Method and Techniques in Geothermal Power Plant Training

# STANDARD OF GEOTHERMAL POWER PLANT DESIGN

Presented by Jooned Hendrarsakti

# TURBINE STANDARD

# API Standard 612:

Petroleum, Petrochemical, and Natural Gas Industries—Steam Turbines—Special-purpose Applications

# ANSI/API STANDARD 612
# SIXTH EDITION, NOVEMBER 2005:

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**SPECIAL-PURPOSE STEAM TURBINE**
**DATA SHEET**
**US CUSTOMARY UNITS**

JOB NO. ____ ITEM NO. ____
REVISION NO. ____ DATE ____
PAGE 4 OF 10 BY ____

1 **BEARINGS AND BEARING HOUSINGS**

| | RADIAL (10.1.1)(10.1.2) | INLET | EXHAUST |
|---|---|---|---|
| 2 | RADIAL (10.1.1)(10.1.2) | INLET | EXHAUST |
| 3 | ☐ TYPE | | |
| 4 | ☐ MANUFACTURER | | |
| 5 | ☐ LENGTH (IN) | | |
| 6 | ☐ SHAFT DIAMETER (IN) | | |
| 7 | ☐ UNIT LOAD (ACT/ALLOW)(PSI) | | |
| 8 | ☐ BASE MATERIAL | | |
| 9 | ☐ BABBIT THICKNESS (IN) | | |
| 10 | ☐ NUMBER OF PADS | | |
| 11 | ☐ LOAD: BETWEEN/ON PAD | | |
| 12 | ☐ PIVOT: CENTER/OFFSET % | | |
| 13 | ☐ ____ | | |
| 14 | ☐ ____ | | |

| THRUST (10.2.1)(10.2.2) | ACTIVE | INACTIVE |
|---|---|---|
| ☐ TYPE | | |
| ☐ MANUFACTURER | | |
| ☐ UNIT LOADING MAX. (psi) | | |
| ☐ UNIT LOAD ULTIMATE (psi) | | |
| ☐ NUMBER OF PADS | | |
| ☐ AREA (IN²) | | |
| ☐ PIVOT: CENTER / OFFSET, % | | |
| ☐ PAD BASE MATERIAL | | |

LUBRICATION: ○ FLOODED ○ DIRECTED
THRUST COLLAR: ○ INTEGRAL ○ REPLACEABLE

15 **BEARING TEMPERATURE DEVICES:**
16 ○ THERMOCOUPLES ○ TYPE ____
17 ○ SELECTOR SWITCH & INDICATOR BY: ____ PURCH ____
18 ○ RESISTANCE TEMPERATURE DETECTORS
19 ○ RESISTANCE MATERIAL ____ ☐ ____ ohm
20 ○ SELECTOR SWITCH & INDICATOR BY: ____ PURCH ____ MFR
21 ○ LOCATION-JOURNAL BEARING
22 TOTAL ____ LOCATION ____
23 SCALE RANGE ____ ALARM SET @ ____ °F
24 SHUTDOWN SET @ ____ °F DELAY ____ s
25 ○ LOCATION-THRUST BEARING
26 ACTIVE SIDE
27 TOTAL ____ LOCATION ____
28 INACTIVE SIDE
29 TOTAL ____ LOCATION ____
30 SCALE RANGE ____ ALARM SET @ ____ °F
31 SHUTDOWN SET @ ____ °F DELAY ____ s
32 ○ MONITOR SUPPLIED BY: ____
33 ○ LOCATION ____ ENCLOSURE ____

**VIBRATION DETECTORS:**
○ TYPE ____ ☐ MODEL ____
○ MANUFACTURER ____
○ NUMBER AT EACH SHAFT BRG ____ TOTAL NUMBER ____
MONITOR SUPPLIED BY ____
○ LOCATION ____ ENCLOSURE ____
○ MFR ____ ☐ MODEL ____
☐ SCALE RANGE ____ ALARM ☐ SET @ ____ mil
○ SHUTDOWN: ☐ SET @ ____ mil ○ DELAY ____ s

**AXIAL POSITION DETECTORS:**
☐ TYPE ____ ☐ MODEL ____
○ MFR ____ ○ NUMBER REQUIRED ____
MONITOR SUPPLIED BY ____
○ LOCATION ____ ENCLOSURE ____
○ MFR ____ ☐ MODEL ____
☐ SCALE RANGE ____ ALARM ☐ SET @ ____ mil
○ SHUTDOWN ☐ SET @ ____ mil ○ DELAY ____ s
○ PROVISION FOR ACCELEROMETER MOUNTED ON BRG HOUSINGS
KEYPHASOR : ○ STEAM TURBINE ○ GEAR ○ DRIVEN EQUIP.

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**Table H.1 — Component inspection**

| Type | Component | Mechanical property analysis | Chemical analysis | Ultrasonic test | Local X-ray test | Test for surface cracks |
|---|---|---|---|---|---|---|
| Forged or rolled components | Wheel discs<br>Shaft<br>Balance pistons | Yes [a] | Product check analysis or cast analysis [a] | Yes | NR | Yes |
| | Stationary blade Carriers<br>Steel casing | Yes [a] | | NR | | Yes [b] |
| | Rotor blades<br>Guide blades | Yes [a] | | NR | | NR |
| Welded components | Wheel discs<br>Stationary blade Carriers | Yes [a] | Yes | If specified [c] | | Yes, in welded areas |
| | Steel casings | Yes [a] | Yes | Yes | Yes [d] | Yes |
| Castings | Steel casings | Yes | Product check analysis or cast analysis [a] | Yes<br>For gauge pressure > 6 200 kPa (62 bar) (900 psi) or temperature > 440 °C (825 °F) | Yes [d]<br>For gauge pressure > 8 600 kPa (86 bar) (1 250 psi) or temperature > 510 °C (950 °F) | Yes (on machined surfaces) |
| | Guide blade carriers | | | Yes | If specified | |
| | Nodular cast iron casings | | | Footnote [c] | | |
| | Lamellar cast iron casings | Footnote [c] | | | | |
| | Rotor blades | Yes [a] | | If specified [c] | Random checks | Footnote [c] |

[a] Per lot.

[b] Typical surface magnetic particle inspection.

[c] The details of testing shall be agreed between purchaser and vendor.

[d] Where practical on larger components.

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## Inspector's checklist

See Table I.1.

**Table I.1 — Inspector's checklist**

| Item | Reference subclause | Reviewed | Observed | Witnessed | Inspected by | Status |
|---|---|---|---|---|---|---|
| **General** | | | | | | |
| Vendor data records | 16.2.1.1 | | | | | |
| Final assembly maintenance and clearances | 16.2.1.1 f) | | | | | |
| Surface and subsurface inspection | 16.2.1.3 | | | | | |
| **Material Inspection** | | | | | | |
| Material inspection certification/testing | 16.2.2 | | | | | |
| **Mechanical Inspection** | | | | | | |
| Stud markings | 7.1.15d) | | | | | |
| Socket clearances | 7.1.15e) | | | | | |
| Equipment feet (vertical and horizontal) jackscrews | 7.1.18<br>15.3.1.2 | | | | | |
| Foot/baseplate shims | 15.3.1.12 | | | | | |
| Nozzle flange dimensions | 7.2.7 | | | | | |
| Casing openings — size/finish | 7.2.3<br>7.2.7 | | | | | |
| Rotor identification | 8.1.3 | | | | | |
| Number of teeth for governor and overspeed shutdown system wheel | 8.4<br>12.2.5 | | | | | |
| Shaft finishes | 8.2.1 | | | | | |
| Shaft electrical and mechanical runout | 8.2.2<br>9.6.9 | | | | | |
| Shaft magnetic flux density | 8.2.5 | | | | | |
| Coupling fit | 8.2.4 | | | | | |
| Rotor balance (balance machine residual) | 9.6.2<br>9.6.5 | | | | | |
| Rotation arrow/nameplate data and units | 6.2.2<br>6.2.3 | | | | | |
| Mounting surfaces coated | 15.3.1.7 | | | | | |
| Mounting surfaces primed | 15.3.1.7 | | | | | |
| [illegible] | [illegible] | | | | | |

# ISO 3529/2 "Vacuum Technology-Vocabulary" Part 2: "Vacuum Pumps and Related Terms"
# 1st. Ed. 1981

**CHARACTERISTIC OF VARIOUS VACUUM PUMPS**

| Type | Operating Pressure* (mm Hg) | Suitability for Suction Gas | | | Note |
|---|---|---|---|---|---|
| | | St'm | Low-Boil'g Gas | Dust | |
| RECIPROCATING<br>One Stage<br>Two Stage | <br>5 - 760<br>$10^{-1}$ - 760 | <br>+<br>+ | <br>+<br>⊕ | ⊕ | Corrosive gases can be handled.<br>Required large<br>Space for installation. |
| NASH<br>(Water seal) | 50 - 760 | + | + | | Suitable for chemical Processes.<br>Consumes much power.<br>Liquid sealed circuit necessary. |
| Roots<br>One stage<br>Two stage | <br>300 - 760<br>100 - 760 | <br>+<br>+ | <br>+<br>+ | <br>⊕<br>⊕ | <br>Large exhaust volume<br>Consumes much power. |
| Rotary<br>(Oil seal | $10^{-4}$ - 760 | --- | --- | | Low resistance against corrosive gases. |
| Mechanical booster | $10^{-3}$ - 10 | + | ⊕ | ⊕ | Large exhaust volum.<br>Consumes less power.<br>Auxiliary pumps necessary. |

# ANSI/API STANDARD 612
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**Table 3 — Welding requirements**

| Requirement | Applicable code or standard |
|---|---|
| Welder/operator qualification | ASME IX or EN 287 |
| Welding procedure qualification | Applicable material specification or, where weld procedures are not covered by the material specification, ASME IX or EN 288 |
| Non-pressure-retaining structural welding such as baseplates or supports | AWS D1.1 |
| Magnetic particle or liquid penetrant examination of the plate edges | ASME VIII, Division 1, UG-93(d)(3) |
| Post-weld heat-treatment | Applicable material specification or ASME VIII, Division 1, UW 40 |
| Post-weld heat-treatment of casing fabrication welds | Applicable material specification or ASME VIII, Division I |

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- The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.
- ISO 7-1, Pipe threads where pressure-tight joints are made on the threads — Part 1: Dimensions, tolerances and designation.
- ISO 261, ISO general-purpose metric screw threads — General plan
- ISO 262, ISO general-purpose metric screw threads — Selected sizes for screws, bolts and nuts
- ISO 724, ISO general-purpose metric screw threads — Basic dimensions
- ISO 965 (all parts), ISO general-purpose metric screw threads -Tolerances
- ISO 1940-1, Mechanical vibration — Balance quality requirements of rigid rotors — Part 1: Determination of permissible residual unbalance

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- ISO 3744, Acoustics — Determination of sound power levels of noise sources using sound pressure —
- Engineering method in an essentially free field over a reflecting plane
- ISO 7005-1, Metallic flanges — Part 1: Steel flanges
- ISO 7005-2, Metallic flanges — Part 2: Cast iron flanges
- ISO 8068, Petroleum products and lubricants — Petroleum lubricating oils for turbines (categories ISO-L-TSA and ISO-L-TGA) — Specifications
- ISO 8501-1, Preparation of steel substrates before application of paints and related products — Visual assessment of surface cleanliness — Part 1: Rust grades and preparation grades of uncoated steel substrates and of steel substrates after overall removal of previous coatings
- ISO 8821, Mechanical vibration — Balancing — Shaft and fitment key convention

# ANSI/API STANDARD 612
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- ISO 10438 (all parts) , Petroleum and natural gas industries — Lubrication, shaft sealing and control oil systems for special-purpose applications.
- ISO 10441, Petroleum and natural gas industries — Flexible couplings for mechanical power transmission — Special purpose applications
- ISO 13691, Petroleum and natural gas industries — High-speed special-purpose gear units
- ISO 15649, Petroleum and natural gas industries — Piping
- IEC 60045-1, Steam turbines — Part 1: Specifications
- IEC 60072, Dimensions and output series for rotating electrical machines
- IEC 60079, Electrical apparatus for explosive atmospheres
- IEC 60953, Rules for steam turbine thermal acceptance tests
- EN 287, Approval testing of welders — Fusion welding2)
- EN 288, Specification and approval of welding procedures for metallic materials
- API RP 520 PT I, Sizing, selection, and installation of pressure-relieving systems in refineries, Part I — Sizing and selection.
- API RP 520 PT II, Sizing, selection, and installation of pressure-relieving systems in refineries, Part II —

