SELECTION, OPERATION, INSPECTION & MAINTENANCE 
OF 
STEAM AND GAS TURBINES

OISD-STD-121 
Amended Edition, August, 1999
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Prepared by

COMMITTEE FOR
REVISION OF STANDARDS ON ROTARY EQUIPMENT

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Preamble

Indian petroleum industry is the energy lifeline of the nation and its continuous performance is essential for sovereignty and prosperity of the country. As the industry essentially deals with inherently inflammable substances throughout its value chain – upstream, midstream and downstream – Safety is of paramount importance to this industry as only safe performance at all times can ensure optimum ROI of these national assets and resources including sustainability.

While statutory organizations were in place all along to oversee safety aspects of Indian petroleum industry, Oil Industry Safety Directorate (OISD) was set up in 1986 Ministry of Petroleum and Natural Gas, Government of India as a knowledge centre for formulation of constantly updated world-scale standards for design, layout and operation of various equipment, facility and activities involved in this industry. Moreover, OISD was also given responsibility of monitoring implementation status of these standards through safety audits.

In more than 25 years of its existence, OISD has developed a rigorous, multi-layer, iterative and participative process of development of standards – starting with research by in-house experts and iterating through seeking & validating inputs from all stake-holders – operators, designers, national level knowledge authorities and public at large – with a feedback loop of constant updation based on ground level experience obtained through audits, incident analysis and environment scanning.

The participative process followed in standard formulation has resulted in excellent level of compliance by the industry culminating in a safer environment in the industry. OISD – except in the Upstream Petroleum Sector – is still a regulatory (and not a statutory) body but that has not affected implementation of the OISD standards. It also goes to prove the old adage that self-regulation is the best regulation. The quality and relevance of OISD standards had been further endorsed by their adoption in various statutory rules of the land.

Petroleum industry in India is significantly globalized at present in terms of technology content requiring its operation to keep pace with the relevant world scale standards & practices. This matches the OISD philosophy of continuous improvement keeping pace with the global developments in its target environment. To this end, OISD keeps track of changes through participation as member in large number of International and national level Knowledge Organizations – both in the field of standard development and implementation & monitoring in addition to updation of internal knowledge base through continuous research and application surveillance, thereby ensuring that this OISD Standard, along with all other extant ones, remains relevant, updated and effective on a real time basis in the applicable areas.

Together we strive to achieve NIL incidents in the entire Hydrocarbon Value Chain. This, besides other issues, calls for total engagement from all levels of the stake holder organizations, which we, at OISD, fervently look forward to.

Jai Hind!!!

Executive Director

Oil Industry Safety Directorate
FOREWORD

The Oil Industry in India is more than 100 years old. As such a variety of practices are in vogue because of collaboration/association with different foreign companies and governments. Earlier, standardisation in design philosophies, selection, operating and maintenance practices at a national level were hardly in existence. This, coupled with feed back from some serious accidents that occurred in India and abroad, emphasised the need for the industry to review the existing state of art in designing, selecting, operating and maintaining oil and gas installations.

With this in view, the then Ministry of Petroleum and Natural Gas in 1986 constituted a Safety Council assisted by Oil Industry Safety Directorate (OISD) staffed from within the industry in formulating and implementing a serious of self-regulatory measures aimed at removing obsolescence, standardising and upgrading the existing standards to ensure safer operations. Accordingly OISD constituted a number of functional committees comprising of experts nominated from the industry to draw up standards and guidelines on various subjects.

The present standard on “Selection, Operation, Inspection & Maintenance of Steam and Gas Turbines” has been prepared by the “Functional Committee on Revision of Standards for Rotary Equipment”. This committee felt that the existing OISD-STD-121 titled “Inspection of Turbines and Diesel Engines” should be bifurcated into two standards namely “Selection, Operation, Inspection and Maintenance of Steam & Gas Turbines” and “Selection, Operation, Inspection & Maintenance of Diesel Engines”. Present document is one of them titled “Selection, Operation, Inspection & Maintenance of Steam and Gas Turbines”.

