

DIN EN ISO 10437

ICS 27.040; 75.180.20

Einsprüche bis 2009-12-26
Vorgesehen als Ersatz für
DIN EN ISO 10437:2005-07

Entwurf

**Erdöl-, petrochemische und Erdgasindustrie –
Dampfturbinen –
Spezial-Einsatzbereiche (ISO/DIS 10437:2009);
Englische Fassung prEN ISO 10437:2009, nur auf CD-ROM**

Petroleum, petrochemical and natural gas industries –
Steam turbines –
Special-purpose applications (ISO/DIS 10437:2009);
English version prEN ISO 10437:2009, only on CD-ROM

Industries du pétrole, de la pétrochimie et du gaz naturel –
Turbines à vapeur –
Usage spécial (ISO/DIS 10437:2009);
Version anglaise prEN ISO 10437:2009, seulement en CD-ROM

Anwendungswarnvermerk

Dieser Norm-Entwurf mit Erscheinungsdatum 2009-10-26 wird der Öffentlichkeit zur Prüfung und Stellungnahme vorgelegt.

Weil die beabsichtigte Norm von der vorliegenden Fassung abweichen kann, ist die Anwendung dieses Entwurfes besonders zu vereinbaren.

Stellungnahmen werden erbeten

- vorzugsweise als Datei per E-Mail an noeg@din.de in Form einer Tabelle. Die Vorlage dieser Tabelle kann im Internet unter www.din.de/stellungnahme abgerufen werden;
- oder in Papierform an den Normenausschuss Erdöl- und Erdgasgewinnung (NÖG) im DIN, 10772 Berlin (Hausanschrift: Burggrafenstr. 6, 10787 Berlin).

Die Empfänger dieses Norm-Entwurfs werden gebeten, mit ihren Kommentaren jegliche relevante Patentrechte, die sie kennen, mitzuteilen und unterstützende Dokumentationen zur Verfügung zu stellen.

Gesamtumfang 159 Seiten

Normenausschuss Erdöl- und Erdgasgewinnung (NÖG) im DIN

Nationales Vorwort

Dieses Dokument (prEN ISO 10437:2009) wurde vom Technischen Komitee CEN/TC 12 „Materialien, Ausrüstungen und Offshore-Bauwerke für die Erdöl-, petrochemische und Erdgasindustrie“ erarbeitet, dessen Sekretariat vom AFNOR (Frankreich) gehalten wird. Es handelt sich dabei um die unveränderte Übernahme von ISO/DIS 104NA.27:2009, erarbeitet vom ISO/TC 67/SC 6/WG 3 „Steam turbines“.

Das zuständige deutsche Gremium ist der NA 109-00-01 AA „Materialien, Ausrüstungen und Offshore-Bauwerke für die Erdöl-, petrochemische und Erdgasindustrie“ im Normenausschuss Erdöl- und Erdgasgewinnung (NÖG).

Dieser europäische Norm-Entwurf enthält unter Berücksichtigung des DIN-Präsidialbeschlusses 1/2004 nur die englische Originalfassung der ISO-Norm.

Dieser Norm-Entwurf enthält neben den gesetzlichen Einheiten auch die Einheiten „inch“, „mil“, „lb“, die im Deutschen Normenwerk nicht zugelassen sind. Es wird jedoch ausdrücklich darauf hingewiesen, dass die Anwendung dieser Einheiten im nationalen amtlichen und geschäftlichen Verkehr aufgrund des Gesetzes über Einheiten im Messwesen nicht zulässig ist.

Nicht-SI-Einheit	SI-Einheit	Umrechnung
in (inch)	mm	1 inch = 25,4 mm
mil	µm	1 mil = 26 µm
r/min	min ⁻¹	1 r/min = 1 min ⁻¹

Für die im Abschnitt 2 zitierten Internationalen Normen wird im Folgenden auf die entsprechenden Deutschen Normen hingewiesen:

ISO 7-1	siehe	DIN EN 10226-1
ISO 261	siehe	DIN ISO 261
ISO 262	siehe	DIN ISO 262
ISO 724	siehe	DIN 13 (alle Teile), DIN ISO 724
ISO 965 (all parts)	siehe	DIN ISO 965 (alle Teile)
ISO 1940-1	siehe	DIN ISO 1940-1
ISO 3744	siehe	DIN 45635-1, DIN EN ISO 3774
ISO 6708	siehe	DIN EN ISO 6708
ISO 8501-1	siehe	DIN EN ISO 8501-1,
ISO 8821	siehe	DIN ISO 8821
ISO 10438 (all parts)	siehe	DIN EN ISO 10438 (alle Teile)
ISO 10441	siehe	DIN EN ISO 10441
ISO 13691	siehe	DIN EN ISO 13691

Änderungen

Gegenüber DIN EN ISO 10437:2005-07 wurden folgende Änderungen vorgenommen:

- a) Bezug zu API Std 612 aus Einleitung entfernt;
- b) Formulierung im Anwendungsbereich geändert;
- c) Normative Verweisungen: ISO 6708 und API RP 684 hinzugefügt;
- d) Abschnitt 4 „Dimensions“ in neuen Abschnitt 4 „General“ eingegliedert;
- e) Abschnitt NA.2 „Terms and definitions“, Abschnitt 5 „Statutory requirements“, Abschnitt 7 „Casings“, Abschnitt 8 „Rotating elements“, Abschnitt 10 „Bearings bearing housings, and seals“, Abschnitt 11 „Materials“, Abschnitt 15 „Accessoires“, Abschnitt 16 „Inspection, testing and preparation for shipment“, Abschnitt 17 „Vendor's information“ inhaltlich erweitert;
- f) Abschnitt 6.1 und 6.2 Unterpunkte hinzugefügt bzw. entfernt sowie Werte in Tabelle 1 geändert;
- g) Abschnitt 9 „Rotor dynamics“, Abschnitt 12 „Controls and instrumentation“ inhaltlich erweitert und Bilder überarbeitet;
- h) Abschnitt 14 „Piping and appurtenances“ inhaltlich erweitert und Tabelle 5 „Minimum Requirements for Piping Materials“ hinzugefügt;
- i) Anhang D „Alarm and shutdown systems“, Anhang E „Coupling guards“ und Anhang F „Foundation drawings“ entfernt;
- j) Anhang D „Calculation of the maximum rotor speed during an overspeed trip“, Anhang E „Mounting Plate Arrangements“ und Anhang J „Typical material specifications“ neu hinzugefügt;
- k) Anhang J „Vendor drawing and data requirements (VDDR)“ wird zu Anhang I;
- l) Anhang I „Inspector's checklist“ wird zu Anhang h;
- m) Anhang h „Typical inspection of components“ wird zu Anhang g;
- n) Anhang g „Gland sealing an leak-off system“ wird zu Anhang f.

Nationaler Anhang NA (informativ)

Allgemeine Hinweise und Begriffe

NA.1 Allgemeines

Diese Internationale Norm legt die Mindestanforderungen an Dampfturbinen für besondere Anwendungen zum Einsatz in der petrochemischen Industrie sowie der Erdöl- und Erdgasindustrie fest. Diese Anforderungen umfassen die Grundausrüstung, Werkstoffe, Herstellung, Abnahmeprüfungen sowie die Vorbereitung zum Versand. Sie behandelt außerdem die zugehörigen Schmierölsysteme, die Geräteausstattung, Regelungseinrichtungen und Zusatzgeräte. Sie gilt nicht für Dampfturbinen für allgemeine Anwendungen, die in API Std 611 behandelt werden.

NA.2 Begriffe

Für die Anwendung dieses Dokuments gelten die folgenden Begriffe. (Für einen Leitfaden zur Terminologie für Dampfturbinen, siehe Anhang B).

NA.2.1

Alarmpunkt

voreingestellter Wert eines gemessenen Parameters, bei dessen Erreichung ein Alarm ausgelöst wird, um auf einen Zustand hinzuweisen, der ein Eingreifen erfordert

NA.2.2

Ankerbolzen

Bolzen, die der Befestigung der Montageplatte an der Stützkonstruktion oder dem Fundament dienen

NA.2.3

axial geteilt

so geteilt, dass die Hauptverbindung parallel zur Wellenachse verläuft

NA.2.4

Fundamentplatte

vorgefertigte Stahlkonstruktion, die als Halterung der vollständigen Dampfturbine und/oder der angetriebenen Ausrüstung und weiterer Zusatzgeräte, die darauf montiert sein können, vorgesehen ist

NA.2.5

Regelungsmechanismus

alle Geräte zwischen dem Drehzahlregler und dem/den durch den Drehzahlregler gesteuerten Ventil(en) (z. B. Kopplungen, Steuerventile, Servoregler usw.)

NA.2.6

kritische Drehzahl

Drehzahl der Welle, bei der sich das Rotorlager-Halterungssystem im Zustand der Resonanz befindet

NA.2.7

Auslegung

vom Hersteller berechnete Parameter

ANMERKUNG Das ist ein Begriff, der vom Hersteller zur Beschreibung verschiedener Parameter, wie z. B. Auslegungsleistung, Auslegungsdruck, Auslegungstemperatur oder Auslegungsdrehzahl verwendet wird. Es ist nicht vorgesehen, dass dieser Begriff vom Kunden verwendet wird.

NA.2.8**Gehäuse**

Raum, der als Schallschutz und/oder Wetterschutz vorgesehen ist

ANMERKUNG Der Raum kann Wände, Türen und ein Dach umfassen.

NA.2.9**störungssicheres System**

System, mit dem die Einrichtung bei Versagen eines Bauteiles oder bei Versagen der Energiezufuhr zum System veranlasst wird, zu einem sicheren Dauerzustand zurückzukehren (Abschaltung und/oder druckloser Zustand)

NA.2.10**vor Ort veränderbar**

Konstruktionsmerkmal, durch das die Änderung einer Funktion nach Einbau der Einrichtung möglich ist

ANMERKUNG Die Änderung kann durch Folgendes vorgenommen werden:

- a) durch Anlöten von Überbrückungskabeln an speziell zu diesem Zweck angebrachte Anschlussstifte;
- b) durch Benutzung von auf einer Leiterplatte montierten Schaltern oder Potentiometern;
- c) durch Verwendung einer Kurzschluss- oder Pin-Dioden-Matrixkarte;
- d) durch Verwendung vorverdrahteter Kurzschluss-Stecker;
- e) durch Anwendung von Zugriffsberechtigungen.

NA.2.11**Messgeräteplatte**

Halterung oder Platte, die zum Halten und Ausstellen von Messgeräten, Schaltern und weiteren Geräten vorgesehen ist

ANMERKUNG Eine Messgeräteplatte ist offen und nicht umschlossen. Eine Schalttafel ist üblicherweise vollständig verkleidet.

NA.2.12**Turbine für allgemeine Anwendungen**

horizontale oder vertikale Turbinen, die zum Antrieb von üblicherweise redundant vorgehaltenen Ausrüstungen dienen

ANMERKUNG Dampfturbinen für allgemeine Anwendungen sind für Einsatzbereiche vorgesehen, bei denen der Eingangsdruck am Druckmessgerät 4 800 kPa (48 bar) (700 psi) nicht überschreitet, die Eintrittstemperatur nicht mehr als 400°C (750 °F) beträgt und die Drehzahl nicht höher ist als 6 000 U/min.

NA.2.13**durch den Drehzahlregler gesteuertes Ventil**

Gerät, das den Dampfstrom in die oder aus der Turbine als Reaktion auf den Drehzahlregler regelt

NA.2.14**Niederhaltebolzen**

Befestigungsbolzen

Bolzen, die das Gerät auf der/den Montageplatte(n) halten

NA.2.15**hydrodynamische Lager**

Lager, die die Prinzipien der hydrodynamischen Schmierung nutzen

ANMERKUNG Die Oberflächen der Lager sind so ausgerichtet, dass sich bei einer Bewegung relativ zueinander ein Ölkeil oder Ölkeile bildet/bilden, um die Last ohne einen Kontakt der Welle mit dem Lager zu tragen.

NA.2.16**informativ**

nur zu Informationszwecken

ANMERKUNG Eine informative Verweisung oder ein informativer Anhang enthält empfehlende oder erklärende Informationen. Er/sie ist dazu vorgesehen, das Verständnis oder die Anwendung des Dokumentes zu unterstützen.

NA.2.17**innere Reibungsdämpfung**

Dämpfungswirkung, die in jedem Werkstoff unter zyklischer Belastung zu einer Phasenverschiebung zwischen der Spannung und der Dehnung führt

ANMERKUNG Diese Phasenverschiebung verursacht die charakteristische Hystereseschleife im Spannungs-Dehnungs-Diagramm und ist somit eine destabilisierende Dämpfungskraft.