# ANSI/API STANDARD 612
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- API Std 526, Flanged steel pressure relief valves
- API Std 613, Special-purpose gear units for petroleum, chemical and gas industry services
- API Std 670, Machine protection systems
- API Std 671, Special-purpose couplings for petroleum, chemical and gas industry services
- API RP 686 (First edition, April 1996), Recommended Practices for machinery installation and installation design
- ASME, Boiler and pressure vessel code, Section V — Nondestructive examination.
- ASME, Boiler and pressure vessel code, Section VIII — Pressure vessels
- ASME, Boiler and pressure vessel code, Section IX — Qualification standard for welding and brazing
- procedures, welders, brazers, and welding and brazing operators
- ASME B1.1, Unified screw threads (UN and UNR Thread Form)
- ASME B16.1, Cast iron pipe flanges and flanged fittings, Class 25, 125 and 250

# ANSI/API STANDARD 612 SIXTH EDITION, NOVEMBER 2005

- ASME B16.5, Pipe flanges and flanged fittings, NPS 1/2 through NPS 24
- ASME B16.11, Forged fittings, socket-welding and threaded
- ASME B16.42, Ductile iron pipe flanges and flanged fittings, classes 150 and 300
- ASME B16.47, Large diameter steel flanges NPS 26 through NPS 60
- ASME B17.1, Keys and keyseats
- ASME PTC 6, Performance test code 6 on steam turbines
- ASME PTC 20.2, Overspeed trip systems for steam turbine-generator units
- ASTM A 194, Standard specification for carbon and alloy steel nuts for bolts for high-pressure or high- temperature service, or both5)

# ANSI/API STANDARD 612 SIXTH EDITION, NOVEMBER 2005

- ASTM A 247, Standard test method for evaluating the microstructure of graphite in iron castings
- ASTM A 278, Standard specification for gray iron castings for pressure-containing parts for temperatures up to 650 °F (350 °C)
- ASTM A 307, Standard specification for carbon steel bolts and studs, 60 000 psi tensile strength
- ASTM A 395, Standard specification for ferritic ductile iron pressure-retaining castings for use at elevated temperatures
- ASTM A 418, Standard test method for ultrasonic examination of turbine and generator steel rotor forgings

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# SIXTH EDITION, NOVEMBER 2005

- ASTM A 472, Standard test method for heat stability of steam turbine shafts and rotor forgings
- ASTM A 536, Standard specification for ductile iron castings
- AWS D1.1, Structural welding code — Steel
- NEMA SM 23, Steam turbines for mechanical drive service.
- NFPA 70, National electrical code.
- NACE MR0175, Sulfide stress cracking resistant metallic materials for oilfield equipment.
- SSPC-SP6/NACE No. 3, Commercial blast cleaning.

# ANSI/API STANDARD 612
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**Table 1 — Design criteria and specifications for cooling water systems**

| Criteria | SI units | US Customary units |
|---|---|---|
| Water velocity over heat exchanger surfaces | 1,5 m/s to 2,5 m/s | 5 ft/s to 8 ft/s |
| Maximum allowable working pressure, gauge | 700 kPa | 100 psi (7 bar) |
| Test pressure (1,5 MAWP), gauge | 1 050 kPa | 150 psi (10,5 bar) |
| Maximum pressure drop | 100 kPa | 15 psi (1 bar) |
| Maximum inlet temperature | 32 °C | 90 °F |
| Maximum outlet temperature | 49 °C | 120 °F |
| Maximum temperature rise | 17 K | 30 °R |
| Minimum temperature rise | 11 K | 20 °R |
| Fouling factor on water side | 0,32 $m^2 \cdot K/kW$ | 0,002 hr-$ft^2$-°F/Btu |
| Shell corrosion allowance | 3 mm | 1/8 in |
| NOTE The criterion for velocity over heat exchange surface is intended to minimize water side fouling; the criterion for minimum temperature rise is intended to minimize the use of cooling water. | | |

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API Standard 612 / ISO 10437

**SPECIAL-PURPOSE STEAM TURBINE**
**DATA SHEET**
**SI UNITS**

JOB NO. ______ ITEM NO. ______
PURCHASE ORDER NO. ______
SPECIFICATION NO. ______
REVISION NO. ______ DATE ______
PAGE 1 OF 10 BY ______

APPLICABLE TO: ○ PROPOSAL ○ PURCHASE ☐ AS-BUILT
FOR ______ UNIT ______
SITE ______ SERIAL NUMBER ______
SERVICE ______ NUMBER REQUIRED ______
MANUFACTURER ______ MODEL ______ DRIVEN EQUIPMENT ITEM NO. ______
DRIVEN EQUIPMENT TYPE: ○ COMPRESSOR ○ GENERATOR ○ OTHER ______
NOTE: INFORMATION TO BE COMPLETED BY: ○ PURCHASER ☐ MANUFACTURER ☐ PURCHASER OR MANUFACTURER

**PERFORMANCE**

| OPERATING POINTS ☐ ☐ AS APPLICABLE | SHAFT POWER kW | SHAFT SPEED r/min | INLET FLOW kg/h | INLET PRESS kPa | INLET TEMP °C (TT) | INDUCTION/EXTRACTION FLOW kg/h | INDUCTION/EXTRACTION PRESS kPa | INDUCTION/EXTRACTION TEMP °C (TT) | EXHAUST PRESS kPa | EXHAUST TEMP °C (TT) | EXHAUST ENTHALPY kJ / kg |
|---|---|---|---|---|---|---|---|---|---|---|---|
| RATED | | | | | | | | | | | |
| NORMAL (3.25)(6.1.4) | | | | | | | | | | | |
| MINIMUM | | | | | | | | | | | |
| | | | | | | | | | | | |

☐ STEAM RATE, kg/kW.h (3.44): ______ NORMAL ______ RATED
INDUCTION ○ CONTROLLED ○ UNCONTROLLED
☐ POTENTIAL MAXIMUM POWER(3.30)
EXTRACTION ○ CONTROLLED ○ UNCONTROLLED

**STEAM CONDITIONS**

| | | ☐ INLET | ☐ EXHAUST | ☐ EXTRACTION INDUCTION | ☐ EXTRACTION INDUCTION | ☐ EXTRACTION INDUCTION |
|---|---|---|---|---|---|---|
| FLOW kg/h | MAXIMUM | | | | | |
| | NORMAL | | | | | |
| | MINIMUM | | | | | |
| PRESSURE kPa | MAXIMUM | | | | | |
| | NORMAL | | | | | |
| | MINIMUM | | | | | |
| TEMPERATURE °C (TT) | MAXIMUM | | | | | |
| | NORMAL | | | | | |
| | MINIMUM | | | | | |

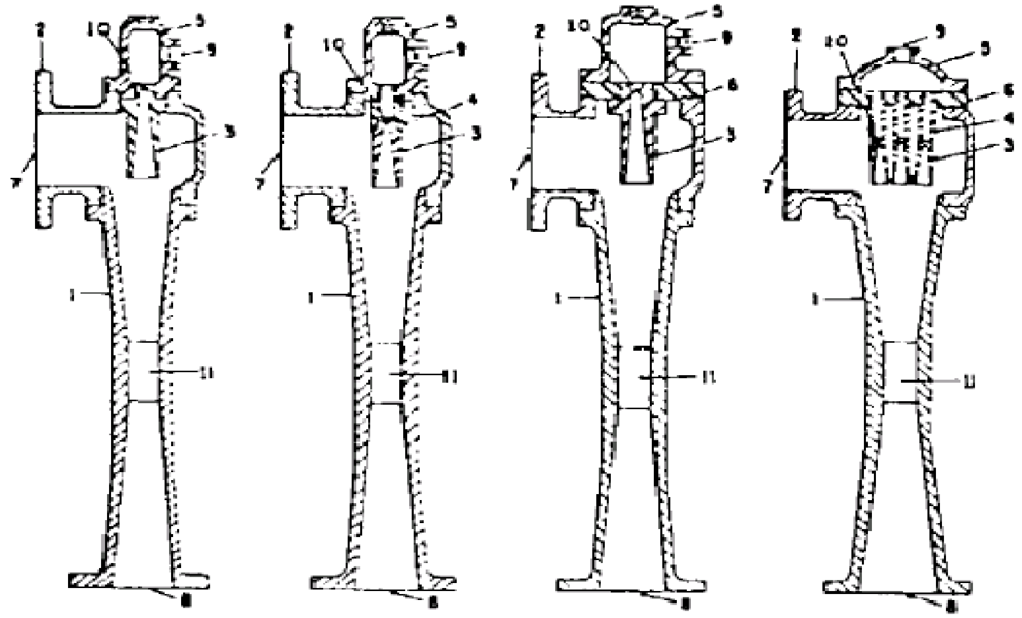
**SITE AND UTILITY DATA**

LOCATION:
○ INDOOR ○ HEATED ○ UNDER ROOF ○ OUTDOOR
○ UNHEATED ○ PARTIAL SIDES ○ GRADE ○ MEZZANINE
○ OTHER: ______
○ WINTERIZATION REQUIRED ○ TROPICALIZATION REQ'D
○ LOW TEMPERATURE ○ CORROSIVE AGENTS
○ ELECTRICAL AREA CLASSIFICATION:
CLASS ___ GROUP ___ DIVISION ______
ZONE ___ GROUP ___ TEMPERATURE RATING: ______
SITE DATA:
○ ELEVATION ______ m ○ BAROM. PRESS ______ kPa
○ WINTER TEMP. ______ °C SUMMER TEMP. ______ °C
○ REL. HUMIDITY ______ % DESIGN WET BULB ______ °C
○ UNUSUAL CONDITIONS: ○ DUST ○ FUMES
○ OTHER ______
UTILITY CONDITIONS:
○ AUXILIARY STEAM: MAX NORM MIN
INITIAL PRESS.(kPa()) ______ ______ ______
INITIAL TEMPERATURE, °C (TT) ______ ______ ______
EXH. PRESS. (kPa) ______ ______ ______
INST. AIR (kPa): NORM ___ MIN ___ MAX ___
INSTRUMENT AIR DEW POINT: °C

○ ELECTRIC: DRIVERS HEATING INSTRUMENT/ CONTROL ALARM/ SHUTDOWN
VOLTS ______ ______ ______ ______
PHASE ______ ______ ______ ______
HERTZ ______ ______ ______ ______
kW AVAILABLE ______ ______ ______ ______
○ COOLING WATER:
INLET TEMPERATURE: ___ °C MAXIMUM RETURN ___ °C
PRESS. NORM.: ______ kPa DESIGN ______ kPa
MINIMUM RETURN PRESSURE: ______ kPa
MAXIMUM ALLOWABLE PRESS. DROP: ______ kPa
WATER SOURCE ______
VELOCITY, m/s: MIN ______ MAX ______
FOULING FACTOR: ______ $m^2$-K/kW
○ UTILITY CONSUMPTION:
COOLING WATER: ______ $m^3$/h INST. AIR ______ $m^3$/h
AUX. STM: NORMAL ______ kg/h MAXIMUM ______ kg/h
AUX. DRIVERS: ELECTRIC ______ kW STEAM ______ kW
HEATER(S): ______ kW OTHER: ______

REMARKS: ______

# ISO 3529/2 "Vacuum Technology-Vocabulary" Part 2: "Vacuum Pumps and Related Terms" 1st. Ed. 1981



TYPICAL STEAM JET EJECTOR STAGE ASSEMBLIES

# API 510: Pressure Vessel Inspection Code

- 30 CFR 250.803(b)(Pressure Vessel Inspection Code: In-Service Inspection, Rating, Repair, and Alteration1)

## SECTION 5—INSPECTION, EXAMINATION AND PRESSURE TESTING PRACTICES

### 5.1 Inspection Plans

An inspection plan shall be established for all pressure vessels and pressure-relieving devices within the scope of this code.