This document, based on the accumulated knowledge and experience of industry members and the various national and international codes and practices, is meant to be used as a supplement and not as a replacement for existing codes standards and manufacturer’s recommendations. It is hoped that the provision of this standard, if implemented objectively, may go a long way to improve the safety and reduce accidents in the Oil and Gas Industry. The users of this document are cautioned that no standard can be a substitute for a responsible and experienced engineer. Suggestions are invited from the users after it is put into practice to improve the standard further. Suggestions for amendment, if any, should be addressed to:

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This standard in no way supersedes the statutory regulations of CCE, Factory Inspectorate or any other statutory body which must be followed as applicable.
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Though every effort has been made to assure the accuracy and reliability of the data contained in these documents, OISD hereby expressly disclaims any liability or responsibility for loss or damage resulting from their use.

These documents are intended to supplement rather than replace the prevailing statutory requirements & best engineering practices in vogue.
COMMITTEE FOR
REVISION OF STANDARDS ON ROTARY EQUIPMENT

List of Members

<table>
<thead>
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<th>Name</th>
<th>Organisation</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Sh. D.K.Puri</td>
<td>Reliance Industries Ltd.</td>
<td>Leader</td>
</tr>
<tr>
<td>2. Sh. S.K.Chatterjee</td>
<td>Hindustan Petroleum Corporation Ltd.</td>
<td>Member</td>
</tr>
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<td>3. Sh. Deepak Prabhakar</td>
<td>Mangalore Refinery &amp; Petrochemicals Ltd.</td>
<td>Member</td>
</tr>
<tr>
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<td>Bharat Petroleum Corporation Ltd.</td>
<td>Member</td>
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<td>Member</td>
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<td>Oil Industry Safety Directorate</td>
<td>Member</td>
</tr>
<tr>
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<td>Oil Industry Safety Directorate</td>
<td>Coordinator</td>
</tr>
</tbody>
</table>
## CONTENTS

<table>
<thead>
<tr>
<th>S.N.</th>
<th>Chapter</th>
<th>Page No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>Introduction</td>
<td>1</td>
</tr>
<tr>
<td>2.0</td>
<td>Scope</td>
<td>1</td>
</tr>
<tr>
<td>3.0</td>
<td>Definitions</td>
<td>1</td>
</tr>
<tr>
<td>4.0</td>
<td>Selection of steam turbines</td>
<td>2</td>
</tr>
<tr>
<td>5.0</td>
<td>Selection of gas turbines</td>
<td>4</td>
</tr>
<tr>
<td>6.0</td>
<td>Inspection &amp; testing of turbines.</td>
<td>7</td>
</tr>
<tr>
<td>7.0</td>
<td>Erection &amp; commissioning of turbines.</td>
<td>8</td>
</tr>
<tr>
<td>8.0</td>
<td>Operation</td>
<td>9</td>
</tr>
<tr>
<td>9.0</td>
<td>Maintenance</td>
<td>9</td>
</tr>
<tr>
<td>10.0</td>
<td>Change Management</td>
<td>10</td>
</tr>
<tr>
<td>11.0</td>
<td>Documentation</td>
<td>10</td>
</tr>
<tr>
<td>12.0</td>
<td>References</td>
<td>11</td>
</tr>
</tbody>
</table>

Annexures (I - IV):

- Typical steam purity limits. 12
- Typical list of checks for overhauling of turbines. 13
- Typical procedure for commissioning of new turbines 20
- Typical inspection schedule of gas turbines. 23
1.0 INTRODUCTION

A turbine is a rotary engine that extracts energy from a fluid flow. Turbines in hydrocarbon industry are vital equipment and proper selection, operation and maintenance of these equipment is critical for safety and environment.

This document covers two types of turbines in use in hydrocarbon industry i.e. steam and gas turbines. Both of these turbines are widely used as prime movers for mechanical drives and power generation purposes.

2.0 SCOPE

This standard specifies the minimum requirements in selection, installation, commissioning, operation, inspection & maintenance of steam & gas turbines and their associated systems. This document covers both onshore & offshore areas of hydrocarbon industry.