NA.2.18**örtlich angebracht**

〈Gerät〉, das auf oder in der Nähe der Anlage oder Ausrüstung angebracht ist

NA.2.19**Hersteller**

Organisation, die für die Konstruktion und Herstellung der Ausrüstung verantwortlich ist

ANMERKUNG Der Hersteller ist oftmals eine andere Organisation als der Verkäufer.

NA.2.20**maximal zulässige Geschwindigkeit**

höchste Geschwindigkeit, bei der die vom Hersteller vorgelegte Bauausführung einen Dauerbetrieb zulässt

ANMERKUNG Die maximal zulässige Geschwindigkeit ist üblicherweise durch die Spannungswerte des Rotationselementes festgelegt.

NA.2.21**maximal zulässige Temperatur**

maximale konstante Temperatur, für die der Hersteller die Ausrüstung (oder ein beliebiges Teil, auf das sich der Begriff bezieht) beim Umgang mit dem festgelegten Fluid unter den festgelegten Betriebsbedingungen ausgelegt hat

NA.2.22**maximal zulässiger Betriebsdruck**

maximaler konstanter Druck, für den der Hersteller die Ausrüstung (oder ein beliebiges Teil, auf das sich der Begriff bezieht) beim Umgang mit dem festgelegten Fluid bei der maximal zulässigen Temperatur ausgelegt hat

NA.2.23**maximale Dauerleistungs-Drehzahl**

höchste Drehzahl, bei der die Turbine wie gebaut und geprüft bei jedem der festgelegten Dampfzustände zu einem Dauerbetrieb in der Lage ist

NA.2.24**maximaler Auslassgehäusedruck**

vom Kunden geforderter höchster Abdampfdruck, den das Gehäuse aufnehmen muss, wobei der Dampf unter maximalen Einlassbedingungen zugeführt wird

ANMERKUNG Das Turbinengehäuse wird unter diesen Bedingungen der maximalen Temperatur und dem maximalen Druck ausgesetzt.

NA.2.25

maximaler Abgasdruck

höchster Abdampfdruck, bei dem die Turbine im Dauerbetrieb arbeiten können muss

NA.2.26

maximaler Eingangsdruck und maximale Eingangstemperatur

höchste Eingangsdampfdruck- und Temperaturbedingungen, unter denen die Turbine im Dauerbetrieb arbeiten können muss

NA.2.27

maximaler Abdichtungsdruck

höchster Druck, dem die Dichtungen unter allen festgelegten Stillstands- oder Betriebsbedingungen und während des An- und Abfahrens standhalten müssen

NA.2.28

kleinste zulässige Geschwindigkeit

niedrigste Geschwindigkeit, bei der die vom Hersteller vorgelegte Bausausführung einen Dauerbetrieb zulässt

NA.2.29

Mindest-Abgasdruck

niedrigster Abdampfdruck, bei dem die Turbine im Dauerbetrieb arbeiten können muss

NA.2.30

Mindesteingangsdruck und Mindesteingangstemperatur

niedrigste Eingangsdampfdruck- und Temperaturbedingungen, unter denen die Turbine im Dauerbetrieb arbeiten können muss

NA.2.31

Montageplatte

Ausrüstung, die zur Befestigung der Anlage an Betonfundamenten/Baustahl dient

ANMERKUNG Die Montageplatte enthält Fundamentplatten und Grundplatten.

NA.2.32

Rohr-Nennweite (NPS)

Dimensionsloser Wert, der etwa dem Durchmesser in Zoll entspricht

NA.2.33

üblicher Betriebspunkt

Punkt, an dem im Allgemeinen der Betrieb erwartet und ein optimaler Wirkungsgrad gewünscht wird

ANMERKUNG Üblicherweise ist es der Punkt, für den der Verkäufer bescheinigt, dass das Betriebsverhalten innerhalb der in dieser Internationalen Norm angegebenen Toleranzen liegt.

NA.2.34

normativ

erforderlich

ANMERKUNG Eine normative Verweisung oder ein normativer Anhang legt eine Anforderung oder eine Anweisung der Spezifikation fest.

NA.2.35

beobachtet (Prüfung oder Kontrolle)

Kontrolle oder Prüfung, bei der dem Kunden der Zeitpunkt der Kontrolle oder Prüfung mitgeteilt wird und die Kontrolle oder Prüfung planmäßig durchgeführt wird, selbst wenn der Kunde oder sein Vertreter nicht anwesend ist

NA.2.36**Eigentümer**

endgültiger Abnehmer der Anlage

ANMERKUNG Der Eigentümer kann die Beschaffung der Anlage einem Vermittler übertragen.

NA.2.37**Schalttafel**

Gehäuse, das der Montage, Ausstellung und dem Schutz von Messgeräten, Schaltern und weiteren Geräten dient

NA.2.38**potenzielle maximale Leistung**

annähernde Höchstleistung, bis zu der die Turbinenleistung unter den festgelegten üblichen Drehzahl- und Dampfbedingungen steigen kann, wenn die Turbine mit geeigneten (d. h. größeren oder zusätzlichen) Düsen und nach Möglichkeit mit einem größeren durch den Drehzahlregler gesteuerten Ventil oder mehreren derartigen Ventilen ausgestattet ist

NA.2.39**Druckgehäuse**

Umgrenzung für alle ortsfesten drucktragenden Teile der Einheit unter Einbeziehung aller Stutzen und aller sonstigen an der Einheit angebrachten Teile

NA.2.40**Käufer**

Organisation die dem Verkäufer den Auftrag erteilt und die Spezifikation anfordert

ANMERKUNG Der Käufer kann der Eigentümer der Anlage sein, in die die Ausrüstung eingebaut werden soll oder der vom Eigentümer ernannte Vertreter.

NA.2.41**radial geteilt**

so geteilt, dass die Hauptverbindung senkrecht zur Wellenachse verläuft

NA.2.42**Nennleistung**

größte festgelegte Leistung der Turbine und ihre zugehörige Drehzahl; darin enthalten ist der gesamte in den Spezifikationen der angetriebenen Anlagen geforderte Leistungsbereich

NA.2.43**Nenngeschwindigkeit****100%ige Geschwindigkeit**

höchste Drehgeschwindigkeit, die erforderlich ist, um allen festgelegten Betriebsbedingungen zu entsprechen

NA.2.44**Abblaseventil-Einstelldruck**

Druck, bei dem das Abblaseventil beginnt, sich zu heben

NA.2.45**ferngesteuert**

〈Gerät〉, das von der Anlage oder Ausrüstung entfernt angeordnet ist, üblicherweise in einem Steuerraum

NA.2.46**muss**

erforderlich, um der Festlegung zu entsprechen

NA.2.47

sollte

empfohlen, aber nicht erforderlich, um der Festlegung zu entsprechen

NA.2.48

Trenngrenze

Abstand zwischen einer kritischen Drehzahl und der nächsten erforderlichen Betriebsdrehzahl

NA.2.49

Sollwert für die Abschaltung

voreingestellter Wert eines gemessenen Parameters, bei dessen Erreichen eine automatische oder manuelle Abschaltung des Systems oder der Anlage erforderlich ist

NA.2.50

langsames Anfahren

vom Verkäufer empfohlene Drehzahl (üblicherweise 400 U/min bis 500 U/min) für die Anlaufphase und die erste Überprüfung der Unversehrtheit der Ausrüstung vor dem Vollbetrieb

NA.2.51

Turbinen für besondere Anwendungen

horizontale Turbinen, die zum Antrieb von üblicherweise nicht redundant vorgehaltenen Ausrüstungen dienen und im ununterbrochenen Dauerbetrieb in kritischen Einsatzbereichen eingesetzt werden

ANMERKUNG Diese Kategorie wird nicht durch Dampfbedingungen, Leistung oder die Turbinendrehzahl eingeschränkt.

NA.2.52

Spezialwerkzeug

Werkzeug, das kein handelsüblicher Katalogartikel ist

NA.2.53

Stabilitätsanalyse

Ermittlung der Eigenfrequenzen und der zugehörigen logarithmischen Dekremente des gedämpften Rotors/Haltesystems durch Anwendung einer komplexen Eigenwertanalyse

NA.2.54

Stufe

ein Satz feststehender und rotierender Schaufelgitter

NA.2.55

Stand-by-Betrieb

Betriebsart, in der ein Teil der Ausrüstung üblicherweise stillsteht oder sich im Leerlauf befindet, jedoch zu einem unverzüglichen automatischen oder manuellen Anfahren und zum Dauerbetrieb in der Lage ist

NA.2.56

synchroner Kippsegment-Beiwert

aus den komplexen frequenzabhängigen Beiwerten abgeleiteter Beiwert, wobei die Frequenz der Drehgeschwindigkeit der Welle entspricht

NA.2.57

Dampfrate

von der Turbine benötigte Dampfmenge je Leistungseinheit, gemessen an der Abgangswelle der Turbine

NA.2.58

Abschaltdrehzahl

Drehzahl, bei der das unabhängige Überdrehzahl-Abschaltsystem anspricht, um eine Turbine abzuschalten

ANMERKUNG Die Abschaltdrehzahl wird üblicherweise in Umdrehungen je Minute angegeben.

NA.2.59**Anlagenverantwortlichkeit**

Verantwortung für die Koordination der technischen Aspekte der Ausrüstung und aller Hilfssysteme, die zum Auftragsumfang gehören

ANMERKUNG Die zu berücksichtigenden technischen Aspekte umfassen solche Faktoren wie z. B. Leistungsanforderungen, Drehzahl, Rotation, Gesamtanordnung, Koppelungen, Dynamik, Störanfälligkeit, Auswahl der Schmiermittel, Messgeräteausrüstung, Verrohrung, Prüfung von Bauteilen, Übereinstimmung mit Spezifikationen und Werkstoffprüfberichten, sind jedoch nicht allein darauf beschränkt.

5.60**Verkäufer****Lieferant**

Partei, die die Ausrüstung als Reaktion auf die Bestellung liefert

ANMERKUNG Der Verkäufer kann der Hersteller der Ausrüstung oder der Vertreter des Herstellers sein und ist üblicherweise für Wartungsleistungen zuständig.

NA.2.61**überwacht**

Kontrolle oder Prüfung, bei der der Käufer anwesend ist

ANMERKUNG Der Produktionsplan wird angehalten und die Kontrolle oder Prüfung wird in Anwesenheit des Käufers oder seines Vertreters durchgeführt.

Nationaler Anhang NB (informativ)

Literaturhinweise

DIN 13-1, *Metrisches ISO-Gewinde allgemeiner Anwendung — Teil 1: Nennmaße für Regelgewinde; Gewinde-Nenndurchmesser von 1 mm bis 68 mm*

DIN 13-2, *Metrisches ISO-Gewinde allgemeiner Anwendung — Teil 2: Nennmaße für Feingewinde mit Steigungen 0, 2 mm, 0, 25 mm und 0, 35 mm; Gewinde-Nenndurchmesser von 1 mm bis 50 mm*

DIN 13-3, *Metrisches ISO-Gewinde allgemeiner Anwendung — Teil 3: Nennmaße für Feingewinde mit Steigung 0, 5 mm; Gewinde-Nenndurchmesser von 3, 5 mm bis 90 mm*

DIN 13-4, *Metrisches ISO-Gewinde allgemeiner Anwendung — Teil 4: Nennmaße für Feingewinde mit Steigung 0, 75 mm; Gewinde-Nenndurchmesser von 5 mm bis 110 mm*

DIN 13-5, *ISO-Gewinde allgemeiner Anwendung — Teil 5: Nennmaße für Feingewinde mit Steigungen 1 mm und 1, 25 mm; Gewinde-Nenndurchmesser von 7, 5 mm bis 200 mm*

DIN 13-6, *Metrisches ISO-Gewinde allgemeiner Anwendung — Teil 6: Nennmaße für Feingewinde mit Steigung 1, 5 mm; Gewinde-Nenndurchmesser von 12 mm bis 300 mm*

DIN 13-7, *Metrisches ISO-Gewinde allgemeiner Anwendung — Teil 7: Nennmaße für Feingewinde mit Steigung 2 mm; Gewinde-Nenndurchmesser von 17 mm bis 300 mm*

DIN 13-8, *Metrisches ISO-Gewinde allgemeiner Anwendung — Teil 8: Nennmaße für Feingewinde mit Steigung 3 mm; Gewinde-Nenndurchmesser von 28 mm bis 300 mm;*

DIN 13-9, *Metrisches ISO-Gewinde allgemeiner Anwendung — Teil 9: Nennmaße für Feingewinde mit Steigung 4 mm; Gewinde-Nenndurchmesser von 40 mm bis 300 mm*

DIN 13-10, *Metrisches ISO-Gewinde allgemeiner Anwendung — Teil 10: Nennmaße für Feingewinde mit Steigung 6 mm; Gewinde-Nenndurchmesser von 70 mm bis 500 mm*

DIN 13-11, *Metrisches ISO-Gewinde allgemeiner Anwendung — Teil 11: Nennmaße für Feingewinde mit Steigung 8 mm; Gewinde-Nenndurchmesser von 130 mm bis 1 000 mm*