#### 5.1.1 Development of an Inspection Plan

**5.1.1.1** The inspection plan should be developed by the inspector or engineer. A corrosion specialist shall be consulted when needed to clarify potential damage mechanisms and specific locations where they may occur. A corrosion specialist shall be consulted when developing the inspection plan for vessels that operate at elevated temperatures (above 750°F (400°C)).

**5.1.1.2** The inspection plan is developed from the analysis of several sources of data. Equipment shall be evaluated based on present or possible types of damage mechanisms. The methods and the extent of NDE shall be evaluated to assure they can adequately identify the damage mechanism and the severity of damage. Examinations must be scheduled at intervals that consider the:

a. Type of damage;
b. Rate of damage progression;
c. Tolerance of the equipment to the type of damage;
d. Probability of the NDE method to identify the damage; and
e. Maximum intervals as defined in codes and standards.

# API 510: Pressure Vessel Inspection Code

**5.1.1.3** The inspection plan should be developed using the most appropriate sources of information including those listed in Section 2 of this inspection code. Inspection plans shall be reviewed and amended as needed when variables that may impact damage mechanisms and/or deterioration rates are identified.

### 5.1.2 Minimum Contents of an Inspection Plan

The inspection plan shall contain the inspection tasks and schedule required to monitor damage mechanisms and assure the mechanical integrity of the equipment (pressure vessel or pressure-relieving device). The plan should:

a. Define the type(s) of inspection needed, e.g. internal, external;
b. Identify the next inspection date for each inspection type;
c. Describe the inspection and NDE techniques;
d. Describe the extent and locations of inspection and NDE;
e. Describe the surface cleaning requirements needed for inspection and examinations;
f. Describe the requirements of any needed pressure test, e.g. type of test, test pressure, and duration; and
g. Describe any required repairs.

Generic inspection plans based on industry standards and practices may be used. The inspection plan may or may not exist in a single document however the contents of the plan should be readily accessible from inspection data systems.

# API 510: Pressure Vessel Inspection Code

### 5.2.1 Probability Assessment

The probability assessment should be in accordance with API 580, Section 9, and must be based on all forms of damage that could reasonably be expected to affect a vessel in any particular service. Examples of those damage mechanisms include: internal or external metal loss from localized or general corrosion, all forms of cracking, and any other forms of metallurgical, corrosion, or mechanical damage, (e.g. fatigue, embrittlement, creep, etc.) Additionally, the effectiveness of the inspection practices, tools, and techniques used for finding the potential damage mechanisms must be evaluated.

Other factors that should be considered in a probability assessment include:

a. Appropriateness of the materials of construction.
b. Vessel design conditions, relative to operating conditions.
c. Appropriateness of the design codes and standards utilized.
d. Effectiveness of corrosion monitoring programs.
e. The quality of maintenance and inspection quality assurance/quality control programs.

Equipment failure data will also be important information for this assessment.

# API 510: Pressure Vessel Inspection Code

**5.4 Inspection for Types of Damage Modes of Deterioration and Failure**

**5.4.1** Pressure vessels are susceptible to various types of damage by several mechanisms. Typical damage types and mechanisms are as follows.

a. General and local metal loss:
   1. Sulfidation;
   2. Oxidation;
   3. Microbiologically induced corrosion;
   4. Naphthenic acid corrosion;
   5. Erosion/erosion-corrosion;
   6. Galvanic.

b. Surface connected cracking:
   1. Fatigue;
   2. Caustic stress corrosion cracking;
   3. Sulfide stress corrosion cracking.

c. Subsurface cracking:
   Hydrogen induced cracking.

d. Microfissuring/microvoid formation:
   1. High temperature hydrogen attack;
   2. Creep.

e. Metallurgical changes:
   1. Graphitization;
   2. Temper embrittlement.

f. Blistering:
   Hydrogen blistering.

# API 510: Pressure Vessel Inspection Code

g. Dimensional changes:
   1. Creep and stress rupture;
   2. Thermal.
h. Material Properties Changes:
   Brittle fracture.

**5.4.2** The presence or potential of damage in a vessel is dependent upon its material of construction, design, construction, and operating conditions. The inspector should be familiar with these conditions and with the causes and characteristics of potential defects and damage mechanisms.

**5.4.3** Detailed information concerning common damage mechanisms (critical factors, appearance, and typical inspection and monitoring techniques) is found in API 571. Additional recommended inspection practices are described in API 572.

## 5.5 General Types of Inspection and Surveillance

### 5.5.1 General

Different types of inspections and examinations are appropriate depending on the circumstances and the pressure vessel. These include the following:

a. Internal inspection.
b. On-stream inspection.
c. External inspection.
d. Thickness inspection.
e. Corrosion under insulation (CUI) inspection.

Inspections should be conducted in accordance with the inspection plan. Refer to Section 6 for the interval/frequency and extent of inspection.

Imperfections identified during inspections and examinations should be characterized, sized, and evaluated per Section 7.

# ISO STANDARDS ISO TC 43/SC MEASURE METHODS FOR NOISE

- ISO 12001:1996 – Acoustics: Noise emitted by machinery and equipment; rules for the drafting and presentation of a noise test code.
- ISO 7574-1:1985 – Acoustics: Statistical methods for determining and verifying stated noise emission values of machinery and equipment; Part 1: General considerations and definitions.
- ISO 7574-2:1985 – Acoustics: Statistical methods for determining and verifying stated noise emission values of machinery and equipment; Part 2: Methods for stated values for individual machines.
- ISO 7574-3:1985 – Acoustics: Statistical methods for determining and verifying stated noise emission values of machinery and equipment; Part 3: Simple (transition) method for stated values for batches of machines.
- ISO 7574-4:1985 – Acoustics: Statistical methods for determining and verifying stated noise emission values of machinery and equipment; Part 4: Methods for stated values for batches of machines.

# ISO 7919-2 MECHANICAL VIBRATION –EVALUATION OF MACHINE VIBRATION BY MEASUREMENT ON ROTATING SHAFTS Part 2: LAND BASED STEAM TURBINES AND GENERATORS IN ESCESS OF 50 MW WITH NORMAL OPERATING SPEEDS OF 1500 rpm-3600 rpm

## 4.1 General

Criteria for vibration magnitude, changes in vibration magnitude and operational limits are presented below.

The vibration magnitude is the higher value of the peak−to−peak displacement measured in two selected orthogonal measurement directions. The values presented are the result of experience with machinery of this type and, if due regard is paid to them, acceptable operation may be expected. If only one measurement direction is used, care should be taken to ensure that it provides adequate information (see ISO 79191).

Two evaluation criteria are used to assess the shaft vibration of steam turbines and generators, measured at or close to the bearings. One criterion considers the magnitude of the observed broad−band shaft vibration; the second considers changes in magnitude, irrespective of whether they are increases or decreases.

Criteria are presented for steady−state operating conditions at the specified rated speed and load ranges, including the normal slow changes in electrical load of the generator. Alternative values of vibration magnitude are also provided for transient operation.

It should be noted that an overall judgement of the vibratory state of a machine is often made on the basis of both shaft vibration as defined above and of measurements made on non−rotating parts (see ISO 10816 1 and ISO 10816 2).

# ISO 7919-2 MECHANICAL VIBRATION –EVALUATION OF MACHINE VIBRATION BY MEASUREMENT ON ROTATING SHAFTS Part 2: LAND BASED STEAM TURBINES AND GENERATORS IN ESCESS OF 50 MW WITH NORMAL OPERATING SPEEDS OF 1500 rpm-3600 rpm

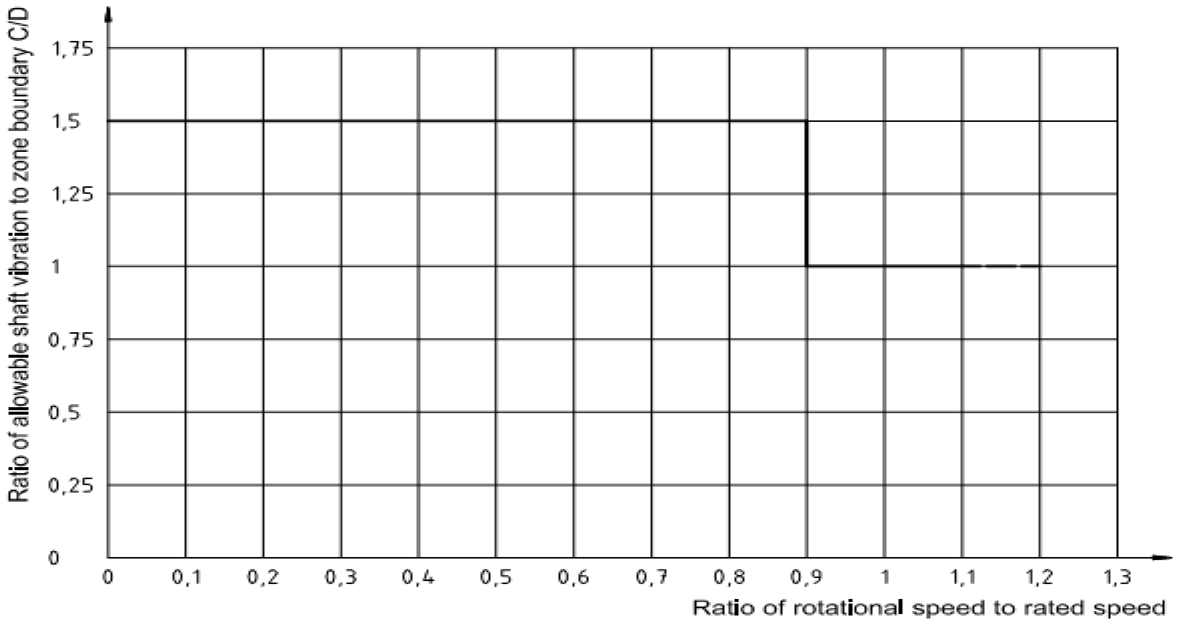



**Figure 1 – Allowable shaft vibration during run up, run down and overspeed**

# ISO 7919-2 MECHANICAL VIBRATION –EVALUATION OF MACHINE VIBRATION BY MEASUREMENT ON ROTATING SHAFTS Part 2: LAND BASED STEAM TURBINES AND GENERATORS IN ESCESS OF 50 MW WITH NORMAL OPERATING SPEEDS OF 1500 rpm-3600 rpm

## Evaluation zones boundaries

In most cases the values given in Tables A.1 and A.2 are consistent with ensuring satisfactory operation. However, in certain cases, specific features associated with a particular machine type might require different zone boundary values to be used (see 4.2.2.3).