3.0 DEFINITIONS

3.1 **Alarm point** is the pre determined value of a measured parameter which actuates an alarm, warning the operator about a condition which requires corrective action.

3.2 **Critical Speed** is the speed at which the rotor natural frequency matches with its excitation (rotating speed) frequency. Running of turbine on this speed is avoided.

3.3 **Gas turbine**, also called a combustion turbine, is a rotary engine that extracts energy from a flow of combustion gas. It has an upstream compressor coupled to a downstream turbine, and a combustion chamber in-between.

3.4 **Governing system** controls and maintains the turbine speed steady, when the turbine power is gradually varied.

3.5 **Maximum allowable speed** is the highest speed at which the manufacturer's design will permit continuous operation.

3.6 **Maximum continuous speed** is the speed which is at least equal to 105 percent of the highest speed required by any of the specified operating conditions.

3.7 **Normal operating point** is the point at which usual operation is expected and optimum efficiency is desired.

3.8 **Shall** Indicates mandatory requirement
3.9 **Should**
Indicates recommendatory requirement.

3.10 **Shutdown point** is the preset value of any parameter at which the shutdown of the equipment shall take place. This shutdown can either be manual or automatic.

3.11 **Steam turbine** is a mechanical device that extracts thermal energy from pressurized steam, and converts it into useful mechanical work.

3.12 **Trip speed** is the speed at which the independent emergency over speed device operates to shutdown a prime mover.

4.0 **SELECTION OF STEAM TURBINES**
The selected steam turbines shall conform to API-STD-612 or equivalent standard. In addition, the following factors shall be considered for selection of steam turbines:

4.1 **Inlet and Exhaust Condition**
   a) The turbine shall be selected for the limiting conditions of inlet and exhaust.
   b) Suitable monitoring and safety systems shall be in place to prevent excessive pressure and temperature on individual turbine sections.
   c) Monitoring systems shall include pressure and temperature measurement and their control systems.
   d) Typical safety systems shall include sentinel valves, rupture discs, safety relief valves and water spray systems.

4.2 **Steam Purity**
   a) Limits of contaminants in steam (like sodium, hydroxides, chlorides, sulphates, copper, lead and silicates) shall be specified. A typical steam limits are given at Annexure-1
   b) Suitable systems with a provision of proper monitoring shall be in place to ensure the quality of the steam.

4.3 **Extractions**
   a) The machine and control system shall be compatible, if required, for specified quantity of extractions.
   b) Suitable safety features shall be in place to protect machine from over pressurization and low flow to turbine sections. These shall include pressure safety valves, min flow overrides in the governing system etc.
4.4 Driven Equipment and Mode of operation

a) Steam turbines and control systems shall be suitable for the entire range of operating parameters and mode of operation of the driven equipment.

b) Proper integration of control and protective systems of the steam turbine shall be ensured for safety of driver as well as driven equipment.

4.5 Seals and Sealing Systems

a) The maximum allowable leakage of steam from the turbine glands shall be specified.

b) Seals and sealing systems shall be suitable to maintain leakage of steam below the specified limit.

c) Suitable condensing/ draining system shall be in place to ensure safe disposal/ routing of leakages.

d) The seals and sealing systems shall be selected as per relevant equipment standards and OISD-STD-125 in case of mechanical seals.

4.6 Lubrication Systems

a) For pressurized lubrication systems, provisions for alarm and safe shutdown of the machines shall be built into the system to guard against unsafe situations on account of lubrication systems failure.

b) The system shall primarily guard against low lube oil pressure and high lube oil temperature.

c) Rundown tanks should be provided for the safe coast-down of the steam turbines with high coast down periods.

d) Emergency power shall be provided in absence of run down tanks.

e) Prevention of any accidental spillage of lube oil on to high temperature surfaces shall be duly ensured.

4.7 Process Control and Protection Systems

The safety of equipment in operation shall be ensured by incorporating the following control, protection and safety systems.

a) Where electronic speed control systems are provided, separate pick-ups for speed control and monitoring the over speed shall be provided.

b) Triple redundancy for speed control and redundancy for over speed shall be considered.

c) Over speed system separate from the turbine control system shall be provided. This over speed protection system shall be mechanical, hydraulic or combined.