DIN 45635-1, *Geräuschmessung an Maschinen — Luftschallemission, Hüllflächen-Verfahren — Rahmenverfahren für 3 Genauigkeitsklassen*

DIN EN 10226-1, *Rohrgewinde für im Gewinde dichtende Verbindungen — Teil 1: Kegelige Außengewinde und zylindrische Innengewinde — Maße, Toleranzen und Bezeichnung*

DIN EN ISO 10438-1, *Erdöl-, petrochemische und Erdgasindustrie — Schmieröl-, Sperröl- und Regelölversorgungsanlagen und Hilfsanlagen — Teil 1: Allgemeine Anforderungen*

DIN EN ISO 10348-2, *Erdöl-, petrochemische und Erdgasindustrie — Schmieröl-, Sperröl- und Regelölversorgungsanlagen und Hilfsanlagen — Teil 2: Ölversorgungsanlagen für besondere Anwendungsfälle*

DIN EN ISO 10438-3, *Erdöl-, petrochemische und Erdgasindustrie — Schmieröl-, Sperröl- und Regelölversorgungsanlagen und Hilfsanlagen — Teil 3: Ölversorgungsanlagen für allgemeine Anwendungsfälle*

DIN EN ISO 10438-4, *Erdöl-, petrochemische und Erdgasindustrie — Schmieröl-, Sperröl- und Regelölversorgungsanlagen und Hilfsanlagen — Teil 4: Sperrgasversorgungsanlagen*

DIN EN ISO 10441, *Erdöl- und Erdgasindustrie — Nachgiebige Kupplungen zur mechanischen Kraftübertragung — Besondere Anwendungsfälle*

DIN EN ISO 13691, *Erdöl- und Erdgasindustrie — Schnellaufgetriebe für spezielle Anwendungen;*

DIN EN ISO 3744, *Akustik — Bestimmung der Schalleistungspegel von Geräuschquellen aus Schalldruckmessungen — Hüllflächenverfahren der Genauigkeitsklasse 2 für ein im wesentlichen freies Schallfeld über einer reflektierenden Ebene*

DIN EN ISO 6708, *Rohrleitungsteile — Definition und Auswahl von DN (Nennweite)*

DIN EN ISO 8501-1, *Vorbereitung von Stahloberflächen vor dem Auftragen von Beschichtungsmitteln — Visuelle Beurteilung der Oberflächenreinheit — Teil 1: Rostgrade und Oberflächenvorbereitungsgrade von unbeschichteten Stahloberflächen und Stahloberflächen nach ganzflächigem Entfernen vorhandener Beschichtungen*

DIN ISO 1940-1, *Mechanische Schwingungen — Anforderungen an die Auswuchtgüte von Rotoren in konstantem (starrem) Zustand — Teil 1: Festlegung und Nachprüfung der Unwuchttoleranz*

DIN ISO 261, *Metrisches ISO-Gewinde allgemeiner Anwendung — Übersicht*

DIN ISO 262, *Metrisches ISO-Gewinde allgemeiner Anwendung — Auswahlreihen für Schrauben, Bolzen und Muttern*

DIN ISO 724, *Metrische ISO-Gewinde allgemeiner Anwendung — Grundmaße*

DIN ISO 8821, *Mechanische Schwingungen; Vereinbarung über die Paßfeder-Art beim Auswuchten von Wellen und Verbundteilen*

DIN ISO 965-1, *Metrisches ISO-Gewinde allgemeiner Anwendung — Toleranzen - Teil 1: Prinzipien und Grundlagen*

DIN ISO 965-2, *Metrisches ISO-Gewinde allgemeiner Anwendung — Toleranzen - Teil 2: Grenzmaße für Außen- und Innengewinde allgemeiner Anwendung; Toleranzklasse mittel*

DIN ISO 965-3, *Metrisches ISO-Gewinde allgemeiner Anwendung — Toleranzen — Teil 3: Grenzabmaße für Konstruktionsgewinde*

DIN ISO 965-4, *Metrisches ISO-Gewinde allgemeiner Anwendung — Toleranzen — Teil 4: Grenzmaße für feuerverzinkte Außengewinde, passend für Innengewinde der Toleranzfeldlagen H oder G nach Aufbringung des Überzuges*

DIN ISO 965-5, *Metrisches ISO-Gewinde allgemeiner Anwendung — Toleranzen — Teil 5: Grenzmaße für Innengewinde, passend für feuerverzinkte Außengewinde mit Höchstmaßen der Toleranzfeldlage h vor Aufbringung des Überzuges*

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English Version

**Petroleum, petrochemical and natural gas industries —
Steam turbines —
Special-purpose applications
(ISO/DIS 10437:2009)**

Industries du pétrole, de la pétrochimie et du gaz naturel —
Turbines à vapeur —
Usage spécial
(ISO/DIS 10437:2009)

Erdöl-, petrochemische und Erdgasindustrie —
Dampfturbinen —
Spezial-Einsatzbereiche
(ISO/DIS 10437:2009)

This draft European Standard is submitted to CEN members for parallel enquiry. It has been drawn up by the Technical Committee CEN/TC 12.

If this draft becomes a European Standard, CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

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EUROPÄISCHES KOMITEE FÜR NORMUNG

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Foreword

This document (prEN ISO 10437:2009) has been prepared by Technical Committee ISO/TC 67 „Materials, equipment and offshore structures for petroleum and natural gas industries“ in collaboration with Technical Committee CEN/TC 12 „Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries“ the secretariat of which is held by AFNOR.

This document is currently submitted to the parallel Enquiry.

This document will supersede EN ISO 10437:2003.

Endorsement notice

The text of ISO/DIS 10437:2009 has been approved by CEN as a prEN ISO 10437:2009 without any modification.

Introduction

Users of this International Standard should be aware that further or differing requirements may be needed for individual applications. This International Standard is not intended to inhibit a vendor from offering, or the purchaser from accepting, alternative equipment or engineering solutions for the individual application. This may be particularly appropriate where there is innovative or developing technology. Where an alternative is offered, the vendor should identify any variations from this International Standard and provide details.

This International Standard requires the purchaser to specify certain details and features.

A bullet (●) at the beginning of a clause or subclause indicates that either a decision is required or further information is to be provided by the purchaser. This information or decision should be indicated on the data sheets; otherwise it should be stated in the quotation request (enquiry) or in the order.

In this International Standard, where practical, US Customary units have been included in brackets for information.

1 Scope

This International Standard specifies the minimum requirements for steam turbines for special purpose applications for use in the petroleum, petrochemical and natural gas industries. These requirements include basic design, materials, fabrication, inspection testing and preparation for shipment. It also covers the related lube-oil systems, instrumentation, control systems and auxiliary equipment. It is not applicable to general-purpose steam turbines, which are covered in API Std 611.

2 Normative references

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*

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 6708, *Pipe work components – Definition and Selection of DN*

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*

ISO 10438, *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 welding*¹⁾

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.*²⁾

API RP 520 PT II, *Sizing, selection, and installation of pressure-relieving systems in refineries, Part II — Installation*

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 684, *API Standard Paragraphs Rotordynamic Tutorial: Lateral Critical Speeds, Unbalance Response, Stability, Train Torsionals and Rotor Balancing.*

API RP 686, *Recommended Practices for machinery installation and installation design*

ASME, *Boiler and pressure vessel code, Section V — Nondestructive examination.*³⁾

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*

1) Comité Européen de Normalisation, 36, rue de Stassart, B-1050 Brussels, Belgium.

2) American Petroleum Institute, Publications and Distribution Section, 1220 L Street Northwest, Washington DC 20005, USA.

3) ASME International, 3 Park Avenue, New York, NY 10016-5990, USA.

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 both⁴⁾*

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*

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 — Steel⁵⁾*

NEMA SM 23, *Steam turbines for mechanical drive service.⁶⁾*

NFPA 70, *National electrical code.⁷⁾*

SSPC-SP6/NACE No. 3, *Commercial blast cleaning.⁸⁾*

4) American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103-1187.

5) American Welding Society, 550 NW Le Jeune Road, PO Box 351040, Miami, FL 33130, USA.

6) National Electrical Manufacturers Association, 1300 N 17th Street; Suite 1847, Rosslyn, VA 22209, USA.

7) National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02269, USA.

8) SSPC: The Society for Protective Coatings, 40 24th Street 6th floor, Pittsburgh, PA 15222-4656, USA.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply. (See Annex B for a guide to steam turbine nomenclature.)

**3.1
alarm point**
preset value of a measured parameter at which an alarm is actuated to warn of a condition that requires corrective action

**3.2
anchor bolts**
bolts used to attach the mounting plate to the support structure or foundation

**3.3
axially split**
split with the principal joint parallel to the shaft centreline

**3.4
baseplate**
fabricated steel structure designed to support the complete steam turbine and / or the driven equipment and other ancillaries which maybe mounted upon it

**3.5
control mechanism**
all of the equipment between the speed governor and the governor-controlled valve(s) (such as linkages, pilot valves, power servos, and so forth)

**3.6
critical speed**
shaft rotational speed at which the rotor-bearing-support system is in a state of resonance

**3.7
design**
Manufacturer's calculated parameter

NOTE This is a term used by the equipment manufacturer to describe various parameters such as design power, design pressure, design temperature, or design speed. It is not intended for the purchaser to use this term.

**3.8
enclosure**
compartment designed to provide noise protection and/or weather protection

NOTE The compartment can include walls, doors and a roof.

**3.9
fail safe system**
system which causes the equipment to revert to a permanently safe condition (shutdown and/or depressurized) in the event of a component failure or failure of the energy supply to the system

**3.10
field changeable**
design feature that permits alteration of a function after the equipment has been installed

NOTE The alteration can be accomplished by the following:

- a) soldering jumper leads to terminal pins especially provided for this purpose;
- b) employing circuit-board-mounted switches or potentiometers;

- c) using a shorting or diode-pin-type matrix board;
- d) using prewired shorting plugs;
- e) using authorized controlled access.

3.11

gauge board

bracket or plate used to support and display gauges, switches, and other instruments

NOTE A gauge board is open and not enclosed. A panel is typically fully enclosed.

3.12

general-purpose turbine

horizontal or vertical turbines used to drive equipment that is usually spared

NOTE General-purpose steam turbines are intended for applications where the inlet gauge pressure does not exceed 4 800 kPa (48 bar) (700 psi) and the inlet temperature does not exceed 400 °C (750 °F), and where the speed does not exceed 6 000 r/min.

3.13

governor-controlled valve

device that controls the flow of steam into or out of the turbine in response to the speed governor

3.14

hold-down bolts

mounting bolts

bolts that hold the equipment to the mounting plate or plates

3.15

hydrodynamic bearings

bearings that use the principles of hydrodynamic lubrication

NOTE The bearing surfaces are oriented so that relative motion forms an oil wedge, or wedges, to support the load without shaft-to-bearing contact.

3.16

informative

information only

NOTE An informative reference or Annex provides advisory or explanatory information. It is intended to assist the understanding or use of the document

3.17

internal friction damping

damping effect that causes a phase difference between the stress and strain in any material under cyclic loading

NOTE This phase difference produces the characteristic hysteric loop on a stress-strain diagram and is thus a destabilizing damping force.

3.18

local

⟨device⟩ mounted on or near the equipment or console

3.19

manufacturer

organization responsible for the design and manufacture of equipment

Note The manufacturer is often a different entity than the vendor.

3.20

maximum allowable speed

highest speed at which the manufacturer's design permits continuous operation

NOTE The maximum allowable speed is usually set by rotation element stress values.

3.21

maximum allowable temperature

maximum continuous temperature for which the manufacturer has designed the equipment (or any part to which the term is referred) when handling the specified fluid at any specified operating conditions

3.22

maximum allowable working pressure

maximum continuous pressure for which the manufacturer has designed the equipment (or any part to which the term is referred) when handling the specified fluid at the maximum allowable temperature

3.23

maximum continuous speed

highest speed at which the turbine, as built and tested, is capable of continuous operation, at any of the specified steam conditions

3.24

maximum exhaust casing pressure

highest exhaust steam pressure that the purchaser requires the casing to contain, with steam supplied at maximum inlet conditions

NOTE The turbine casing is subjected to the maximum temperature and pressure under these conditions.