**Table A.1 — Recommended values for maximum relative displacement of the shaft for steam turbines and generators at the zone boundaries**

| Zone boundary | Shaft rotational speed<br>r/min | | | |
|---|---|---|---|---|
| | 1 500 | 1 800 | 3 000 | 3 600 |
| | Peak–to–peak relative displacement of shaft<br>µm | | | |
| A/B | 100 | 90 | 80 | 75 |
| B/C | 200 | 185 | 165 | 150 |
| C/D | 320 | 290 | 260 | 240 |

**Table A.2 — Recommended values for maximum absolute displacement of the shaft for steam turbines and generators at the zone boundaries**

| Zone boundary | Shaft rotational speed<br>r/min | | | |
|---|---|---|---|---|
| | 1 500 | 1 800 | 3 000 | 3 600 |
| | Peak–to–peak absolute displacement of shaft<br>µm | | | |
| A/B | 120 | 110 | 100 | 90 |
| B/C | 240 | 220 | 200 | 180 |
| C/D | 385 | 350 | 320 | 290 |

# ANSI/AHRI Standard 400-2001 Performance Rating of Liquid to Liquid Heat Exchangers

**C6.3** *Computation of Results.*

**C6.3.1** Average the consecutive test readings as specified in C6.2.2. From the averaged test data, the heat transfer rate on the Cold Stream, $Q_{cs}$, shall be calculated as:

$$Q_{cs} = w_{cs}\, c_{p,cs}\left(T_{cs,\ out} - T_{cs,\ in}\right) \qquad \text{(C1)}$$

**C6.3.2** From the averaged test data, the heat transfer rate on the Hot Stream, $Q_{hs}$, shall be calculated as:

$$Q_{hs} = w_{hs}\, c_{p,hs}\left(T_{hs,in} - T_{hs,out}\right) \qquad \text{(C2)}$$

**C6.3.3** The total average heat transfer rate, $Q_{tavg}$, shall be calculated as the average of the hot stream heat transfer rate and the cold stream heat transfer rate:

$$Q_{tavg} = \left(\frac{Q_{hs} + Q_{cs}}{2}\right) \qquad \text{(C3)}$$

**C6.3.4** The Number of Transfer Units, NTU of the heat exchanger is calculated as follows:

$$* \; NTU = \frac{\Delta T_{max}}{LMTD} \qquad \text{(C4)}$$

$$NTU = \frac{U \cdot A}{(w \cdot c_p)_{\min}} \qquad \text{(C4.2)}$$

From: $Q = U\ A\ A\ \ A\ LMTD$

$$U \cdot A = \frac{Q}{LMTD} \qquad \text{(C4.3)}$$

from:

$$Q = (w \cdot c_p)\ (\Delta T) = Q_{hs} = Q_{cs}$$

$$Q = (w \cdot c_p)_{\min} (\Delta T)_{\max} = (w \cdot c_p)_{\max} (\Delta T)_{\min}$$

$$(w \cdot c_p)_{\min} = \frac{Q}{(\Delta T)_{\max}} \qquad \text{(C4.4)}$$

Substituting equations C4.3 and C4.4 in C4.2:

$$NTU = \left[\frac{Q}{LMTD}\right]\left[\frac{\Delta T_{\max}}{Q}\right]$$

$$NTU = \frac{\Delta T_{\max}}{LMTD} \qquad \text{(C4)}$$

**C6.3.5** The overall heat transfer coefficient in the clean condition, $U_c$, shall be calculated as:

$$U_c = Q_{tavg} / (CLMTD \cdot A) \qquad \text{(C5)}$$

---

*Derivation of $NTU$:

$$NTU = \frac{U \cdot A}{C_{\min}} \qquad \text{(C4.1)}$$

where: $C = w \cdot c_p$ = Capacity Rate

# STANDARD TEST METHOD FOR SILICA IN WATER

# ASTM D 859 – 00: Standard Test Method for Silica in Water

- This test method covers the determination of silica in water and waste water colorimetric method that determines molybdate-reactive silica. It is applicable to most waters,but some waters may require filtration and dilution to remove interferences from color and turbidity. This test method is useful for concentrations as low as 20 µg/L from 20 to 1000 µg/L at the higher wavelength (815 nm) and 0.1 to 5 mg/L at the lower wavelength (640 nm).

# Reference Documents

2.1 ASTM Standards:

- D 1066 Practice for Sampling Steam
- D 1129 Terminology Relating to Water
- D 1193 Specification for Reagent Water
- D 2777 Practice for Determination of Precision and Bias of Applicable Methods of Committee D-19 on Water
- D 3370 Practices for Sampling Water from Closed Conduits
- D 4841 Practice for Estimation of Holding Time for Water Samples Containing Organic and Inorganic Constituents
- D 5810 Standard Guide for Spiking into Aqueous Samples
- D 5847 Standard Practice for the Writing Quality Control Specifications for Standard Test Methods for Water Analysis
- E 60 Practice for Photometric and Spectrophotometric Methods for Chemical Analysis of Metals
- E 275 Practice for Describing and Measuring Performance of Ultraviolet, Visible, and Near Infrared Spectrophotometers

# PROCESS DESIGN OF COOLING TOWERS (PROJECT STANDARDS AND SPECIFICATIONS)

1. BSI (British Standards Institution)

BS 4485 "British Standard Specification for Water Cooling Towers"

- Part 1: 1969, "Glossary of Terms"
- Part 2: 1988, "Methods for Performance Testing"
- Part 3: 1988, "Thermal Design Principles"
- Part 4: 1975, "Structural Design of Cooling Towers“

2. CTI (Cooling Tower Institute, USA)

CTI Bulletin "Nomenclature for Industrial Water Cooling Tower“ NCL-109

- "Acceptance Test Code“

3. ASME (American Society of Mechanical Engineers)

- "ASME Test Code Section VIII

# AMERICAN NATIONAL STANDARD FOR WELDED AND SEAMLESS WROUGT STEEL PIPE (ANSI B36.10)

## 1. SCOPE

This Standard covers the standardization of dimensions of welded and seamless wrought steel pipe, for high or low temperatures and pressures.

The word *pipe* is used as distinguished from *tube* to apply to tubular products of dimensions commonly used for pipeline and piping systems. Pipe dimensions of sizes 12 inch and smaller have outside diameters numerically larger than corresponding sizes. In contrast, the outside diameters of tubes are numerically identical to the size number for all sizes.

# AMERICAN NATIONAL STANDARD FOR WELDED AND SEAMLESS WROUGT STEEL PIPE (ANSI B36.10)

Table 1 Specifications for Pipe with ANSI Designations and Titles of Standard Specifications

| ASTM or API Designation | ANSI Designation | Title |
|---|---|---|
| ASTM A53 | B125.1 | Welded and Seamless Steel Pipe |
| ASTM A106 | B125.30 | Seamless Carbon Steel Pipe for High-Temperature Service |
| ASTM A120 | B125.2 | Black and Hot-Dipped Zinc-Coated (Galvanized) Welded and Seamless Steel Pipe for Ordinary Uses |
| ASTM A134 | B125.55 | Electric-Fusion (Arc)-Welded Steel Plate Pipe (Sizes 16 in. and Over) |
| ASTM A135 | B125.3 | Electric-Resistance-Welded Steel Pipe |
| ASTM A139 | B125.31 | Electric-Fusion (Arc)-Welded Steel Plate Pipe (Sizes 4 in. and Over) |
| ASTM A155 | B125.4 | Electric-Fusion-Welded Steel Pipe for High-Pressure Service |
| ASTM A211 | B122.56 | Spiral-Welded Steel or Iron Pipe |
| ASTM A312 | B125.16 | Seamless and Welded Austenitic Stainless Steel Pipe |
| ASTM A333 | B125.17 | Seamless and Welded Steel Pipe for Low-Temperature Service |
| ASTM A335 | B125.24 | Seamless Ferritic Alloy Steel Pipe for High-Temperature Service |

# AMERICAN NATIONAL STANDARD FOR WELDED AND SEAMLESS WROUGT STEEL PIPE (ANSI B36.10)

| | | |
|---|---|---|
| ASTM A358 | B125.57 | Electric-Fusion-Welded Austenitic Chromium-Nickel Alloy Steel Pipe for High-Temperature Service |
| ASTM A369 | B125.27 | Carbon and Ferritic Alloy Steel Forged and Bored Pipe for High-Temperature Service |
| ASTM A376 | B125.25 | Seamless Austenitic Steel Pipe for High-Temperature Central-Station Service |
| ASTM A381 | B125.35 | Metal-Arc-Welded Steel Pipe for High-Pressure Transmission Systems |
| ASTM A405 | B125.26 | Seamless Ferritic Alloy Steel Pipe Specially Heat Treated for High-Temperature Service |
| ASTM A523 | G62.5 | Plain End Seamless and Electric-Resistance-Welded Steel Pipe for High Pressure Pipe-Type Cable Circuits |
| ASTM A524 | B125.37 | Seamless Carbon Steel Pipe for Process Piping |
| ASTM A530 | B125.20 | General Requirements for Specialized Carbon and Alloy Steel Pipe |
| API 5L | | Line Pipe |
| API 5LX | | High-Test Line Pipe |
| API 5LS | | Spiral Weld Line Pipe |

# ANSI Z89.2-1971 SAFETY REQUIREMENTS FOR INDUSTRIAL PROTECTIVE HELMETS FOR ELECTRICAL WORKERS, CLASS B

## 3. Types and Class

Protective helmets shall be of the following types and class:

Type 1 — Helmet, full brim
Type 2 — Helmet, brimless with peak
Class B — High-voltage protection

# ANSI Z35.1-1968: SPECIFICATIOS FOR ACCIDENT PREVENTION SIGNS
# CFR SECTION: 29 CFR 1926.200

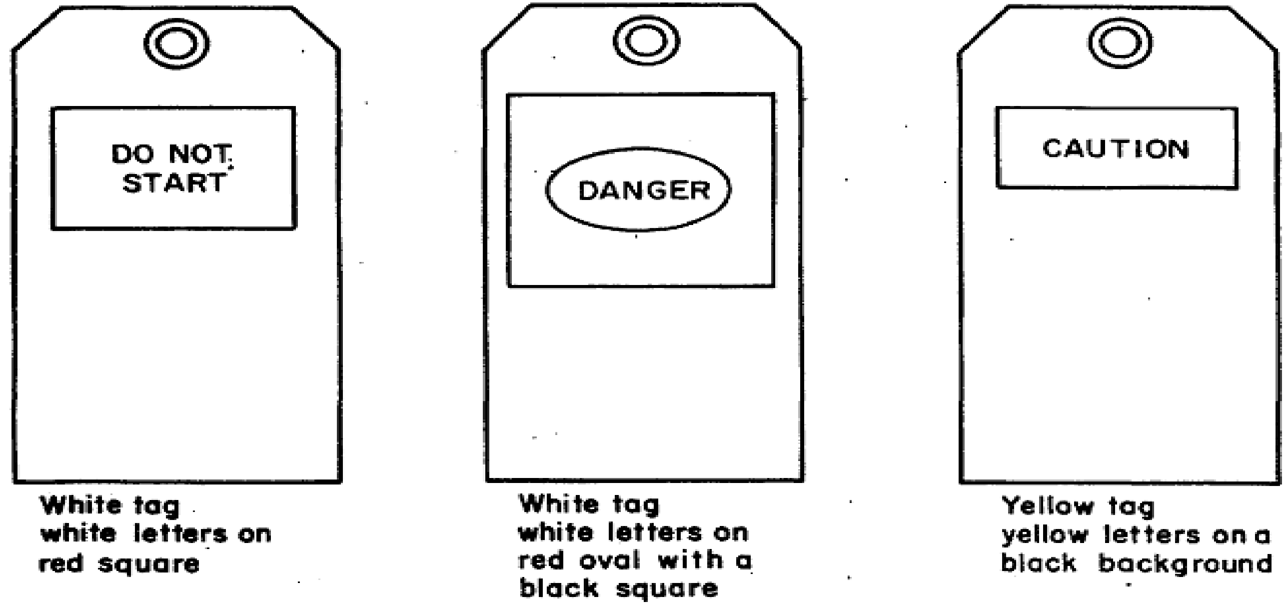


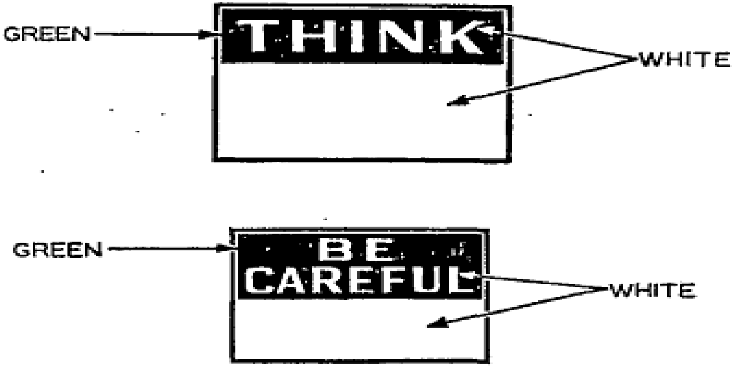

Fig. 1 Do Not Start Tag

Fig. 2 Danger Tag

Fig. 3 Caution Tag

# ANSI Z35.1-1968: SPECIFICATIOS FOR ACCIDENT PREVENTION SIGNS
# CFR SECTION: 29 CFR 1926.200


**Fig. 4**
**Caution Sign**




NOTE: The words "Think" and "Be Careful," given here, are only illustrations. Other wordings may be used.

# API 5L: SPECIFICATION FOR LINE PIPE
# 49 CFR 192.113

## 1.1 PURPOSE AND COVERAGE

The purpose of this specification is to provide standards for pipe suitable for use in conveying gas, water, and oil in both the oil and natural gas industries.

This specification covers seamless and welded steel line pipe. It includes plain-end, threaded-end, and belled-end pipe, as well as through-the-flowline (TFL) pipe and pipe with ends prepared for use with special couplings.

