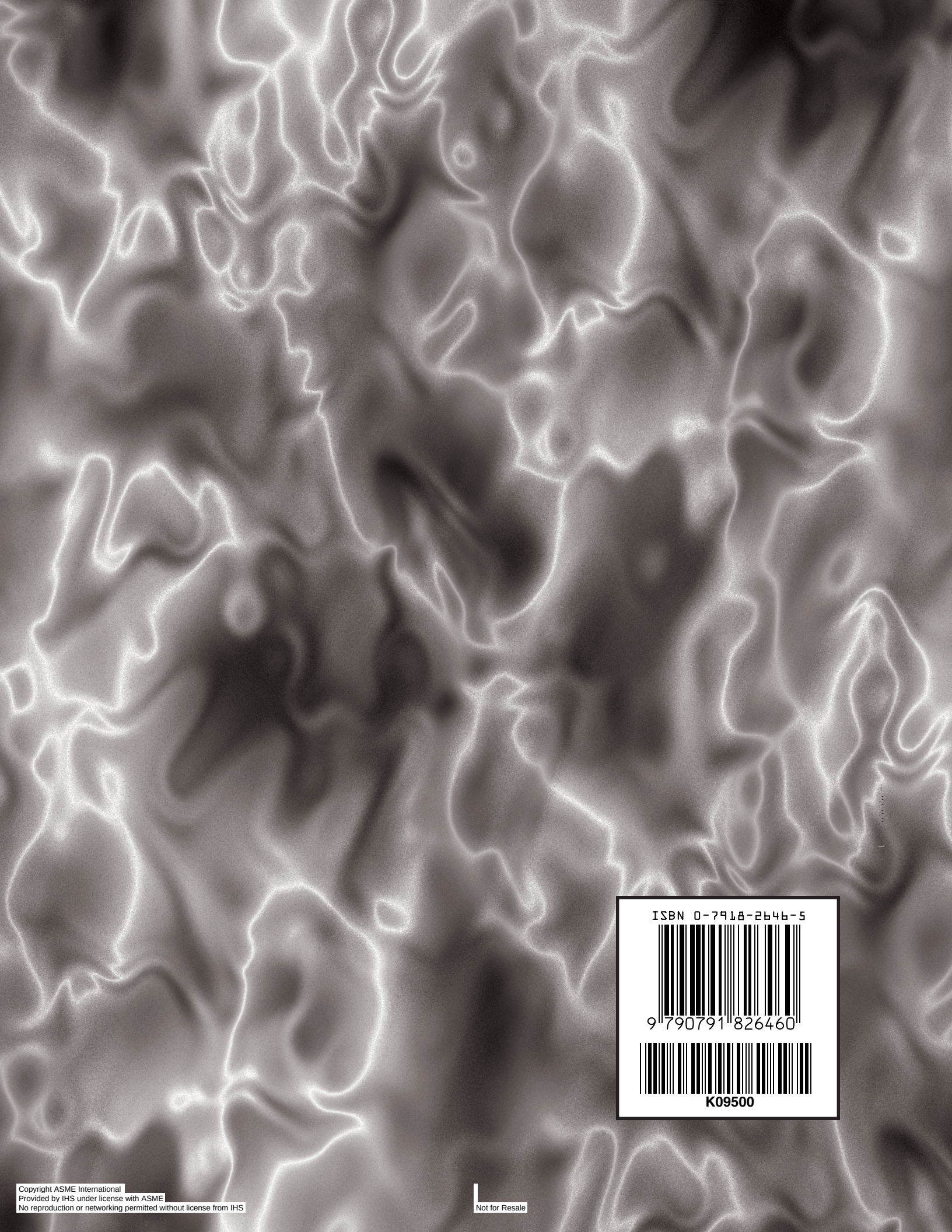

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