3.25

maximum exhaust pressure

highest exhaust steam pressure at which the turbine is required to operate continuously

3.26

maximum inlet pressure and temperature

highest inlet steam pressure and temperature conditions at which the turbine is required to operate continuously

3.27

maximum sealing pressure

highest pressure the seals are required to seal during any specified static or operating conditions and during startup and shutdown

3.28

minimum allowable speed

lowest speed at which the manufacturer's design permits continuous operation

3.29

minimum exhaust pressure

lowest exhaust steam pressure at which the turbine is required to operate continuously

3.30

minimum inlet pressure and temperature

lowest inlet steam pressure and temperature conditions at which the turbine is required to operate continuously

3.31

mounting plate

device used to attach equipment to concrete foundations/structural steel

NOTE The mounting plate includes baseplates and soleplates

3.32

nominal pipe size (NPS)

dimensionless value approximately equal to the diameter in inches

3.33

normal operating point

point at which usual operation is expected and optimum efficiency is desired

NOTE This point is usually the point at which the vendor certifies that performance is within the tolerances stated in this International Standard.

3.34

normative

required

NOTE A normative reference or Annex enumerates a requirement or mandate of the specification

3.35

observed (test or inspection)

inspection or test where the purchaser is notified of the timing of the inspection or test and the inspection or test is performed as scheduled even if the purchaser or his representative is not present

3.36

owner

final recipient of the equipment

NOTE The owner can delegate procurement of the equipment to an agent.

3.37

panel

enclosure used to mount, display and protect gauges, switches and other instruments

3.37

potential maximum power

approximate maximum power to which the turbine can be uprated at the specified normal speed and steam conditions when it is furnished with suitable (that is, larger or additional) nozzles and, possibly, with a larger governor-controlled valve or valves

3.39

pressure casing

composite of all stationary pressure-containing parts of the unit, including all nozzles and other attached parts

3.40

purchaser

agency that issues the order and specification to the vendor

NOTE The purchaser can be the owner of the plant in which the equipment is to be installed or the owner's appointed agent.

3.41

radially split

split with the principal joint perpendicular to the shaft centreline

3.42
rated power

greatest turbine power specified and its corresponding speed; it includes all the margin required by the specifications of the driven equipment

3.43
rated speed

100 % speed

highest rotational speed required to meet any of the specified operating conditions

3.44
relief valve set pressure

pressure at which a relief valve starts to lift

3.45
remote

(device) located away from the equipment or console, typically in a control room

3.46
shall

required in order to conform to the specification

3.47
should

recommended but not required in order to conform to the specification

3.48
separation margin

margin between a critical speed and the nearest required operating speed

3.49
shutdown set point

preset value of a measured parameter at which automatic or manual shutdown of the system or equipment is required

3.50
slow roll

speed recommended by the vendor (typically 400 r/min to 500 r/min) for warm-up and initial check of equipment integrity prior to full operation

3.51
special-purpose turbines

horizontal turbines used to drive equipment that are usually not spared and are used in uninterrupted continuous operation in critical service

NOTE This category is not limited by steam conditions, power or turbine speed.

3.52
special tool

tool which is not a commercially available catalogue item

3.53

Stability analysis

determination of the natural frequencies and the corresponding logarithmic decrement of the damped rotor/support system using a complex Eigen value analysis.

3.54

Stage

one set of stationary and rotating blade rows

3.55

standby service

service in which a piece of equipment normally idle, or idling, but is capable of immediate automatic or manual start-up and continuous operation

3.56

synchronous tilt pad coefficient

coefficient derived from the complex frequency-dependent coefficients with the frequency equal to the rotational speed of the shaft

3.57

steam rate

quantity of steam required by the turbine per unit of power output measured at the output shaft of the turbine

3.58

trip speed

rotational speed at which the independent overspeed shutdown system operates to shut down a turbine

NOTE Trip speed is usually expressed in revolutions per minute.

3.59

unit responsibility

responsibility for coordinating the technical aspects of the equipment and all auxiliary systems included in the scope of the order

NOTE The technical aspects to be considered include, but are not limited to, such factors as the power requirements, speed, rotation, general arrangement, couplings, dynamics, noise, lubricant selection, instrumentation, piping, testing of components, conformance to specifications and material test reports.

3.60

vendor

supplier

agency that supplies the equipment in response to the order

NOTE The vendor may be the manufacturer of the equipment or the manufacturer's agent and is normally responsible for service support.

3.61

witnessed

inspection or test that the purchaser attends

NOTE A hold is applied to the production schedule and the inspection or test is carried out with the purchaser or purchaser's representative in attendance

4 General

4.1 Unit Responsibility

The vendor who has unit responsibility shall assure that all sub-vendors comply with the requirements of this International Standard.

4.2 Dimensions

- Drawings and maintenance dimensions shall be in SI units or US Customary units. Use of an ISO datasheet indicates that SI units shall be used. Use of a US Customary datasheet indicates that US Customary units shall be used. Typical datasheets in both systems of units are given in Annex A.

4.3 Unit Conversion

The factors in API MPMS – Manual of Petroleum Measurement Standards, Chapter 15, shall be used to convert between US Customary units and SI units.

4.4 Nomenclature

A guide to steam turbine nomenclature is presented in Annex B.

4.5 Conflicting requirements

In the event of conflict between this International Standard and the enquiry, the enquiry shall govern. At the time of the order, the order shall govern.

5 Statutory requirements

The purchaser and vendor shall mutually determine the measures to be taken to comply with any governmental codes, regulations, ordinances or rules that are applicable to the equipment, its packaging and preservatives used.

6 Basic design

6.1 General

6.1.1 The equipment (including auxiliaries) covered by this International Standard shall be designed and constructed for a minimum service life of 20 years and at least five years of uninterrupted operation.

NOTE It is recognized that achievement of this objective requires a joint effort of the purchaser, vendor and user.

6.1.2 The vendor shall assume unit responsibility for all equipment and all auxiliary systems included in the scope of the order.

6.1.3 The vendor who has unit responsibility shall assure that all sub-vendors comply with the requirements of this International Standard.

- **6.1.4** The purchaser shall specify the equipment's normal operating point and any other required operating points, including the inlet and exhaust steam conditions and any extraction or induction steam quantities and pressures. The purchaser shall also specify the maximum and minimum values of the inlet, exhaust and extraction/induction steam conditions.

6.1.5 Unless otherwise specified, steam purity limits shall be in accordance with IEC 60045-1 and NEMA SM 23.

6.1.6 Variations from Maximum Inlet steam Pressure and Maximum Inlet Steam Temperature can be expected for short durations. These swings and time durations over a 12 month period are defined in NEMA SM23-1991. The turbine shall be capable of withstanding these variations.

6.1.7 For generator drive applications in which process steam to or from the turbine is associated with a critical service need or if the power required from the turbine generator is deemed as critical service, this International Standard may invoke.

6.1.8 Turbines shall be capable of the following:

- a) operation at normal power and speed with normal steam conditions, with the steam rate certified by the manufacturer at these conditions;
- b) delivering rated power at its corresponding speed with coincident minimum inlet and maximum exhaust conditions specified.

NOTE To prevent oversizing or to obtain higher operating efficiency or both, it may be desirable to limit maximum turbine capability by specifying normal power or a selected percentage of rated power instead of rated power at the conditions specified.

- c) continuous operation at maximum continuous speed and at any other speed within the range specified, with a maximum continuous speed of at least 105 % of rated speed;
- d) continuous operation at rated power and speed with maximum inlet steam conditions and maximum or minimum exhaust steam conditions;
- e) continuous operation at the lowest speed at which maximum torque is required with minimum inlet and maximum exhaust conditions, with the purchaser specifying both the speed and torque values required;
- f) continuous operation at specified conditions for extraction and/or induction;
- g) operation with variations from rated steam conditions and steam purity levels recommended in IEC 60045-1 or NEMA SM 23;
- h) operation uncoupled with maximum inlet steam conditions.

Governing instability and high acceleration rates can occur and may require action such as throttling of the inlet pressure. Care should also be taken when operating at no or light load (in any turbine section) and high speed or uncoupled, as typically applicable for generator sets, but occasionally also applicable to mechanical drive applications. This type of operation may require reducing the inlet temperature to keep exhaust and/or extraction temperature within acceptable limits for the turbine, piping and (if applicable) condenser. One concern that should be evaluated is the risk of the rotor expansion above the normal case when the turbine is operated at high exhaust temperatures.

6.1.9 Equipment shall be designed to run to the trip speed without damage. The turbine trip speed shall be 110 % of maximum continuous speed, normally 116 % of rated speed.

This requirement should not be construed to allow continuous operation above maximum continuous speed.

6.1.10 The turbine and accessories shall perform on the test stand and when installed on the permanent foundation within the specified acceptance criteria. After installation, the performance of the combined units shall be the joint responsibility of the purchaser and the vendor who has unit responsibility.

- **6.1.11** Many factors can adversely affect site performance. These factors include such items as piping loads, alignment at operating conditions, supporting structure, handling during shipment, and handling and assembly

at the site. To minimize the influence of these factors, the vendor shall review and comment on the purchaser's piping and foundation drawings.

If specified, the vendor's representative shall witness:

- a) A check of the piping alignment performed by unfastening the major flanged connections of the equipment;
- b) The initial shaft alignment check;
- c) Shaft alignment at operating temperature.

NOTE Further information on machinery installation and installation design is given in API RP 686.

6.1.12 The arrangement of the equipment, including piping and auxiliaries, shall be developed jointly by the purchaser and the vendor. The arrangement shall provide adequate clearance areas and safe access for operation and maintenance.

6.1.13 All equipment shall be designed to permit rapid and economical maintenance. Major parts, such as casing components and bearing housings, shall be designed and manufactured to ensure accurate alignment on reassembly. This may be accomplished by the use of shouldering, cylindrical dowels or keys.

6.1.13.1 Any maintenance item with a mass more than 20 kg (44 lb) shall be provided with lifting lugs or similar dedicated fixed lifting point(s). Screw-in eyebolts are only acceptable for bearing housing covers and for internal components where other lifting arrangements are impractical. Holes for eyebolts shall be permanently marked with the correct bolt size to be used. If this marking is impractical, bolt size information shall be clearly indicated in the instruction manual.

6.1.14 Oil reservoirs and housings that enclose moving lubricated parts (such as bearings, shaft seals), highly polished parts, instruments, and control elements, shall be designed to minimize contamination by moisture, dust and other foreign matter during periods of operation or idleness.

6.1.15 Unless otherwise specified, cooling water systems shall be designed for the conditions specified in Table 1. Provision shall be made for complete venting and draining of the system.

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	30 °C	90 °F
Maximum outlet temperature	50 °C	120 °F
Maximum temperature rise	20 K	30 °R
Minimum temperature rise	10 K	20 °R
Fouling factor on water side	0,32 m ² ·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 waterside fouling; the criterion for minimum temperature rise is intended to minimize the use of cooling water.		

6.1.16 The vendor shall notify the purchaser if the criteria for minimum temperature rise and velocity over heat exchange surfaces result in a conflicting design. If such a conflict exists, the purchaser shall approve the final selection.

- **6.1.17** Control of the sound pressure level (SPL) of all equipment furnished shall be a joint effort of the purchaser and the vendor. The equipment furnished by the vendor shall conform to the maximum allowable sound pressure level specified. The vendor shall provide details of any special measures taken to achieve the stated levels.

6.1.17.1 In order to determine compliance, the vendor shall provide both maximum sound pressure and sound power level data per octave band for each principal component supplied.

6.1.17.2 Sound enclosures shall be in accordance with NFPA 497.

6.1.17.3 When a sound enclosure is provided over a steam turbine the turbine supplier shall not provide any sentinel valves or relief valves that have the potential to discharge steam into the enclosure.

- **6.1.18** Motors, electrical components, and electrical installations shall be suitable for the area classification (class, group, and division or zone) specified by the purchaser and shall meet the requirements of the applicable sections of IEC 60079 or NFPA 70, Articles 500, 501, 502, and 504, as well as any local codes specified (and, if requested by the vendor, furnished) by the purchaser.
- **6.1.19** The equipment, including all auxiliaries, shall be suitable for operation under the environmental conditions specified by the purchaser. These conditions shall include whether the installation is indoors (heated or unheated) or outdoors (with or without a roof), maximum and minimum temperatures, unusual humidity, and dusty or corrosive conditions.
- **6.1.20** The equipment, including all auxiliaries, shall be suitable for operation, using the utility conditions specified by the purchaser.

6.1.21 Spare parts for the machine and all furnished auxiliaries shall meet all the criteria of this International Standard.

6.2 Nameplates and rotation arrows

6.2.1 A nameplate shall be securely attached at a readily visible location on the equipment and on any other major piece of auxiliary equipment.

6.2.2 Rotation arrows shall be cast in, or attached to, each major item of rotating equipment at a readily visible location. Welding is not permitted. A rotation arrow shall be located on the thrust-bearing housing.

6.2.3 Nameplates and rotation arrows (if attached) shall be of austenitic stainless steel or of nickel-copper alloy. Attachment pins shall be of the same material.