Although the plain-end line pipe meeting this specification is primarily intended for field makeup by circumferential welding, the manufacturer will not assume responsibility for field welding.

# API 5L: SPECIFICATION FOR LINE PIPE
# 49 CFR 192.113

# API 5L: SPECIFICATION FOR LINE PIPE
# 49 CFR 192.113

# API 6D: SPECIFICATION FOR PIPELINE VALVE
# 49 CFR 195.116

# API 6D: SPECIFICATION FOR PIPELINE VALVE 49 CFR 195.116

# API 510: PRESSURE VESSEL INSPECTION CODE 30 CFR 250.803 (b)(1)

# API 510: PRESSURE VESSEL INSPECTION CODE
# 30 CFR 250.803 (b)(1)

# API 510: PRESSURE VESSEL INSPECTION CODE 30 CFR 250.803 (b)(1)

Different types of inspections and examinations are appropriate depending on the circumstances and the pressure vessel. These include the following:

a. Internal inspection.
b. On-stream inspection.
c. External inspection.
d. Thickness inspection.
e. Corrosion under insulation (CUI) inspection.

Inspections should be conducted in accordance with the inspection plan. Refer to Section 6 for the interval/frequency and extent of inspection.

Imperfections identified during inspections and examinations should be characterized, sized, and evaluated per Section 7.

# API 510: PRESSURE VESSEL INSPECTION CODE 30 CFR 250.803 (b)(1)

### 5.5.2.1 General

The internal inspection shall be performed by an inspector in accordance with the inspection plan. An internal inspection is conducted inside the vessel and shall provide a thorough check of internal pressure boundary surfaces for damage. A primary goal of the internal inspection is to find damage that cannot be found by regular monitoring of external CMLs. Specific NDE techniques, e.g. WFMT, ACFM, ET, PT, etc., may be required by the owner/user to find damage specific to the vessel or service conditions.

API 572, provides more information on pressure vessel inspection and should be used when performing this inspection.

For equipment not designed for entrance by personnel, inspection ports shall be opened for examination of surfaces. Remote visual inspection techniques may aid the check of these equipment internal surfaces.

### 5.5.2.2 Vessel Internals

When vessels are equipped with removable internals, internals may need to be removed, to the extent necessary, to allow inspection of pressure boundary surfaces. The internals need not be removed completely as long as reasonable assurance exists that damage in regions rendered inaccessible by the internals is not occurring to an extent beyond that found in more accessible parts of the vessel.

Inspectors may inspect the non-pressure internals, if requested by other operations personnel, and report current condition to the appropriate operation personnel.

### 5.5.2.3 Deposits and Linings

The inspector, in consultation with the corrosion specialist, should determine when it is necessary to remove deposits or linings to perform adequate inspections.

# API 510: PRESSURE VESSEL INSPECTION CODE 30 CFR 250.803 (b)(1)

**5.5.3 On-stream Inspection**

**5.5.3.1** The on-stream inspection may be required by the inspection plan. All on-stream inspections should be conducted by either an inspector or examiner. All on-stream inspection work performed by an examiner shall be authorized and approved by the inspector. When on-stream inspections of the pressure boundary are specified, they shall be designed to detect the damage mechanisms identified in the inspection plan.

**5.5.3.2** The inspection may include several NDE techniques to check for various types of damage. Techniques used in on-stream inspections are chosen for their ability to identify particular internal damage mechanisms from the exterior and their capabilities to perform at the on-stream conditions of the pressure vessel (e.g. metal temperatures). The external thickness inspection described in 5.5.4 may be a part of an on-stream inspection.

**5.5.3.3** On-stream inspection may be acceptable in lieu of internal inspection for vessels under the specific circumstances defined in 6.5.2. In situations where on-stream inspection is acceptable, such inspection may be conducted either while the vessel is depressurized or pressured.

# API STANDARD 598 EIGHTH EDITION, MAY 2004: Valve Inspection and Testing

The following tests and examinations are specified in this standard:

a. Shell test.

b. Backseat test.

c. Low-pressure closure test.

d. High-pressure closure test.

e. Visual examination of castings.

f. High-pressure pneumatic shell test

# API STANDARD 598 EIGHTH EDITION, MAY 2004: Valve Inspection and Testing

Table 1-A—Pressure Tests

Valves: NPS ≤ 4 & ASME Class ≤ 1500
NPS > 4 & ASME Class ≤ 600

| Test Description | Valve Type | | | | | |
|---|---|---|---|---|---|---|
| | Gate | Globe | Plug | Check | Floating Ball | Butterfly and Trunnion Mounted Ball |
| Shell | Required | Required | Required | Required | Required | Required |
| Backseat[a] | Required | Required | NA | NA | NA | NA |
| Low-pressure Closure | Required | Optional[c] | Required[b] | Optional[c] | Required | Required |
| High-pressure Closure[d] | Optional[c, f] | Required[e] | Optional[b, c, f] | Required | Optional[c, f] | Optional[c, f] |

Notes: NA = Not applicable.
[a]The backseat test is required for all valves, except for bellows seal valves, that have the backseat feature.
[b]For lubricated plug valves, the high-pressure closure test is mandatory and the low-pressure closure test is optional.
[c]When the purchaser specifies an "optional" test, the test shall be performed in addition to the required tests.
[d]The high-pressure closure test of resilient-seated valves may degrade subsequent sealing performance in low-pressure service.
[e]For power-operated and manually operated gear actuated globe valves, including non-return type globe valves, the high-pressure closure test shall be performed at 110% of the design differential pressure used for sizing of the operator.
[f]A high-pressure closure test is required for all valves specified to be double block and bleed valves.

# ISO 3529/2 "Vacuum Technology-Vocabulary" Part 2: "Vacuum Pumps and Related Terms" 1st. Ed. 1981

**6.2.2.2.2 Steam conditions**

The following characteristics of the operating steam shall be specified:

a) Maximum steam line pressure and temperature.

b) Maximum steam pressure and temperature at the ejector steam inlet.

c) Minimum steam pressure at the ejector steam inlet.

d) Design steam pressure and temperature.

e) Quality of the steam, if it is not superheated, at the ejector steam inlet.

# Reference Standards for Vibration Monitoring and Analysis

The stated scope of TC108 is “Standardization in the field of mechanical vibration and shock and condition monitoring and diagnostics of machines, including:

- terminology;
- excitation by sources, such as machines and vibration and shock testing devices;
- elimination, reduction and control of vibration and shock, especially by balancing,
- isolation and damping;
    - measurement and evaluation of human exposure to vibration and shock;
    - methods and means of measurement and calibration;
    - methods of testing;
    - methods of measurement, handling and processing of the data required to perform condition monitoring and diagnostics of machines

# Reference Standards for Vibration Monitoring and Analysis

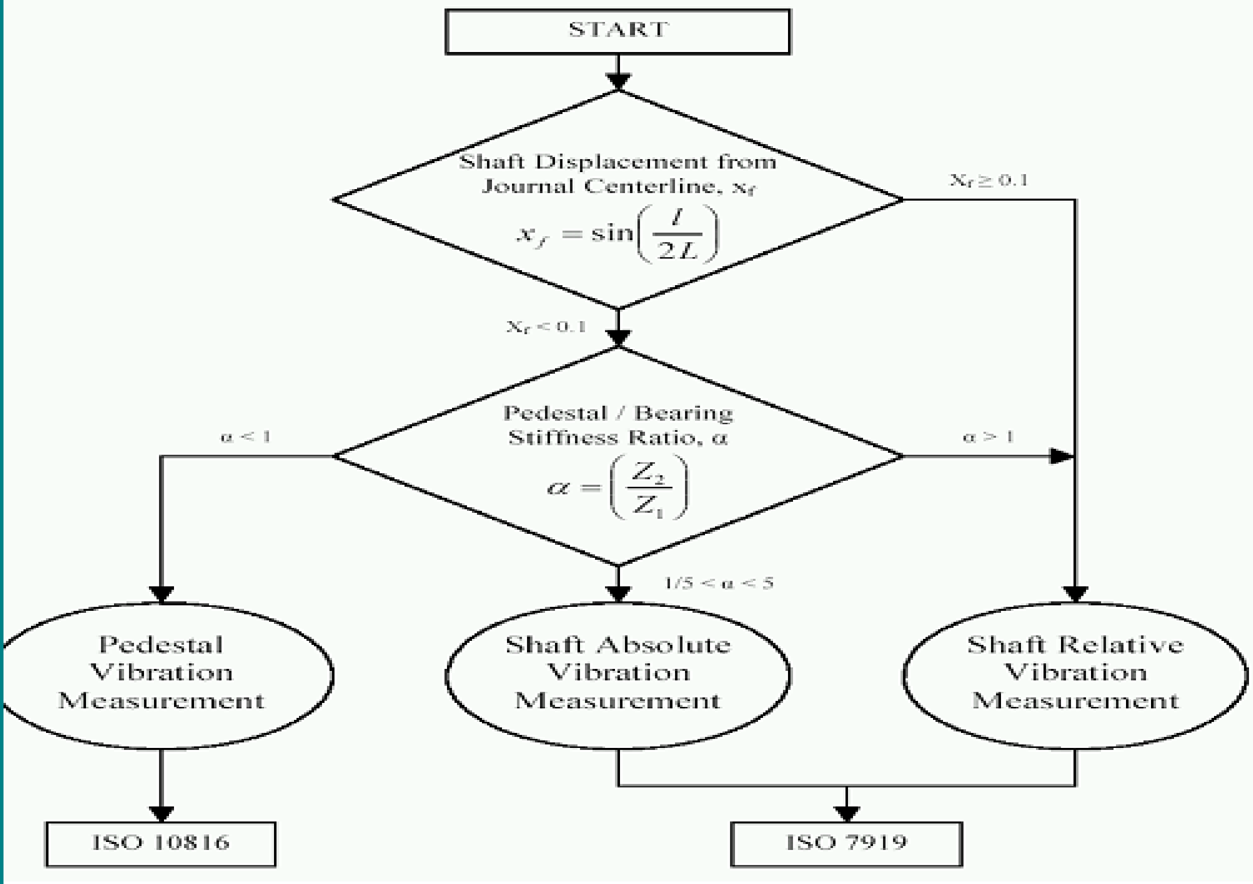
| ISO 7919 Series | Mechanical vibration of non-reciprocating machines - Measurement on rotating shafts and evaluation criteria |
|---|---|
| 7919-1:1996 | Part 1: General Guidelines |
| 7919-2: 2001 | Part 2: Land-based steam turbines and generators in excess of 50 MW with normal operating speeds of 1500 r/min, 1800 r/min, 3000 r/min and 3600 r/min |
| 7919-3: 1996 | Part 3: Coupled industrial machines |
| 7919-4: 1996 | Part 4: Gas turbine sets |
| 7919-5: 1997 | Part 5: Machines set in hydraulic power generating and pumping plants |

# Reference Standards for Vibration Monitoring and Analysis

| ISO 10816 Series | Mechanical vibration<br>- Evaluation of machine vibration by measurements on non-rotating parts |
|---|---|
| 10816-1: 1995 | Part 1: General Guidelines |
| 10816-2: 2001 | Part 2: Land-based steam turbines and generators in excess of 50 MW with normal operating speeds of 1500 r/min, 1800 r/min, 3000 r/min and 3600 r/min |
| 10816-3: 1998 | Part 3: Industrial machines with normal power above 15kW and nominal speeds between 120 r/min and 15000 r/min when measured in situ |
| 10816-4: 1998 | Part 4: Gas turbine sets excluding aircraft derivatives |
| 10816-5: 2000 | Part 5: Machines set in hydraulic power generating and pumping plants |
| 10816-6: 1995 | Part 6: Reciprocating machines with power ratings above 100 kW |
| 10816-7‡ | Part 7: Rotodynamic pumps for industrial application |