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d) A manual trip device/ button shall be provided near the turbine.

e) On extraction turbines, the extraction lines shall be provided with a non-return valve (combined check/ trip valve).

f) High temperature surfaces shall be suitably protected to prevent exposure or ingress of oil.

5.0 SELECTION OF GAS TURBINES

The selected gas turbine shall conform to API-STD-616/ equivalent international standard/ proven vendor standards. Electrical auxiliaries/ fittings shall conform to the hazard area classification as per OISD-STD-113.

In addition the following factors shall be considered for selection of gas turbines;

5.1 Inlet and Exhaust Conditions

a) Gas turbine shall be provided with suitable air filtration system based on the condition of the ambient air.

b) Flue gas exhaust system ducting shall be provided with suitable silencer to limit the sound as per applicable standard/ statutory requirement.

c) Corrosion protection of filter media, ducting and silencer etc shall be ensured.

d) Exhaust systems shall have suitable protections against abnormal conditions such as high temperature, expansion etc.

e) Exhaust from the turbine shall meet applicable legislation on contaminants; temperature and location (stack height).

5.2 Fuel Systems

a) The turbine shall be selected for the fuel/s to be used.

b) The firing systems shall be suitable for safe firing, depending upon the specified fuel/s.

c) The venting/ draining of fuel/s from the gas turbine and its fuel skids shall be routed to the flare system (wherever available.) or to a safe location in line with OISD standards.

d) Usage of flexible hoses in fuel gas systems shall be minimized and limited to places where operating conditions are expected to result in relative movement of connecting flanges/ nipples.

e) Facilities with dual fuel firing capability shall have provision for continuously purging the liquid fuel lines when the turbine is running on gaseous fuel.

f) Both the fuel systems Fuel Oil /Fuel Gas shall have separate provision of fuel shutoff valves in the circuit. This shutoff valve shall completely stop the fuel supply to the turbine.

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in case of any shutdown/ trip condition. Valve shall only be opened when all firing permissive are met.

g) All the drains/ vents from the liquid fuel skid shall be routed to closed blow down system.

h) Provision for conditioning of fuel (gas/ liquid) shall be in place to ensure quality of fuel being fired. The conditioning systems shall include filtration, coalescing/ centrifuging, additive injection systems etc.

i) All fuel additives handling facilities shall have display boards of their respective MSDS.

j) In case the turbine fails to fire during start ups, the ignition system must get de-energized automatically after a pre-determined time period.

k) Total sulphur content in the fuel oil shall be considered for designing the metallurgy of downstream HRSG coil, stack etc.

l) Auxiliaries systems shall meet relevant equipment and OISD standards.

5.3 Driven Equipment and Mode of Operation

a) Gas turbines and their respective control systems shall be suitable for the entire range of operating parameters and the mode of operation of the driven equipment.

b) Proper integration of control and protective systems of the gas turbine shall be ensured for safety of driver as well as driven equipment.

5.4 Lubrication Systems

a) For pressurized lubrication systems, provisions for alarm and safe shutdown of the machines shall be built into the system to guard against unsafe situations on account of lubrication systems failure.

b) Turning gear/ ratchet device wherever provided shall not engage without adequate system lube oil pressure at the bearings.

c) Turning devices shall be independent of starting device clutch, for their operation. Manual barring of gas turbines shall be made possible during loss of power or failure of power to the turning/ ratcheting device.

d) Lubricating oil pumps with separate emergency source of power supply shall be made available for safe cool down of the gas turbines.

e) Rundown tanks shall be provided for the safe coast-down of the turbines with high coast down periods.

f) Emergency power shall be provided in absence of run down tanks.

g) Lubrication systems shall be designed so as to prevent accidental spillage of lube oil on to high temperature surfaces.
5.5 Noise and Environment Control

a) Suitable acoustic enclosures shall be provided to meet the applicable statutory requirements with respect to noise and ambient temperature.

b) Enclosures shall have provisions to open the access doors from inside also.

c) Access doors shall be designed so as to prevent accidental closure.

d) Exhaust systems shall be provided in the enclosure to vent out oil/ fuel vapors.

e) Exhaust from the gas turbine shall meet the applicable statutory emission norms for environment.