- **6.2.4** Data shall be clearly stamped on the nameplate and shall include, but not be limited to, the following:
 - a) purchaser's equipment item number (may be on a separate nameplate if there is insufficient space on the rating nameplate);
 - b) vendor's name;
 - c) year ship;
 - d) serial number;
 - e) size and type;
 - f) rated power and speed;
 - g) all lateral critical speeds less than trip speed;
 - h) the next lateral critical speed greater than trip speed;
 - i) maximum continuous speed;

- j) trip speed;
- k) normal and maximum inlet steam temperature and pressure;
- l) normal and maximum exhaust steam pressure;
- m) number of teeth in the multi-toothed surface provided for speed sensing.

The purchaser shall specify whether SI or US customary units are to be shown.

6.2.5 Any lateral critical speeds determined from mechanical running tests shall be stamped on the nameplate followed by the word "Test". Critical speeds, predicted by calculation, up to and including the first critical speed above trip speed, and not identifiable by test, shall be stamped on the nameplate followed by the abbreviation "Calc".

7 Casings

7.1 Pressure casings

7.1.1 All pressure parts shall be suitable for operation at the most severe conditions of coincident pressure and temperature predicted with the specified steam conditions.

7.1.2 The tensile stress used in the design of the pressure casing for any material shall not exceed 0,25 times the minimum ultimate tensile strength for that material at the maximum specified operating temperature, and, for castings, multiplied by the appropriate casting factor as shown in Table 2. The manufacturer shall state the source of the material properties, such as ASTM, as well as the casting factors applied in his/her proposal.

NOTE For bolting, the allowable tensile stress is used to determine the total bolting area based on pressure load or gasket preload. It is recognized that to provide the initial load required to obtain a reliable bolted joint, the bolting will be tightened to produce a tensile stress higher than the design tensile stress. Values in the range of 0,7 times yield are common.

Table 2 — Casting factors

Type of NDE	Casting factor
Visual, magnetic particle and/or liquid penetrant	0,8
Spot radiography	0,9
Ultrasonic	0,9
Full radiography	1,0

7.1.3 The relief valve set pressure(s) shall be set no higher than the casing maximum allowable working pressure. For condensing turbines, the exhaust casing shall be designed for both full vacuum and for a maximum allowable working gauge pressure of at least 70 kPa (10 psi).

A full-capacity safety relief valve shall be installed in the exhaust piping between each exhaust connection and exhaust block valve to prevent overpressure and possible rupture of the turbine casing. For condensing turbines where there is no exhaust block valve the relief valve may be located on the condenser.

Unless otherwise specified, the purchaser shall provide the safety relief valve(s).

7.1.4 The vendor shall define the maximum allowable working pressure of the turbine casing and of each part of turbine casings designed for more than one maximum allowable pressure level (split-pressure-level casings). The turbine casing shall be capable of operation at 150 °C (300 °F).

7.1.5 The turbine casing shall be axially split. Turbine casings may also be split radially between high-pressure and low-pressure sections.

7.1.6 The main joint of axially and radially split casings shall use a metal-to-metal joint that is tightly maintained by bolting. The joint shall be sealed with a compound that is compatible with the fluids to be handled. Gaskets (including string type) shall not be used.

7.1.7 Each axially split casing shall be sufficiently rigid to allow removal and replacement of its upper half without disturbing rotor-to-casing running clearances.

If the clearances vary from the closed casing readings they shall be compared with manufacturer's allowable clearance tolerance and guidelines.

7.1.8 Casings and supports shall be designed to have sufficient strength and rigidity to limit any change in the relative position of the shaft ends caused by the worst combination of allowable pressure, torque, and piping forces and moments, to 50 µm (0,002 in) – see 7.4.

NOTE This clause does not apply to thermal growth.

7.1.9 Supports, and the design of jackscrews and their attachments, shall be rigid enough to permit the machine to be moved by the use of its lateral and axial jackscrews without flexing and damage.

7.1.10 Jackscrews, guide rods, cylindrical casing-alignment dowels and/or other appropriate devices shall be provided to facilitate disassembly and reassembly. Guide rods shall be of sufficient length and rigidity to prevent damage to the internals or casing studs by the casing during disassembly and reassembly. Lifting lugs or eyebolts shall be provided for lifting only the top half of the casing.

7.1.11 When jackscrews are used as a means of parting contacting faces, one of the faces shall be relieved (counter bored or recessed) to prevent a leaking joint or an improper fit caused by marring of the face.

7.1.12 The steam chest and casing shall be provided with connections to ensure complete drainage. Drain connections shall be DN 25 (NPS 1) minimum size.

7.1.13 The use of threaded holes in pressure parts shall be minimized. To prevent leakage in pressure sections of casings, metal equal in thickness to at least half the nominal bolt diameter, in addition to any allowance for corrosion, shall be left around and below the bottom of drilled and threaded holes. The depth of the threaded holes shall be at least 1,5 times the stud diameter. Through bolting is preferred in areas of the casing where the temperature may exceed 410 °C (775 °F).

7.1.14 Studded connections shall be furnished with studs installed. The first 1,5 threads at both ends of each stud shall be removed.

7.1.15 Bolting shall be furnished as follows.

- a) The details of threading shall conform to ISO 261, ISO 262, ISO 724 and ISO 965, or ASME B1.1.
- b) Studs or through bolts shall be supplied on the main joint of axially split casings and end covers of radially split casing joint(s).
- c) Studs or through bolts shall be used instead of cap screws on all other joints, except where hexagonal head cap screws are essential for assembly purposes and have been approved by the purchaser.
- d) The manufacturer's marking, in accordance with the appropriate standard (e.g. ASTM), shall be located on all fasteners 6 mm (1/4 in) and larger (excluding washers and headless set screws). For studs, the marking shall be located on the nut end of the exposed stud.
- e) Adequate clearance shall be provided at all bolting locations to permit the use of socket or box wrenches.
- f) If specified, the main casing joint studs and nuts shall be designed for the use of hydraulic bolt tensioning. The vendor shall provide procedures and any special tooling required.

- g) Internal socket-type, slotted-nut or spanner-type bolting shall not be used on the exterior of the turbine case unless specifically approved by the purchaser.
- h) The vendor shall provide a bolt torque schedule for main horizontal joint, valve chest (if bolted to the casing) and exhaust, which shall detail the bolt torque requirements and tightening patterns. ASME flanges shall be torqued in accordance with ASME B31.3.

7.1.16 Mounting surfaces shall meet the following criteria.

- a) The surface finish shall be 6 μm (250 μin) arithmetic average roughness, R_a , or better.
- b) The mounting surfaces in one plane shall be machined such that no point on any surface deviates from the common plane by more than 50 μm (0,002 in).
- c) The different mounting planes shall be parallel to each other within 1 in 1 000, in any direction.
- d) The upper surfaces shall be machined or spot-faced to a diameter larger than the bolt head, nut or washer, parallel to the mounting surface.
- e) Unless the manufacturer provides special tools, mounting surfaces shall be designed to accept standard tools.

7.1.17 Hold-down boltholes shall be drilled perpendicular to the mounting surface(s) and shall be 15 mm (0,6 in) larger in diameter than the hold-down bolt. Holes shall be machined or spot faced to a diameter suitable for a fully eccentric washer next to the hole to allow for equipment alignment. Holes shall not be slotted.

7.1.18 The equipment feet shall be provided with vertical jackscrews and shall be drilled with pilot holes that are accessible for use in final doweling if required.

7.1.19 If casing expansion keys and slide surfaces are used, the vendor shall provide a suitable material combination that prevents sticking during transient and normal operating conditions.

7.2 Casing connections

- **7.2.1** The purchaser shall specify the orientation of the main inlet and outlet steam connections. All connections shall be suitable for the maximum allowable working pressure(s) of the casing. Flanged connections shall be integral with the casing or, for casings of weldable material, may be formed by a socket-welded or butt-welded pipe nipple or transition piece, and shall terminate with a weld-neck or socket-weld flange.

7.2.2 Connections welded to the casing shall meet the material requirements of the casing, including impact values, rather than the requirements of the connected piping (see 11.3.4). All welding of connections shall be completed before the casing is hydrostatically tested (see 16.3.2).

7.2.3 Casing openings for piping connections shall be at least DN 20 (NPS 3/4) and shall be flanged or machined and studded. For casings of non-weldable materials, and where flanged or machined and studded openings are impractical, threaded openings in DN 20 (NPS 3/4) to DN 40 (NPS 1½) are permissible. These connections shall be in accordance with ISO 6708. Connections to these threaded openings shall be installed as follows.

- a) Pipe nipples shall be provided with a weld-neck or socket-weld flange.
- b) The nipple and flange materials shall meet the requirements of 7.2.2.
- c) Threaded openings and bosses for tapered pipe threads shall conform to ASME B16.5.
- d) Pipe threads shall be tapered threads conforming to ISO 7-1.

NOTE For the purpose of this provision, ASME B1.20.1 is equivalent to ISO 7-1.

- e) Threaded connections shall not be seal welded.

A process-compatible thread lubricant of proper temperature specification shall be used on all threaded connections. Thread tape shall not be used.

7.2.4 Pipe nipples screwed or welded to the casing should not be more than 150 mm (6 in) long and shall be a minimum of Schedule 160 seamless for sizes DN 25 (NPS 1) and smaller, and a minimum of Schedule 80 for DN 40 (NPS 1½). Bracing or reinforcement is required when nipples longer than 150 mm (6 in) are necessary.

7.2.5 Sizes DN 32, DN 65, DN 90, DN 125, DN 175 and DN 225 (NPS 1 1/4, 2 1/2, 3 1/2, 5, 7, and 9) shall not be used.

7.2.6 For non-weldable casing materials, threaded openings not required to be connected to piping shall be plugged with solid, round-head steel plugs in accordance with ASME B16.11. As a minimum, these plugs shall meet the material requirements of the pressure casing. Plugs that may later require removal shall be of a corrosion-resistant material. Plastic plugs are not permitted.

7.2.7 Flanges shall conform to the following.

- a) Cast iron flanges shall be flat faced and conform to the dimensional requirements of ISO 7005-2 or ASME B16.1 or ASME 16.42. Class 125 flanges shall have a minimum thickness equal to Class 250 for sizes DN 200 (8 NPS) and smaller. Gray cast iron shall not be used.
- b) Steel flanges shall conform to ISO 7005-1 Series 1, including Annex D & E or 7005-2 Series 1 or ASME B16.1, B16.5, B16.42 or B16.47 (Series B), as specified. Flanges other than those covered in ISO 7005-2 shall conform to the dimensional requirements specified above

ISO 7005-1 (steel flanges) PN 20, 50, 110, 150, 260, 420 are designed to be interchangeable with ASME B16.5 and MSS SP-44 flanges. ISO 7005-1 flanges are not identical to ASME B 16.5 and MSS SP 44 flanges but are deemed to comply with the dimensions specified in the ASME B 16.5 and MSS SP 44. ISO 7005-2 (cast iron) flanges PN 20, 50 are designed to be interchangeable with ANSI/ASME B16.1 (gray cast iron) and B 16.42 (ductile cast iron) but they are not identical. They are deemed to comply with dimensions specified in ASME B16.1 (gray cast iron) and B 16.42 (ductile cast iron). ISO PN 2.5 AND PN 6 do not have a corresponding ASME class and ASME Class ES 75, 400 and 800 do not have corresponding ISO PN designations. These PN and Class flange ratings should therefore not be used.

7.2.7.1 Machined and studded connections and flanges not in accordance with ISO 7005-1, ISO 7005-2, ASME B16.1, ASME B16.5, ASME B16.42 or ASME B16.47 require purchaser's approval. Unless otherwise specified, the vendor shall supply mating flanges, studs nuts and gaskets for these non-standard connections.

7.2.7.2 The concentricity of the bolt circle and the bore of all casing flanges shall be such that the area of the machined gasket-seating surface is adequate to accommodate a complete standard gasket without protrusion of the gasket into the fluid flow.

7.2.7.3 Flanges shall be full faced or spot faced on the back and shall be designed for through bolting.

- **7.2.7.4** If ISO 7005-1 has been specified, materials shall be in accordance with ISO 7005-1 Annex D-1 (DIN) or Annex D-2 (ASTM) as specified. The Pressure Temperature ratings in Annex E shall correspond to the materials specified.

NOTE ISO 7005-1:1992 Annex E Table 1-4 covers D-1 materials and Table 5-21 covers D-2 materials.

7.2.7.5 For all steel flanges, imperfections in the flange facing finish shall not exceed those permitted by ASME B16.5 or ASME 16.47 as applicable.

7.2.7.6 Flat face flanges with full raised face thickness are acceptable on casings of all materials. Flanges in all materials that are thicker or have a larger outside diameter than required by ISO or ANSI are acceptable. Non-standard (oversized) flanges shall be completely dimensioned on the arrangement drawing.

7.2.8 Machined and studded connections shall conform to the facing and drilling requirements of ISO 7005-1 or ISO 7005-2, or ASME B16.1, ASME B16.5, ASME B16.42 or ASME B16.47.