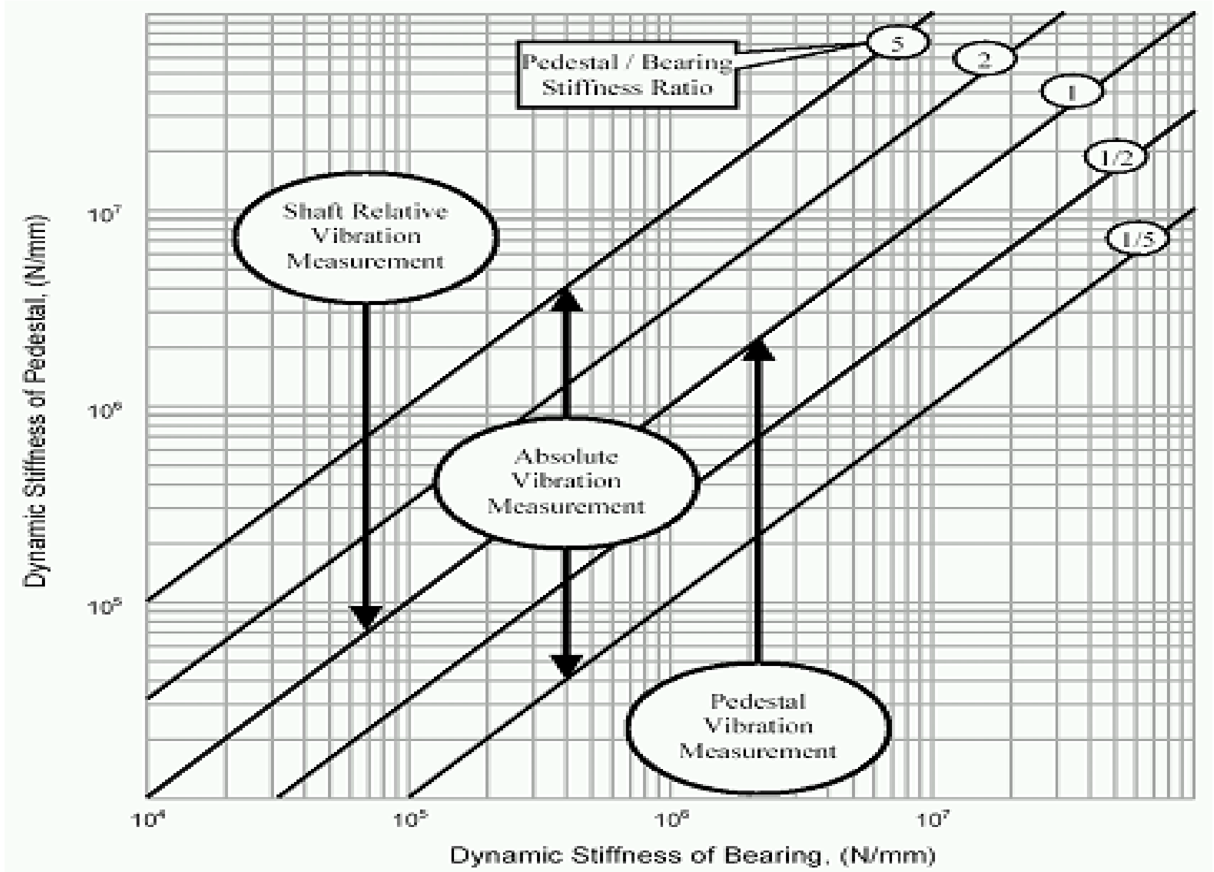
**Table 1 • ISO Standards for Evaluation of Vibration Severity†**

# Reference Standards for Vibration Monitoring and Analysis



ure 1 • Flow Diagram for selection of measurements and evaluation of vibration severity

# Reference Standards for Vibration Monitoring and Analysis

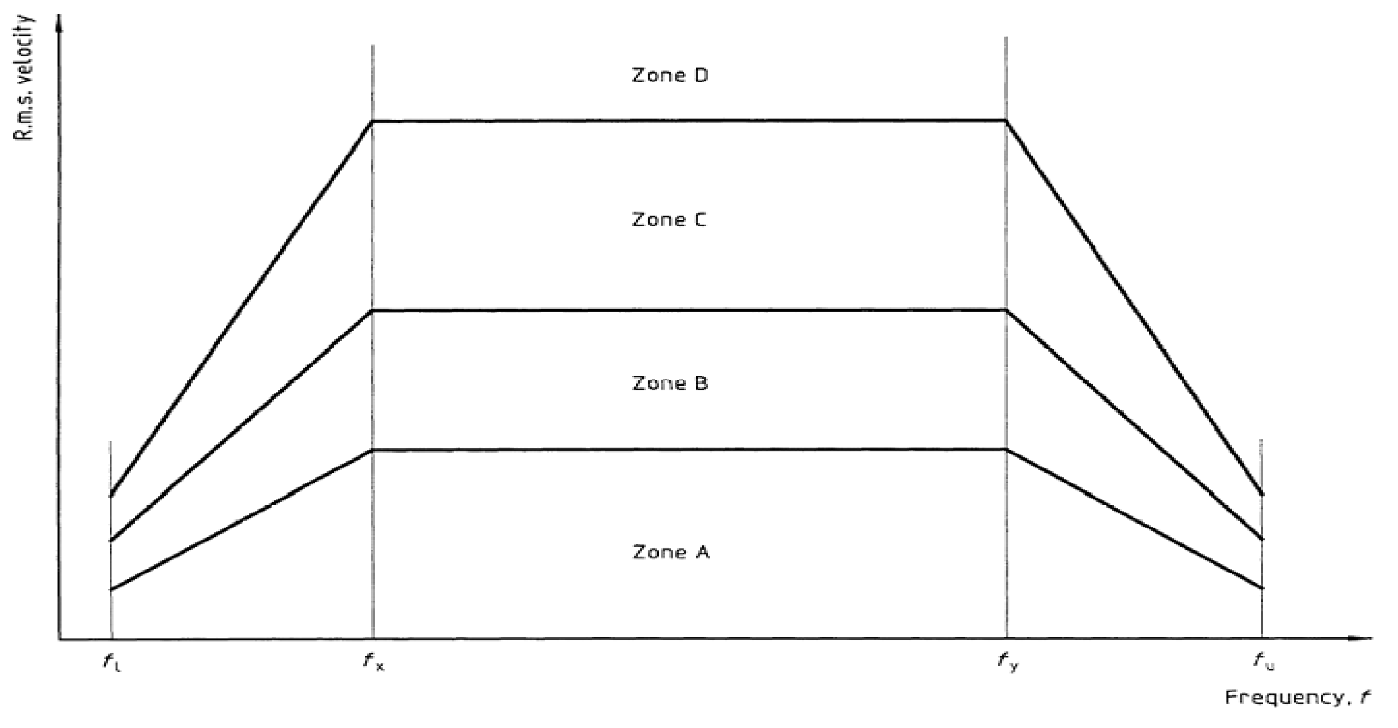


# Reference Standards for Vibration Monitoring and Analysis

| Machine | Dynamic Stiffness Ratio, α | ISO 10816 (pedestal) | ISO 7919 (shaft) |
|---|---|---|---|
| High Pressure Turbine | 5 | Moderate | Good |
| Low Pressure Turbine | 1.5 | Moderate | Good |
| Large Generator | 1.5 | Moderate | Good |
| High Pressure Centrifugal Compressor | 5 | Not Good | Good |
| Large Fan | 2/3 | Good | Moderate |
| Small Fan & Pump | 1/3 | Good | Moderate |
| Vertical Pump | 1/10 | Good | Not Good |
| Large Steam Turbine Generator Set | 1.5 to 3 | Moderate | Good |

Table 2 • Example ISO Standards selection guideline

# Reference Standards for Vibration Monitoring and Analysis



# Reference Standards for Vibration Monitoring and Analysis

<table>
<tr><th>R.m.s. vibration velocity<br>mm/sec</th><th>up to 15 kW<br>Class I</th><th>15 to 75 kW<br>Class II</th><th>> 75 kW<br>(rigid)<br>Class III</th><th>> 75 kW<br>(soft)<br>Class IV</th></tr>
<tr><td>0,28</td><td rowspan="3">A</td><td rowspan="4">A</td><td rowspan="5">A</td><td rowspan="6">A</td></tr>
<tr><td>0,45</td></tr>
<tr><td>0,71</td></tr>
<tr><td>1,12</td><td rowspan="2">B</td></tr>
<tr><td>1,8</td><td rowspan="2">B</td></tr>
<tr><td>2,8</td><td rowspan="2">C</td><td rowspan="2">B</td></tr>
<tr><td>4,5</td><td rowspan="2">C</td><td rowspan="2">B</td></tr>
<tr><td>7,1</td><td rowspan="5">D</td><td rowspan="2">C</td></tr>
<tr><td>11,2</td><td rowspan="4">D</td><td rowspan="2">C</td></tr>
<tr><td>18</td><td rowspan="3">D</td></tr>
<tr><td>28</td><td rowspan="2">D</td></tr>
<tr><td>45</td></tr>
</table>

Table 3 • Typical Evaluation Criteria Zone Vibration Magnitude

# Reference Standards for Vibration Monitoring and Analysis

- measurement methods and parameters
- transducer selection, location, and attachment
- data collection
- machine operating conditions
- vibration monitoring systems
- signal conditioning systems
- interfaces with data processing systems
- continuous and periodic monitoring

# ISO Standards For Training and Certification

August, 2003, ISO 18436-2:2003 Condition monitoring and diagnostics of machines — Requirements for training and certification of personnel — Part 2: Vibration condition monitoring and diagnostics

# ISO Standards For Training and Certification

1. Part 1: Requirements for certifying bodies and the certification process
2. Part 3: Requirements for training bodies
3. Part 4: Lubrication management and analysis
4. Part 5: Thermography
5. Part 6: Diagnostics and prognostics
6. Part 7: Condition monitoring specialists
7. Part 8: Balancing

# OTHER STANDARDS FOR VIBRATION MONITORING AND ANALYSIS

- API Standards

| Equipment Type | API Standard | Acceptance Test | Other Requirements |
|---|---|---|---|
| Pumps | 610 (9TH edition March '03) | Shaft Relative + Casing | Vertical Pump (0.20 ips pk) |
| Fans | 673 (2ND edition November '01) | Casing (0.1 ips pk) | |
| Steam Turbines | 612 (4TH edition June '95) | Shaft Relative (mil pk-pk) | 4 hour run in test required |
| Gears | 613 (5TH edition March '03) | Casing (0.15 ips pk) | Unbalance 4 W/N oz-in |
| Centrifugal Compressors | 617 (7TH edition July '02) | Shaft Relative (mil pk-pk) | 4 hour run in test required |
| Screw Compressors | 619 (3RD edition June '97) | Shaft Relative (mil pk-pk) | Unbalance 4 W/N oz-in |
| Induction Motors (≥ 250 hp) | 541 (4Th edition March '03) | | Unbalance 4 W/N oz-in |

**Table 4 • Sample API Standards for Accptance Testing**

- 2 applicable, but often ignored reference standards, are the NBC and Steel Design Code. Each of these important standards make specific reference to the problem of structural resonance, and state that a dynamic analysis may be required (National Building Code (1995) and Steel Design Code CAN/CSA-S16.1)

# OTHER STANDARDS FOR VIBRATION MONITORING AND ANALYSIS

National Building Code (1995) and Steel Design Code CAN/CSA-S16.1

# PROCESS REQUIREMENTS OF HEAT EXCHANGING EQUIPMENT (PROJECT STANDARDS AND SPECIFICATIONS)

TEMA (The Tubular Exchanger Manufacturers Association)
"Standards of the Tubular Exchanger Manufacturers Association (TEMA)" 9th Ed.2007

2. API (American Petroleum Institute)
API Std. 660, "Shell & Tube Heat Exchangers for General Refinery Services" for General Refinery Services" 7th. Ed., April 2003, Reaffirmed Dec. 1987

API Std. 662 "Plate Heat Exchanger for General Refinery Services"
Part I- Plate-and Frame Heat Exchangers 1st.Ed.Feb.2006

API Std. 662 "Plate Heat Exchanger for General Refinery Services”
Part II- Brazed Aluminum Plate –Fin Heat Exchangers
1st.Ed.Feb.2006

# PROCESS REQUIREMENTS OF HEAT EXCHANGING EQUIPMENT (PROJECT STANDARDS AND SPECIFICATIONS)

Chiller - The chiller is a typical kettle type exchanger, and the bundles has tubes to a height of about 60 per cent of the diameter. The vapor space above is for disengagement of the vapor from the liquid. Chillers are used in refrigeration processes of the vapor-compression type. A chiller cools a fluid with a refrigerant to a temperature below that obtainable using air or cooling water as the heat sink. Common refrigerants are propane, ethylene and propylene; chilled water or brines are less frequently used.