7.2.9 Machined and studded connections and flanges not in accordance with ISO 7005-1:1992, 7005-2:1988 or ASME B16.1, B16.5, B16.42 or B16.47 require purchaser's approval. Unless otherwise specified, the vendor shall supply mating flanges, studs and nuts for these nonstandard connections.

7.2.10 To minimize nozzle loading and facilitate installation of piping, machine flanges shall be parallel to the plane shown of the flange as shown on the general arrangement drawing to within 0.5°. Studs or boltholes shall straddle centerlines parallel to the main axes of the equipment.

7.2.11 All of the purchasers' connections shall be accessible for disassembly without requiring the steam turbine, any major part or attached auxiliary piping to be moved.

- **7.2.12** If specified, appropriate casing connections with valves shall be provided for an inert gas blanket to be used as preservation during long periods of standstill.

7.2.13 The exhaust casing on condensing turbine shall be designed with adequate inspection openings for blade inspection and general access to the exhaust hood.

- **7.2.14** If specified, permanent connections with valves shall be provided to provide wet and dry preservation of the steam turbine during stand still.

7.3 Internal stationary components

7.3.1 All control stage nozzle rings shall be replaceable. Nozzle rings welded to the outer casing are acceptable only when approved in advance by the purchaser.

7.3.2 All other stationary blading shall be mounted in replaceable diaphragms or blade carriers. Nozzles or blades welded to the diaphragm are preferred.

7.3.3 Any internal fasteners shall be positively retained to prevent them from entering the steam path.

7.3.4 The design shall ensure that water cannot be trapped in the wet region of a condensing turbine. The design of water drain holes in the wet region of a condensing turbine shall avoid the holes becoming blocked by corrosion or debris. In the case of drain holes in the diaphragms of an impulse type turbine, this shall be achieved by lining the drain holes with corrosion resistant material.

7.3.5 All diaphragms, blade carriers or other inner casings shall be designed with vertical levelling and positioning lugs or shims located near the horizontal split-line. Radial ground crush pins shall not be used to set the alignment. On condensing sections of reaction machines the diaphragms may be bolted to the exhaust casing. The vendor shall indicate the required assembly vertical and horizontal clearances for each diaphragm or blade carrier

7.3.6 Packing holders for shaft end seals shall be designed with vertical levelling lugs located near the split line for adjustment. If adjustable packing holders are not supplied, the vendor shall define how the clearances can be adjusted during future maintenance. Manufacturer shall provide information and data that defines how future changes can be made and the relationship between the changes and final packing clearances.

7.3.7 Turbines operating on saturated steam shall have components in the steam path (e.g. nozzles, blading, diaphragms) made of erosion-resistant materials or appropriate coatings applied.

7.3.8 Consideration for water cutting shall be made for wet stages at the horizontal joint and the diaphragm steam face. Options to minimize the problem include stainless steel inlay or inserted rings.

7.4 External forces and moments

7.4.1 Turbines shall be designed to withstand external forces and moments at least equal to the values calculated in accordance with NEMA SM 23.

7.4.2 The turbine supplier shall tabulate the allowable forces and moments for each casing connection.

8 Rotating elements

8.1 General

8.1.1 Rotors shall be capable of safe operation at momentary maximum overshoot speed of 127 % of rated speed at any specified operating temperature. Following such an excursion, the rotor shall be capable of operation without immediate maintenance intervention.

NOTE Rubbing of seals and minor localized yielding of rotor components can occur and vibration levels can increase after such an event.

- **8.1.2** The purchaser's approval is required for built-up rotors (disks shrunk on the shaft) if blade tip velocities exceed 250 m/s (825 ft/s) at maximum continuous speed or if stage inlet steam temperatures exceed 440 °C (825 °F).

8.1.3 Each rotor shall be permanently marked with a unique identification number. This number shall be on the shaft end, in an area that is not prone to damage.

- **8.1.4** If specified, provisions shall be made for field balancing without disassembly of the turbine. The vendor shall describe these provisions and the method of use in the proposal.

8.1.5 Rotors shall be designed with an integral "flinger" between the bearing housings and gland seals to help prevent moisture from entering the bearing housing.

8.2 Shafts

8.2.1 Shafts shall be accurately finished throughout their entire length. The surface of the shaft at shrink fit areas and bearing areas shall be finished to a roughness not exceeding 0,8 µm (32 µin) *Ra*.

8.2.2 The rotor shaft sensing areas to be observed by radial vibration probes shall be concentric with the bearing journals. All sensing areas (both radial vibration and axial position) shall be free from stencil and scribe marks or any other surface discontinuity, such as an oil hole or a keyway, for a minimum of one probe-tip diameter on each side of the probe. These areas shall not be metallized, sleeved or plated. The surface shall be finished to a roughness not exceeding 0,8 µm (32 µin) *Ra*. These areas shall be properly demagnetized to the levels specified in API Std 670 or otherwise treated so that the combined total electrical and mechanical runout does not exceed the following.

- a) For areas to be observed by radial-vibration probes, 25 % of the allowed peak-to-peak vibration amplitude or 6,3 µm (0,25 mil), whichever is greater.
- b) For areas to be observed by axial-position probes, 12,7 µm (0,5 mil).

8.2.3 All shaft keyways shall have fillet radii conforming to ASME B17.1.

8.2.4 Shafts shall be capable of transmitting torque at least equal to the torque determined by potential maximum power. The coupling shaft end design shall conform to the requirements of ISO 10441 or API Std 671.

8.2.4 Shafts shall be capable of transmitting torque at least equal to the torque determined by potential maximum power at maximum continuous speed. The shaft end(s) design shall conform to the requirements of ISO 10441 or API Std 671.

8.2.5 To prevent the build-up of harmful potential voltage, magnetic flux density of any part of the rotating element shall not exceed 0,000 3 T (3 G).

8.2.6 The turbine vendor shall, jointly with the driven equipment vendor, establish the maximum transient torque value that can occur in the shafting system under start-up, running, and fault conditions. All components, including couplings, and fit of coupling hub on shaft, shall be suitable for at least 115 % of this value.

8.3 Blading

8.3.1 The vendor shall design each blade row analyzing potential resonances of the blades' natural modes in the specified operating speed range with any harmonic of rotating speed, up to 15 x rev. and 1st and 2nd upstream vane passing frequency.

NOTE Excitation sources to be considered in the in the design analysis include — but are not limited to — first and second passing frequencies of upstream and downstream stationary blade rows, steam passage splitters, irregularities in vane pitch at horizontal casing flanges, the first four turbine speed harmonics, casing openings (exhaust or extraction), partial arc diaphragms or nozzle plates, internal struts and structural members in the inlet and exhaust casing or horizontal joints, and meshing frequencies in gear units.

8.3.2 The blade natural modes to be considered in the design analysis shall include at least the tangential (in-phase and out of phase), axial and torsional modes, including, if applicable, packet (blades per banded group) modes. Blades' natural frequencies calculations shall include a correction for actual operating temperature and operating speed.

8.3.3 Blade design shall meet one of the following requirements:

- a) Resonance shall not occur with excitation frequencies mentioned in 8.3.1.
- b) If any resonance is possible, the relevant dynamic stresses for any specified operating condition shall be low enough to ensure continuous, trouble free operation. This shall be assessed during the design phase according to the following methods:
 - 1) Resonance dynamic stresses calculation and comparison with allowable limits (using Goodman, Haigh or equivalent diagram) to check that the safety factor meets manufacturer's design practices.
 - 2) Resonance is acceptable according to the standard design practices of the manufacturer if the same type of blade and the same or scaled blade design has already been operated at the same or higher load in the same speed range.
- c) Blades shall be designed to withstand operation at all resonances with relevant excitations encountered during normal start-up.

8.3.4 Prior to manufacturing, the manufacturer shall provide the following design data for each row of blades for the owner's review and acceptance:

- a) Steam bending stresses
- b) Campbell or Haigh or equivalent diagrams
- c) Goodman diagrams together with supporting computations showing total operating stress (steady state plus cyclic) of all blading for which resonant interference occurs within the normal operating speed range. The vendor shall also list the maximum allowable blade stresses.
- d) Calculation stresses on the closing block assemblies.
- e) Information on blades and shrouds, in order to allow for an independent verification of the blade stresses.

8.3.5 All blades shall be mechanically suitable for operation (including transient conditions) over the specified speed range. The vendor shall assume that the driven equipment torque varies with the square of the speed, unless otherwise specified by the purchaser or by the vendor having unit responsibility.

8.3.6 Tenon holes in the shrouds shall be drilled or milled and finished with radii or chamfers on both sides of the holes.

8.3.7 Shrouds shall be rolled to the proper radius prior to fitting, and shall be fitted to the blades and peened so that there are no gaps between the shrouds and the blades. The vendor shall state the method used for peening the tenons.

8.4 Speed-sensing element

A dedicated multi-toothed surface for speed sensing shall be provided integral with, or positively attached and locked to, the turbine shaft. Other speed sensors may share this surface. The multi-toothed surface shall not be used as a gear for driving other mechanical components. The axial width of the multi-toothed surface (the width of the surface being viewed by radial probes) shall be a minimum of one and one-half times the diameter of the probe tip.

9 Rotor dynamics

9.1 General

9.1.1 API RP 684 provides further information on rotordynamics.

9.1.2 In the design of rotor-bearing systems, consideration shall be given to all potential sources of excitation, which shall include, but are not limited to, the following:

- a) unbalance in the rotor system;
- b) fluid destabilizing forces from bearings, seals, and aerodynamics;
- c) internal rubs;
- d) blade and nozzle passing frequencies;
- e) gear-tooth meshing and side bands;
- f) coupling misalignment;
- g) loose rotor-system components;
- h) internal friction within the rotor assembly;
- i) synchronous excitation from complimentary geared elements;
- j) control loop dynamics such as those involving active magnetic bearings;
- k) electrical line frequency.

NOTE 1 The frequency of a potential source of excitation can be less than, equal to, or greater than the rotational speed of the rotor.

NOTE 2 When the frequency of an excitation—applied to a rotor-bearing support system coincides with a natural frequency of that system, the system is in a state of resonance. A rotor-bearing-support-system in resonance can have the magnitude of its normal vibration amplified. The magnitude of amplification and, in the case of critical speeds, the rate of change of the phase-angle with respect to speed, are related to the amount of damping in the system.

9.1.3 Resonances of structural support systems that are within the vendor's scope of supply and that affect the rotor vibration amplitude shall not occur within the specified operating speed range or the specified separation margins (SM) (see 9.2.11). The dynamic characteristics of the structural support shall be considered in the analysis of the rotor-bearing-support system (see 9.2.6d).

- **9.1.4** The vendor who is specified to have unit responsibility for the complete drive train shall communicate the existence of any undesirable running speeds in the range from zero to trip speed. This shall be illustrated

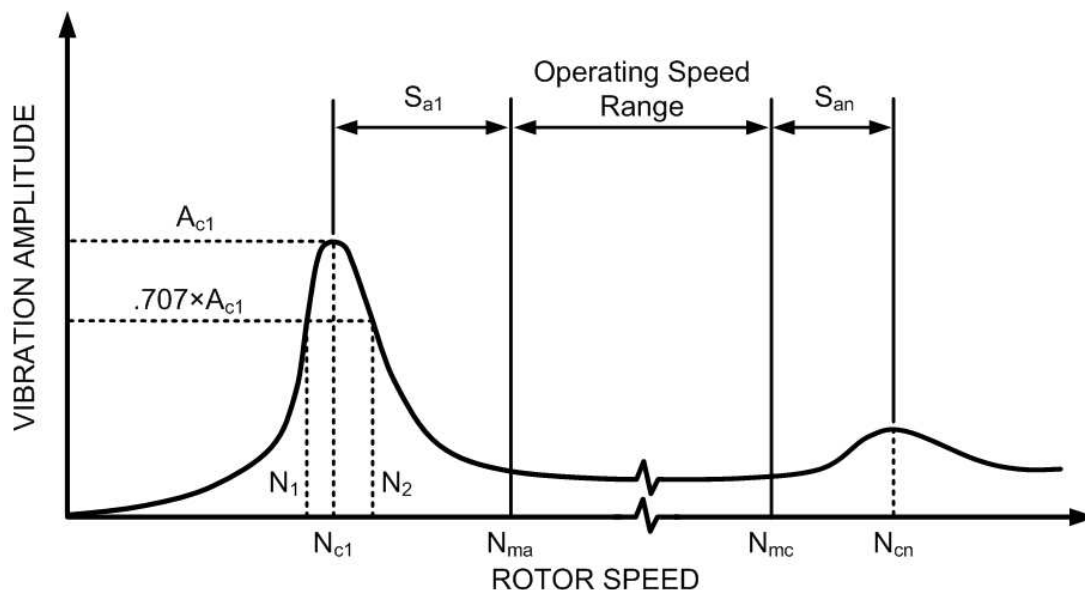
by the use of Campbell (forced frequency) diagrams for individual machines or, if specified, for the complete train, or for both. These diagrams shall be submitted to the purchaser for review and included in the instruction manual.

NOTE Examples of undesirable speeds are those associated with rotor lateral critical, train torsional natural frequencies and blading modes.

9.2 Lateral analysis

9.2.1 Critical speeds and their associated amplification factors shall be determined by means of a damped unbalanced rotor response analysis.

9.2.2 For the purposes of this International Standard, resonant conditions of concern are those with an amplification factor (AF) equal to or greater than 2.5 (see Figure 1).



N_{c1} = Rotor first critical speed
 N_{cn} = n^{th} critical speed
 N_{ma} = Minimum allowable speed
 N_{mc} = Maximum continuous speed

A_{c1} = Amplitude at N_{c1}
 N_1 = Initial (lesser) speed at $0.707 \times A_{c1}$
 N_2 = Final (greater) speed at $0.707 \times A_{c1}$
 AF_1 = Amplification factor of the first critical speed
 $= N_{c1} / (N_2 - N_1)$

S_{a1} = Actual separation between N_{c1} and the operating speed range
 S_{an} = Actual separation between N_{cn} and the operating speed range
 SM_{a1} = Actual separation margin of first critical speed (%)
 $= 100 \times S_{a1} / N_{ma}$
 SM_{an} = Actual separation margin of n^{th} critical speed (%)
 $= 100 \times S_{an} / N_{mc}$

Note: The shape of the curve is for illustration only and does not necessarily represent any actual rotor response plot.

Figure 1 — Rotor response plot

9.2.3 The location of all critical speeds below the trip speed shall be confirmed on the test stand during the mechanical running test. The accuracy of the numerical model shall be demonstrated.

9.2.4 The vendor shall conduct an undamped analysis to identify the undamped critical speeds and determine the their mode shapes. The analysis shall identify the first four undamped critical speeds and cover as a minimum the stiffness range from 0.1x to 10x the expected support stiffness.

9.2.5 The results of the undamped analysis performed in accordance with 9.2.4 shall be provided to the Purchaser. The presentation of the results shall include:

- a) mode shape plots (relative amplitude vs. axial position on the rotor);
- b) critical speed-support stiffness map (frequency vs. support stiffness); Superimposed on this map shall be the calculated system support stiffness, horizontal (k_x) and vertical (k_y) (see Figure 2).
- c) operating speed range showing N_{ma} and N_{mc} .

NOTE For machinery with widely varying bearing loads and/or load direction, the vendor may propose to substitute mode shape plots listing the undamped critical speed for each of the identified modes in lieu of the undamped critical speed map.

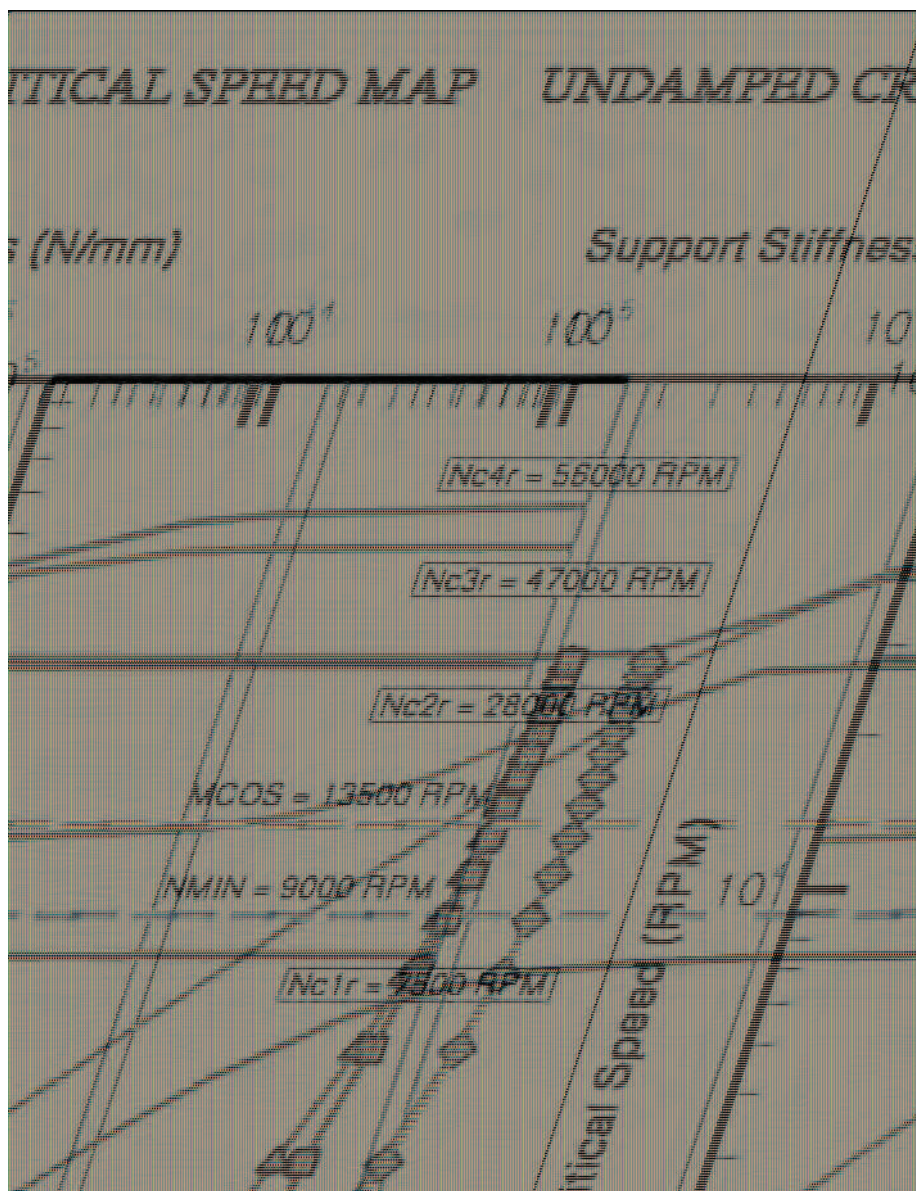


Figure 2 — Undamped critical speed map

9.2.6 The damped unbalanced response analysis shall include, but shall not be limited to, the following:

- a) rotor masses and polar and transverse moments of inertia, including coupling halves, and rotor stiffness;

- b) bearing lubricant-film stiffness and damping values including changes due to speed, load, preload, range of oil inlet temperature, maximum to minimum clearances resulting from accumulated assembly tolerances, and the effect of asymmetrical loading which may be caused by partial arc steam admission, side streams, eccentric clearances, etc;
- c) for tilt-pad bearings, the pad pivot stiffness;
- d) support stiffness, mass, and damping characteristics, including effects of excitation frequency over the required analysis range. The term “support” includes the foundation or support structure, the base, the machine frame and the bearing housing as appropriate. For machines whose dynamic support stiffness values are less than or equal to 3.5 times the bearing oil film stiffness values in the range from 0 to 150% of N_{mc} , the support characteristics shall be incorporated as an adequate dynamic system model, calculated frequency dependent support stiffness and damping values (impedances), or support stiffness and damping values (impedances) derived from modal or other testing. The vendor shall state the support stiffness values used in the analysis and the basis for these values (for example, modal tests of similar rotor support systems, or calculated support stiffness values).
- e) rotational speed, including the various starting-speed detents, operating speed and load ranges (including agreed upon test conditions if different from those specified), trip speed, and coast-down conditions;
- f) the influence of hydrodynamic stiffness and damping generated by the casing end seals over the operating range;
- g) location and orientation of the radial vibration probes which shall be the same in the analysis as in the machine.
- h) squeeze film damper mass, stiffness and damping values considering the component clearance and centering tolerance, oil inlet temperature range, and operating eccentricity.

- **9.2.6** If specified, the vendor with train responsibility shall conduct a train lateral analysis.

9.2.7 The vendor with train responsibility shall conduct a train lateral analysis for machinery trains with rigid couplings.

9.2.8 A separate damped unbalanced response analysis shall be conducted within the speed range of 0 to 1.5 N_{mc} . Unbalance shall analytically be placed at the locations defined in Figures 3 and 3a. For the translatory (symmetric) modes, the unbalance shall be based on the sum of the journal static loads. For conical (asymmetric) modes unbalances shall be 180° out of phase and of a magnitude based on the static load on the adjacent bearing. For overhung modes, the unbalances shall be based on the overhung mass. Figures 3 and 3a show the typical mode shapes and indicate the location and definition of U_a for each of the shapes. The magnitude of the unbalances shall be two times the value of U_r as calculated by Equations (2a) or (2b).

In SI units:

$$U_r = 6350 \text{ W} / N_{mc} \quad (2a)$$

In US Customary units:

$$U_r = 4 \text{ W} / N_{mc} \quad (2b)$$

where

$U_a = 2U_r$ is the input unbalance for the rotordynamic response analysis, expressed in g.mm (oz-in);

U_r is the maximum allowable residual unbalance, expressed in g.mm (oz-in);

N_{mc} maximum continuous operating speed, , expressed in r/min;

W is the journal static load or, for bending modes where the maximum deflection occurs at the shaft ends, the overhung mass (that is the mass of the rotor outboard of the bearing), expressed in kg (lb) (see Figures 3 and 3a).

9.2.9 As a minimum, the unbalanced response analysis shall produce the following:

- a) identification of the frequency of each critical speed in the range from 0 to $1.5 N_{mc}$;
- b) frequency, phase and amplitude (Bode plots) at the vibration probe locations in the range from 0 to $1.5 N_{mc}$ resulting from the unbalances specified in 9.2.8. If there are no vibration probes near a bearing centerline then Bode plots shall be shown at the bearing centreline;
- c) plots of deflected rotor shape for each critical speed in the range from 0 to $1.5 N_{mc}$ and at N_{mc} resulting from the magnitudes specified in 9.2.11, showing the major-axis amplitude at the centrelines of each bearing, the locations of each radial probe, and at each seal area throughout the machine as appropriate, while, in addition, the minimum design diametral running clearance of the seals shall be indicated;
- d) when the support stiffness used in the analysis is less than infinite, the Bode plots which represent the relative shaft motion and absolute bearing housing response shall be included.

9.2.10 Additional analyses shall be made for use with the verification test specified in 9.3. The location of the unbalance shall be determined by the vendor. The unbalance shall not be less than 2 times the value from equations 2a or 2b and shall not exceed 8 times the value from equations 2a or 2b. Any test stand parameters, which influence the results of the analysis, shall be included.

NOTE There may only be one plane readily accessible for the placement of an unbalance; for example, the coupling flange on a single ended drive turbine. However, some turbines may provide additional externally accessible balance planes. When these planes exist there exists the possibility of exciting other critical speeds; multiple runs may be required.