# PROCESS REQUIREMENTS OF HEAT EXCHANGING EQUIPMENT (PROJECT STANDARDS AND SPECIFICATIONS)

Condenser - A condenser is a unit in which a process vapor is totally or partially converted to liquid. The heat sink is ordinarily a utility, such as cooling water. The term "surface condenser" refers specifically to shell and tube units, used to condense the steam from a preceding ejector stage, thus reducing the inlet quantity of vapor mixture to the following stage. This is a means of increasing steam economy. They do not affect ejector performance, but they do avoid the nuisance of exhausting steam to the atmosphere, thus, they allow steam to be recovered. A "direct contact condenser" refers to a unit in which the vapor is condensed by direct contact heat exchange with droplets of water.

# PROCESS REQUIREMENTS OF HEAT EXCHANGING EQUIPMENT (PROJECT STANDARDS AND SPECIFICATIONS)

The selection of TEMA "Class R" or TEMA "Class C" exchangers shall be governed by the following:

a) TEMA "R" is required when:
   - Tube side or shell side fouling factor is greater than 0.00035 $m^2.K/W$;

or

   - Shell side corrosion allowance is greater than 3.175 mm (1/8 inch);
   - Shell side corrosion rate is greater than 0.254 mm/y (10 mils per year).

b) TEMA "C" may be used when exchanger is designed for chemical cleaning maintenance and fouling factor do not exceed 0.00035 $m^2.K/W$ on both tube side and shell side.

# PROCESS REQUIREMENTS OF HEAT EXCHANGING EQUIPMENT (PROJECT STANDARDS AND SPECIFICATIONS)

- Heat exchangers should be of the horizontal type, however, for process requirements and where cleaning and other maintenance will be infrequent and space requirements make it more attractive, the vertical arrangement may be considered and this should be discussed with the Company.

- Centerline elevation of the top bundle of stacked exchangers shall be limited to 3.5 m except for large exchangers which shall be limited to two stacked shells.

- When horizontal arrangements are preferred, the stacking of exchangers should be considered to conserve space in the structure

# MATERIAL STANDARDS

# ANSI/API STANDARD 612
# SIXTH EDITION, NOVEMBER 2005

**11.1.4** External parts that are subject to rotary or sliding motions (such as control linkage joints and adjusting mechanisms) shall be of corrosion-resistant materials suitable for the site environment.

**11.1.5** Minor parts that are not identified (such as nuts, springs, washers, gaskets and keys) shall have corrosion resistance at least equal to that of parts identified in accordance with 11.1.2 in the same environment.

**11.1.6** The purchaser shall specify any corrosive agents exceeding IEC 60045-1 or NEMA SM 23 steam quality requirements present in the steam and in the environment, including constituents that may cause stress corrosion cracking.

The vendor should recognize that some steam systems include contaminants such as sodium hydroxide, chlorides, sulfates, phosphates, copper and lead, and should consider these when selecting materials.

**11.1.7** If austenitic stainless steel parts exposed to conditions that may promote intergranular corrosion are to be fabricated, hard faced, overlaid or repaired by welding, they shall be made of low-carbon or stabilized grades.

NOTE Overlays or hard surfaces that contain more than 0,10 % carbon can sensitize both low-carbon and stabilized grades of austenitic stainless steel unless a buffer layer that is not sensitive to intergranular corrosion is applied.

**11.1.8** Where mating parts such as studs and nuts of austenitic stainless steel or materials with similar galling tendencies are used, they shall be lubricated with an anti-seizure compound of the appropriate temperature specification and compatible with steam.

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**11.1.10** Unless otherwise specified, the vendor shall list in the proposal all steam path components (valves, seats, blades, shrouds, closing pieces, pins, damping wires, wheels, bolting, and so forth) with a hardness of more than Rockwell C 22. The vendor shall also indicate the hardness range of each component.

**11.1.11** Pressure-containing parts subject to steam conditions exceeding gauge pressures of 520 kPa (5,2 bar) (75 psi) or temperatures of 230 °C (450 °F) shall be steel. In the case of the exhaust casing of non-condensing turbines, this shall be based on the maximum specified exhaust pressure and the maximum no-load exhaust temperature. Alloy steels shall be used for maximum steam temperatures exceeding 410 °C (775 °F).

**11.1.12** The material limits for pressure bolting based upon the actual bolting temperature shall be as specified in ISO 15649. Nuts shall conform to ASTM A 194, Grade 2H (or ASTM A 307, Grade B, case-hardened, where space is limited) or better material.

NOTE For the purpose of this provision, ASME B31.3 is equivalent to ISO 15649.

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# SIXTH EDITION, NOVEMBER 2005

**11.1.13** Material for turbine wheels and shafts shall be forged steel. Unless otherwise approved, 11 % to 13 % chromium steel, titanium, or nickel-copper alloy (similar to ASTM B 127) shall be used for nozzles, closing pieces, rotating and stationary blading, shrouding and steam strainers.

**11.1.14** Bearing surfaces (journals and thrust faces) shall be of a material containing less than 2,5 % Cr, to prevent the risk of wire wool type bearing failures.

**11.1.15** Low-carbon steels can be notch-sensitive and susceptible to brittle fracture at ambient or lower temperatures. Therefore, only fully killed, normalized steels made to fine-grain practice shall be used. Steel made to a coarse grain size practice (such as ASTM A 515) shall not be used.

The purchaser shall specify the minimum design metal temperature used to establish impact test and other material requirements.

# ANSI/API STANDARD 612
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**11.2.3** If repairs to castings are necessary, pressure-containing ferrous castings shall not be repaired except as follows.

a) Weldable grades of castings shall be repaired by welding, using a qualified welding procedure (including pre- or post-weld heat treatment or both, when necessary) as specified in Table 3. After major weld repairs, and before hydrostatic testing, the complete casting shall be given a postweld heat treatment to ensure stress relief and continuity of mechanical properties of both weld and parent metal and dimensional stability during subsequent machining.

b) Cast iron may be repaired by plugging within the limits specified in ASTM A 278, ASTM A 395 or ASTM A 536. The holes drilled for plugs shall be carefully examined, using liquid penetrant, to ensure that all defective material has been removed.

c) All repairs that are not covered by the material specifications shall be subject to the purchaser's approval. All major repairs, as defined by the material specifications, shall be recorded (on a drawing, if appropriate) and reported [see 16.2.1.1 g)] as part of the vendor's documentation (11.3.2).

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11.1.6 The purchaser shall specify any corrosive agents exceeding IEC 60045-1 or NEMA SM 23 steam quality requirements present in the steam and in the environment, including constituents that may cause stress corrosion cracking. The vendor should recognize that some steam systems include contaminants such as sodium hydroxide, chlorides, sulfates, phosphates, copper and lead, and should consider these when selecting materials.

11.1.7 If austenitic stainless steel parts exposed to conditions that may promote intergranular corrosion are to be fabricated, hard faced, overlaid or repaired by welding, they shall be made of low-carbon or stabilized grades.

NOTE Overlays or hard surfaces that contain more than 0,10 % carbon can sensitize both low-carbon and stabilized grades of austenitic stainless steel unless a buffer layer that is not sensitive to intergranular corrosion is applied.

11.1.8 Where mating parts such as studs and nuts of austenitic stainless steel or materials with similar galling tendencies are used, they shall be lubricated with an anti-seizure compound of the appropriate temperature specification and compatible with steam.

# ANSI/API STANDARD 612 SIXTH EDITION, NOVEMBER 2005

11.1.9 If the purchaser has specified the presence of hydrogen sulfide in any fluid, materials exposed to that fluid shall be selected in accordance with the requirements of NACE MR0175. Ferrous materials not covered by NACE MR0175 shall not have a yield strength exceeding 620 N/mm2 (90 000 psi) or a hardness exceeding Rockwell C 22. Components that are fabricated by welding shall be postweld heat treated, if required, so that both the welds and the heat-affected zones meet the yield strength and hardness requirements.

In many applications, small amounts of wet $H_2S$ are sufficient to require materials resistant to sulfide stress corrosion cracking. When there are trace quantities of wet $H_2S$ known to be present or if there is any uncertainty about the amount of wet $H_2S$ that may be present, the purchaser should automatically note on the data sheets that materials resistant to sulfide stress corrosion cracking are required.

## ANSI/API STANDARD 612 SIXTH EDITION, NOVEMBER 2005

11.1.10 Unless otherwise specified, the vendor shall list in the proposal all steam path components (valves, seats, blades, shrouds, closing pieces, pins, damping wires, wheels, bolting, and so forth) with a hardness of more than Rockwell C 22. The vendor shall also indicate the hardness range of each component.

11.1.11 Pressure-containing parts subject to steam conditions exceeding gauge pressures of 520 kPa (5,2 bar) (75 psi) or temperatures of 230 °C (450 °F) shall be steel. In the case of the exhaust casing of non-condensing turbines, this shall be based on the maximum specified exhaust pressure and the maximum no-load exhaust temperature. Alloy steels shall be used for maximum steam temperatures exceeding 410 °C (775 °F).

## ANSI/API STANDARD 612 SIXTH EDITION, NOVEMBER 2005

11.1.12 The material limits for pressure bolting based upon the actual bolting temperature shall be as specified in ISO 15649. Nuts shall conform to ASTM A 194, Grade 2H (or ASTM A 307, Grade B, case-hardened, where space is limited) or better material.

NOTE For the purpose of this provision, ASME B31.3 is equivalent to ISO 15649. 11.1.13 Material for turbine wheels and shafts shall be forged steel. Unless otherwise approved, 11 % to 13 % chromium steel, titanium, or nickel-copper alloy (similar to ASTM B 127) shall be used for nozzles, closing pieces, rotating and stationary blading, shrouding and steam strainers.

11.1.14 Bearing surfaces (journals and thrust faces) shall be of a material containing less than 2,5 % Cr, to prevent the risk of wire wool type bearing failures.

11.1.15 Low-carbon steels can be notch-sensitive and susceptible to brittle fracture at ambient or lower temperatures. Therefore, only fully killed, normalized steels made to fine-grain practice shall be used. Steel made to a coarse grain size practice (such as ASTM A 515) shall not be used.

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## 11.2 Castings

11.2.1 Castings shall be sound and free from porosity, hot tears, shrink holes, blow holes, cracks, scale, blisters and similar injurious defects. Surfaces of castings shall be cleaned by sandblasting, shotblasting, chemical cleaning or any other standard method. Mold-parting fins and remains of gates and risers shall be chipped, filed or ground flush.

11.2.2 The use of chaplets in pressure castings shall be held to a minimum. Where chaplets are necessary, they shall be clean and corrosion-free (plating is permitted) and of a composition compatible with the casting.

ANSI/API STANDARD 612 SIXTH EDITION, NOVEMBER 2005

11.2.3 If repairs to castings are necessary, pressure-containing ferrous castings shall not be repaired except as follows.

a) Weldable grades of castings shall be repaired by welding, using a qualified welding procedure (including pre- or post-weld heat treatment or both, when necessary) as specified in Table 3. After major weld repairs, and before hydrostatic testing, the complete casting shall be given a postweld heat treatment to ensure stress relief and continuity of mechanical properties of both weld and parent metal and dimensional stability during subsequent machining.

b) Cast iron may be repaired by plugging within the limits specified in ASTM A 278, ASTM A 395 or ASTM A 536. The holes drilled for plugs shall be carefully examined, using liquid penetrant, to ensure that all defective material has been removed.

c) All repairs that are not covered by the material specifications shall be subject to the purchaser’s approval. All major repairs, as defined by the material specifications, shall be recorded (on a drawing, if appropriate) and reported [see 16.2.1.1 g)] as part of the vendor’s doc

11.2.4 Fully enclosed cored voids, which become fully enclosed by methods such as plugging, welding, or assembly, are prohibited.