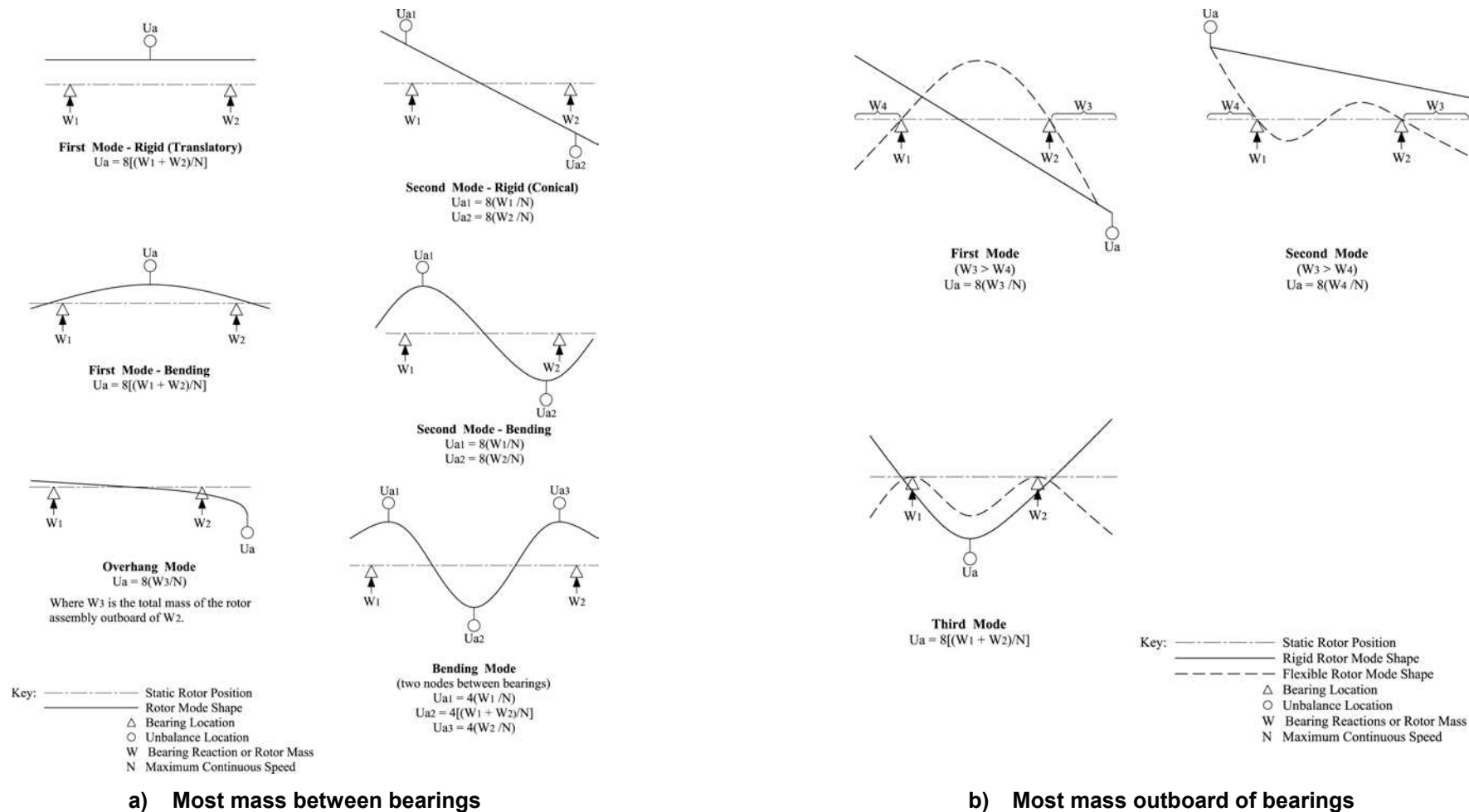


Figure 3 — Typical mode shapes

9.2.11 The damped unbalanced response analysis shall indicate that the machine will meet the following requirement:

$$SM_a \geq SM_r$$

where;

SM_r required separation margin, %.

- a) If the amplification factor at a particular critical speed is less than 2.5, the response is considered critically damped and no separation margin is required ($SM_r = 0$.)
- b) If the amplification factor at a particular critical speed is greater than or equal to 2.5 and that critical speed is below the minimum speed, SM_r is given by Equation (3)

$$SM_r = 17 \left(1 - \frac{1}{AF - 1.5} \right) \quad (3)$$

- c) If the amplification factor at a particular critical speed is greater than or equal to 2.5 and that critical speed is above the maximum continuous speed, SM_r is given by Equation (4) .

$$SM_r = 10 + 17 \left(1 - \frac{1}{AF - 1.5} \right) \quad (4)$$

- d) If the amplification factor at a particular critical speed is greater than or equal to 2.5 and that critical speed is greater than or equal to the minimum speed, and is less than or equal to the maximum continuous speed, SM_a is less than SM_r .

9.2.12 The calculated unbalanced peak-to-peak response at each vibration probe, for each unbalance amount and case as specified in 9.2.10, shall not exceed the mechanical test vibration limit of 25.4 μm (1.0 mil) or Equation (5), whichever is less, over the range of N_{ma} to N_{mc} as shown in Figure 4.

In SI units:

$$A_1 = 25.4 \sqrt{\frac{12,000}{N}}$$

In US Customary units:

$$A_1 = \sqrt{\frac{12,000}{N}} \quad (5)$$

where $N = N_{mc}$

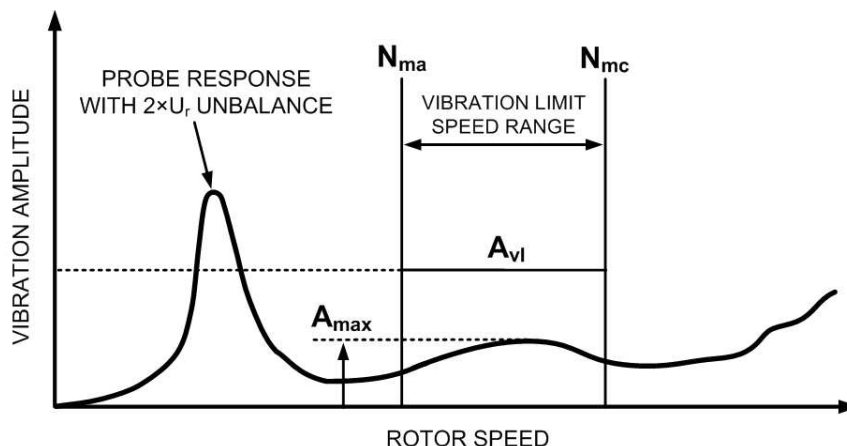


Figure 4 — Vibration limits

9.2.13 The following shall apply:

- a) For each unbalance amount and case as specified in 9.2.8, the calculated major-axis, peak-to-peak response at each close clearance location shall be multiplied by a scale factor defined by Equation (6).

$$S_{cc} = A_{vl} / A_{max} \text{ or } 6, \text{ whichever is less} \quad (6)$$

where:

S_{cc} scale factor for close clearance check

A_{vl} mechanical test vibration limit defined in 9.2.12

A_{max} maximum probe response amplitude (p-p) considering all vibration probes, over the range of N_{ma} to N_{mc} , for the unbalance amount/case being considered

NOTE To meet the requirements of 9.2.12, the scale factor must be greater than one.

- b) For each close clearance location, the scaled response shall be less than 75 % of the minimum design diametral running clearance over the range from zero to trip speed.
- c) For this evaluation, floating-ring, abradable and compliant seals are not considered to be close clearance locations. The response amplitude to the running clearance at these locations shall be mutually agreed.
- d) Running clearances may be different than the assembled clearances with the machine shutdown. Consideration should be given to:
- 1) centrifugal / thermal growth;
 - 2) bearing lift;
 - 3) rotor sag;
 - 4) non-concentricity (of stator to the bearings).

9.2.14 If the analysis indicates that:

- the required separation margins cannot be met; or
- A non-critically damped response peak falls within the operating speed range; or

- vibration limits are exceeded at the probes or close clearance locations;

and the purchaser and vendor have agreed that all practical design efforts have been exhausted, then acceptable amplitudes and amplification factors shall be agreed upon by the purchaser and the vendor, subject to the requirements of 9.3.

9.3 Stability Analysis

9.3.1 A stability analysis shall be performed on all rotors except those whose maximum continuous speed is below the first undamped critical speed on rigid supports, FCSR, in accordance with 9.2.4. The stability analysis shall be calculated at the maximum continuous speed.

9.3.2 The stability analysis shall identify the first forward whirl damped natural frequency and corresponding logarithmic decrement of the rotor, bearing and support system when operating at Nmc.

9.3.3 Level I Stability Analysis

- **9.3.3.1** If specified, a Level I stability analysis shall be conducted in accordance with 9.3.3.1 through 9.3.3.8. For this analysis, the turbine steam conditions, power and speed shall be at the rated condition unless the vendor and purchaser agree upon another operating point.

NOTE Level I analysis was developed to fulfill two purposes: first, it provides an initial screening to identify rotors that do not require a more detailed study. The approach as developed is conservative and not intended as an indication of an unstable rotor. Second, the Level I analysis specifies a standardized procedure applied to all manufacturers. API RP 684 provides further information on rotordynamics

9.3.3.2 The model used in the Level I analysis shall include the items listed in 9.2.6.

9.3.3.3 If tilting pad journal bearings are used, the analysis shall be performed with synchronous tilting pad coefficients.

9.3.3.4 For rotors that have quantifiable external radial loading (including partial admission steam forces), the stability analysis shall also include the external loads associated with the operating conditions defined in 9.3.3. For some rotors, the unloaded (or minimal load condition) may represent the worst stability case and should be considered.

9.3.3.5 The anticipated cross coupling, QA, present in the rotor shall be calculated using the following equation:

For axial flow rotors:

$$q_a = \frac{(HP)B_t C}{D_t H_t N_r} \quad (7)$$

Equation (7) is calculated for each stage of the rotor. Q_A is equal to the sum of q_a for all stages. Equation variables are defined in 9.3.4.9

9.3.3.6 An analysis shall be performed with a varying amount of cross coupling introduced at the rotor mid-span for between -bearing rotors or at the centre of gravity of the wheel for single overhung rotors. For double-overhung rotors, the cross coupling shall be placed at each wheel concurrently and should reflect the ratio of the anticipated cross coupling, QA, calculated for each stage.

9.3.3.7 The applied cross coupling shall extend from zero to the lesser of:

- A level equal to 10 times the anticipated cross coupling, QA;
- The amount of the applied cross coupling required to produce a zero log decrement, Q0. This value can be reached by extrapolation or linear interpolation between two adjacent points on the curve.

9.3.3.8 A plot of the calculated log decrement, δ , for the first forward mode shall be prepared for the minimum and maximum component stiffness as defined in 9.2.6. b, f, and h. Each curve shall contain a minimum of five calculated stability points. The ordinate (y axis) shall be the log decrement. The abscissa (x-axis) shall be the applied cross coupling with the range defined in 9.3.3.6. For double overhung rotors, the applied cross coupling shall be the sum of the cross coupling applied to each wheel.

NOTE A typical plot is presented in Figure 5. Q_0 and δ_A are identified as the minimum values from either component clearance curves.

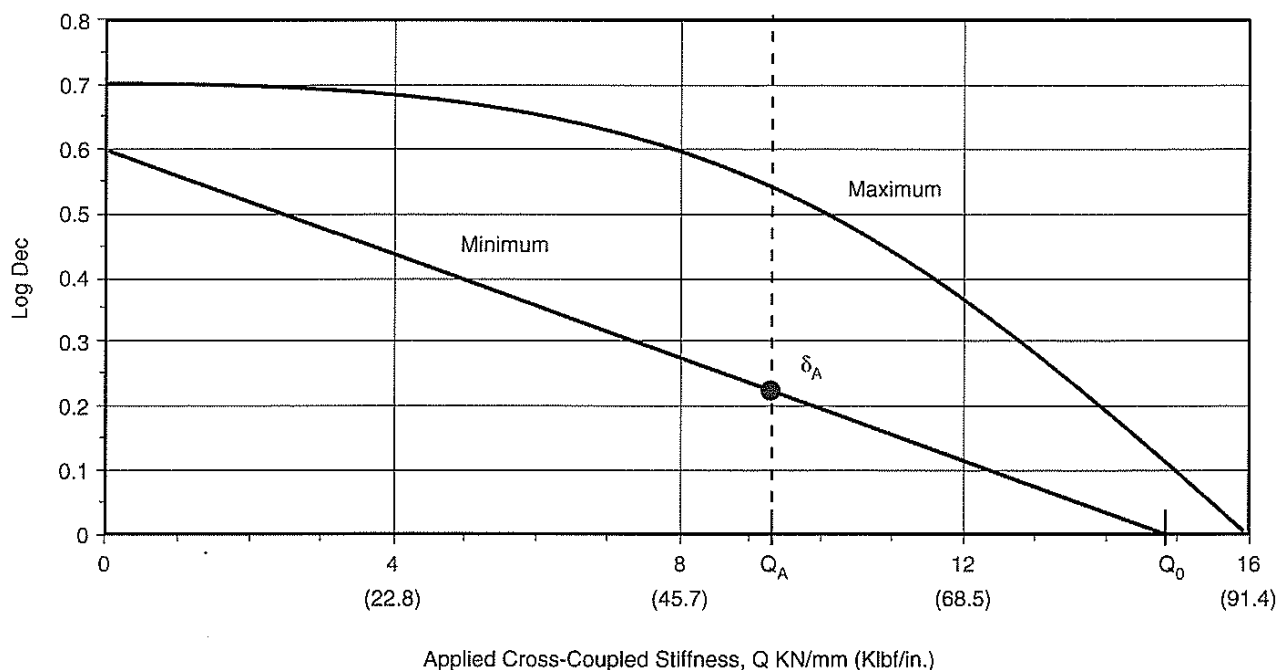


Figure 5 — Typical plot of log decrement versus component stiffness

9.3.3.9 Level I Screening Criteria for axial flow rotors:

If $\delta_A < 0.1$, a Level II stability analysis shall be performed. Otherwise, the stability is acceptable and no further analyses are required.

9.3.4 Level II Stability Analysis

9.3.4.1 A Level II analysis, which reflects the actual dynamic forces (both stabilizing and destabilizing) of the rotor, shall only be performed if required by 9.3.3.8.

9.3.4.2 The Level II analysis shall include the dynamic effects from all sources that contribute to the overall stability of the rotating assembly. These dynamic effects shall replace the anticipated cross coupling, Q_A . The following sources shall be included in the analysis,

- a) Labyrinth seals
- b) Damper seals
- c) Impeller/blade flow aerodynamic effects
- d) Internal friction

The vendor shall state how the sources are handled in the analysis.