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11.2.5 Nodular iron castings shall be produced in accordance with an internationally recognized standard such as ASTM A 395. The production of the castings shall also conform to the conditions specified in a) to e), as follows.

a) The keel or Y-block cast at the end of the pour shall be at least as thick as the thickest section of the main casting. This test block shall be tested for tensile strength and hardness and shall be microscopically examined. Classification of graphite nodules under microscopic examination shall be in accordance with ASTM A 247.

b) If critical sections of a casting have different thicknesses, average size keel or Y blocks may be selected in accordance with ASTM A 395. Minimum quality levels should be agreed upon between the purchaser and the vendor. Critical sections are typically heavy sections, section changes and high-stress points. Normally, bosses and similar sections are not considered critical sections of a casting.

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c) A minimum of one set (three samples) of Charpy V-notch impact specimens at one-third the thickness of the test block shall be made from the material adjacent to the tensile specimen on each keel or Y-block. These specimens shall have a minimum impact value of 12 J (9 ft-lbf) and the mean of the three specimens shall not be less than 14 J (10 ft-lbf) at room temperature.

d) Integrally cast test bosses, preferably at least 25 mm (1 in) in height and diameter, shall be provided at critical areas of the casting for subsequent removal for the purposes of hardness testing and microscopic examination. Critical areas are typically heavy sections, section changes, flanges and other high-stress points as agreed upon by the purchaser and the vendor. Classification of graphite nodules shall be in accordance with ASTM A 247.

# MATERIAL AND EQUIPMENT STANDARD FOR STEAM JET EJECTORS

- HEI (HEAT EXCHANGE INSTITUTE)
  - "Standards for Steam Jet Ejectors"
  - "Standards for Steam Surface Condensers"
  - "Standards for Direct Contact Barometric Low Level Condensers"
  - "Construction Standards for Surface Condensers"
- ASTM (AMERICAN SOCIETY FOR TESTING AND MATERIALS)
- ASME (AMERICAN SOCIETY OF MECHANICAL ENGINEERS)
  - B16.5 "Pipe Flanges & Flanged Fitting"
  - B31.1 "Power Piping"
  - B31.3 "Process Piping"
  - B1.20.1 "Pipe Threads General Purpose (INCH)"
  - PTC 24 "Performance Test Code for Ejectors".
  - Section VIII div. 1 "Rules for Construction of Pressure Vessels"
  - Section IX "Welding and Brazing Qualifications"

# MATERIAL AND EQUIPMENT STANDARD FOR STEAM JET EJECTORS

TYPICAL MATERIALS OF CONSTRUCTION AND ALLOWABLE STRESS VALUES

| Part | Material | Specification | Allowable Stress * |
|---|---|---|---|
| DIFFUSER: | Carbon Steel Plate | ASTM A-36 (except Bessemer Steel) | |
| | | ASTM A-283 | |
| | | ASTM A-285 | |
| | | ASTM A-515 | |
| | Stainless Steel Plate | ASTM A-240 TP 304 | |
| | | ASTM A-240 TP 316 | |
| | Carbon Steel Bar | ASTM A-36 | |
| | | ASTM A-675 | |
| | ** Stainless Steel Bar | ASTM A-276 TP 304 | |
| | | ASTM A-276 TP 316 | |
| | | ASTM A-276 TP 321 | |
| | | ASTM A-276 TP 347 | |
| | ** Cast Iron | ASTM A-48 | 0.1 × Min. Tensile |
| | | ASTM A-278 | 0.1 × Min. Tensile |
| | | ASTM A-395 | 0.1 × Min. Tensile |
| | Cast Steel | ** ASTM A-27 | |
| | | ASTM A-216 | |
| | | ASTM A-217 | |
| | Cast Bronze | ASTM B-62 | |
| | | ASTM B-584 | |
| | Cast Stainless Steel | ** ASTM A-296 | |
| | | ASTM A-351 | |
| | Carbon Steel Forging | ASTM A-105 | |
| | | ASTM A-181 | |

# MATERIAL AND EQUIPMENT STANDARD FOR STEAM JET EJECTORS

| | | |
|---|---|---|
| SUCTION CHAMBER: | Carbon Steel Plate | ASTM A-36 (except Bessemer Steel) |
| | | ASTM A-283 |
| | | ASTM A-285 |
| | | ASTM A-515 |
| | Stainless Steel Plate | ASTM A-240 TP 304 |
| | | ASTM A-240 TP 316 |

| Part | Material | Specification | Allowable Stress * |
|---|---|---|---|
| SUCTION CHAMBER (Continued): | Carbon steel Pipe | ASTM A-53 | |
| | | ASTM A-106 | |
| | Stainless Steel Pipe | ASTM A-312 | |
| | | ASTM A-376 | |
| | ** Cast Iron | ASTM A-48 | 0.1 × Min. Tensile |
| | | ASTM A-278 | 0.1 × Min. Tensile |
| | | ASTM A-395 | 0.1 × Min. Tensile |
| | Cast Steel | ** ASTM A-27 | |
| | | ASTM A-216 | |
| | | ASTM A-217 | |
| | Cast Bronze | ASTM B-62 | |
| | | ASTM B-584 | |
| | Cast Stainless Steel | ** ASTM A-296 | |
| | | ASTM A-351 | |
| | Carbon Steel Forging | ASTM A-105 | |
| | | ASTM A-181 | |
| | Carbon Steel Wrought | ASTM A-234 | |
| | Stainless Steel Wrought | ASTM A-403 TP 304 | |
| | | ASTM A-403 TP 316 | |

# MATERIAL AND EQUIPMENT STANDARD FOR STEAM JET EJECTORS

| | | | |
|---|---|---|---|
| NOZZLE: | Stainless Steel Bar | ** ASTM A-276 TP 304 | |
| | | ** ASTM A-276 TP 316 | |
| | | ** ASTM A-276 TP 321 | |
| | | ** ASTM A-276 TP 347 | |
| | | ASTM A-479 TP 316 | |
| | | **ASTM A-482 TP 303 | |
| | | ** ASTM A-582 TP 416 | |
| | Stainless Steel Plate | ASTM A-240 TP 304 | |
| | | ASTM A-240 TP 316 | |
| | | ASTM A-240 TP 416 | |
| | Nickel Copper | ASTM B-164 | (to be continued) |

| Part | Material | Specification | Allowable Stress * |
|---|---|---|---|
| STEAM CHEST: | Carbon Steel Bar | ASTM A-36 | |
| | | ASTM A-675 | |
| | Steel Pipe | ASTM A-53 | |
| | | ASTM A-106 | |
| | | ASTM A-335 | |
| | Cast Steel | ASTM A-216 | |
| | | ASTM A-217 | |
| | Cast Stainless Steel | ASTM A-296 | |
| | | ASTM A-351 | |
| | Carbon Steel Forging | ASTM A-105 | |
| | | ASTM A-181 | |
| | Low Alloy Steel Forging | ASTM A-182 F-11 | |
| | | ASTM A-182 F-22 | |
| | Stainless Steel Forging | ASTM A-182 F-316 | |
| | | ASTM A-182 F-321 | |
| | | ASTM A-182 F-347 | |
| | Cast Bronze | ASTM B-62 | |
| | | ASTM B-584 | |

# MATERIAL AND EQUIPMENT STANDARD FOR STEAM JET EJECTORS

| | | |
|---|---|---|
| **EXTENSION:** | Stainless Steel Bar | **ASTM A-276 TP 304 |
| | | **ASTM A-276 TP 316 |
| | | **ASTM A-276 TP 321 |
| | | **ASTM A-276 TP 347 |
| | | ASTM A-479 TP 316 |
| | | **ASTM A-482 TP 303 |
| | | **ASTM A-582 TP 416 |
| **STEAM PIPING:** | Steel pipe | ASTM A-53 |
| | | ASTM A-106 |
| | | ASTM A-335 |
| | Stainless Steel Pipe | ASTM A-312 |
| | | ASTM A-376 |
| | Carbon Steel Forging | ASTM A-105 |
| | | ASTM A-181 |

(to be continued)

# MATERIAL AND EQUIPMENT STANDARD FOR STEAM JET EJECTORS

| Part | Material | Specification | Allowable Stress * |
|---|---|---|---|
| STEAM PIPING: (Continued): | Low Alloy Steel Forging | ASTM A-182 F-11 | |
| | | ASTM A-182 F-22 | |
| | Stainless Steel Forging | ASTM A-182 F-316 | |
| | | ASTM A-182 F-321 | |
| | | ASTM A-182 F-347 | |
| VAPOR PIPING: | Carbon Steel Pipe | ASTM A-53 | |
| | | ASTM A-106 | |
| | Carbon Steel Wrought | ASTM A-234 | |
| | Carbon Steel Plate | ASTM A-285 Gr C | |
| FASTENERS: | Bolts | ASTM A-193 | |
| | | ASTM A-325 | |
| | Nuts | ASTM A-194 | |
| | | ASTM A-325 | |

* Allowable Stress Values should be taken from Section VIII, Division I of the ASME Pressure Vessel Code, except where noted (**).

** Allowable Stress Values used should conform to accepted engineering practice.

# LIQUID RING VACUUM PUMP

## Accessories

- *Inlet non-return valve*
- *Inlet isolating valve*
- *Inlet vacuum gauge*
- *Vacuum relief valve*
- *Automatic seal water make-up kit*
- *Custom built and hybrid vacuum pump systems available*

## Materials of construction

| | | Standard | Stainless Steel | Stainless Steel |
|---|---|---|---|---|
| Pump | Casing | Cast Iron | CF8M | Cast Iron |
| | Impeller | Bronze | CF8M | CF8M |
| | Port plates | Cast Iron | CF8M | Cast Iron |
| | Body | Cast Iron | CF8M | Cast Iron |
| | Shaft | 420S27 | 420S38 | 420S39 |
| | Mechanical seal | Carbon/Silicon Carbide/Viton | Carbon/Silicon Carbide/Viton | Carbon/Silicon Carbide/Viton |
| Components | Discharge separator | Stainless Steel | Stainless Steel | Stainless Steel |
| | Piping | Stainless Steel | Stainless Steel | Stainless Steel |
| | Fittings & Valves | Stainless Steel | Stainless Steel | Stainless Steel |
| | Heat exchanger | Stainless Steel | Stainless Steel | Stainless Steel |

# API 6D: SPECIFICATION FOR PIPELINE VALVE 49 CFR 195.116

**8.4 Composition limits**

The chemical composition of carbon steel pressure-containing and pressure-controlling parts shall be in accordance with the applicable material standards.

The chemical composition of carbon steel welding ends shall meet the following requirements unless otherwise agreed.

— The carbon content shall not exceed 0,23 % by mass.

— The sulfur content shall not exceed 0,035 % by mass.

— The phosphorus content shall not exceed 0,035 % by mass.

— The carbon equivalent, CE, shall not exceed 0,43 %.

# API 6D: SPECIFICATION FOR PIPELINE VALVE 49 CFR 195.116

The CE shall be calculated in accordance with Equation (2)[6]:

$$CE = \% C + \% Mn/6 + (\% Cr + \% Mo + \% V)/5 + (\% Ni + \% Cu)/15 \quad (2)$$

The chemical composition of other carbon steel parts shall be in accordance with the applicable material standards.

The carbon content of austenitic stainless steel welding ends shall not exceed 0,03 % by mass, except for stabilized material in which case a carbon content of up to 0,08 % by mass is permissible.

The chemical composition of other materials shall be established by agreement.

# API 6D: SPECIFICATION FOR PIPELINE VALVE 49 CFR 195.116

## 8.5 Toughness test requirements

All carbon, alloy steels and non-austenitic stainless steel for pressure-containing parts in valves shall meet the toughness test requirements of the applicable pipeline design standard.

All carbon, alloy steels and non-austenitic stainless steel for pressure-containing parts in valves with a specified design temperature below – 29 °C (– 20 °F) shall be impact-tested using the Charpy V-notch technique in accordance with ISO 148-1 or ASTM A370.

NOTE Design standards or local requirements can require impact testing for minimum design temperatures higher than – 29 °C (– 20 °F).

A minimum of one impact test, comprised of a set of three specimens, shall be performed on a representative test bar of each heat of the material in the final heat-treated condition.

Test specimens shall be cut from a separate or attached block taken from the same heat, reduced by forging where applicable, and heat-treated to the same heat treatment, including stress-relieving, as the product materials, except that it is not necessary to retest pressure-containing parts stress-relieved at or below a previous stress-relieving or tempering temperature.

The impact test shall be performed at the lowest temperature as defined in the applicable material specifications and pipeline design standard.