5.6 Fire Protection Systems

a) Gas turbines enclosures shall have provision of sufficient numbers of hydrocarbon detectors with a provision for audio visual alarm in field as well as control room for detection of the leaks inside the enclosure.

b) System shall be provided to detect and suppress fire/s inside the enclosure of the gas turbines.

c) Gas turbine shall not be run without the fire suppression system in place. Fire suppressant in use, should either be connected to reserve source or else provision for spare bank of filled cylinder shall be made.

d) Audio Visual systems shall be provided to generate alarm/ warning in case of fire.

e) Suitable operating instructions /system shall be in place to avoid actuation of CO₂ fire suppressant system while the operating/ maintenance crew performs maintenance/ inspection checks inside the turbine enclosure.

f) Testing and inspection schedule of the fire suppressant system in use shall be guided by the relevant NFPA code/standard or equivalent international standard.

5.7 Seals and Sealing Systems

a) Suitable sealing systems shall be provided to prevent leakage of gases to the atmosphere.

b) Systems shall have the provision for purging the seals with air.

5.8 Process Control, Protection and Safety Systems

a) Loss of flame protection shall be provided and should be with redundancy.

b) Alarms/trips shall be provided for high exhaust temperature.

c) Alarms/ Trips shall be provided for exhaust temperature spread and High Wheel Space temperature.

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d) Alarms/ Trips shall be provided for high differential pressure across inlet filter.

e) Separate pick-ups for speed control and over speed trip shall be provided. Triple redundancy for speed control and redundancy for over speed should be considered.

f) Over speed system separate from the turbine control system shall be provided. This over speed protection system shall be mechanical, hydraulic, electronic or combined.

g) A manual trip device/ button shall be provided near the turbine.

h) In all the trip conditions of the gas turbines, triple redundancy logic with 2 out of 3 voting should be considered.

i) High temperature surfaces shall be suitably protected to prevent exposure or ingress of oil.

5.9 Machine Monitoring and Protection system

The monitoring and protection system shall be able to achieve the following:

a) Shall have provisions to monitor the various machine conditions like exhaust gas temperatures, vibrations, turbine over speed, loss of flame, bearing metal temperatures, axial displacement, oil/ cooling water pressures and temperatures etc.

b) Acceptable limits for all machine condition parameters.

c) Generate alarms when any machine parameter reaches the pre-set values in order to facilitate evaluation and carry out suitable measures as deemed fit.

d) Generate machine trip when any machine parameter exceeds the specified limits to protect from possible catastrophic results.

6.0 INSPECTION & TESTING OF TURBINES (STEAM & GAS)

a) Stage inspections and tests at various manufacturing stages shall be selected such that the integrity of the rotating components and the turbine is ensured. A typical test that shall be carried out includes Material Testing, Dimensional Checks, and Impeller over Speed, Dynamic Balancing, Testing of Rotors, Mechanical Test Run of Turbine, Hydro-Testing & Dynamic Pressure Testing for Seals.

b) If specified, performance / Complete Unit test shall be carried out.

c) Records of such tests shall be evaluated and maintained for future reference.

d) The inspection checks of turbines during overhauling are detailed at Annexure-2
7.0 ERECTION & COMMISSIONING (STEAM AND GAS TURBINES)

7.1 Erection

a) Equipment erection shall be done in accordance with approved procedures laid down based on OEM recommendations.

b) Erection quality shall be ensured with the use of Installation & Test Procedure (ITP), Stage-wise inspection and hold points.

c) Only such tools, tackles and lifting equipment shall be used which are periodically inspected, calibrated and certified as ‘fit for use’ by the competent person.

7.2 Commissioning

Commissioning of Steam and Gas Turbines shall be ensured with following activities (as minimum) applicable for the particular type of turbine.

7.2.1 Pre-commissioning Activities


b) Ensuring cleanliness of all fuel, oil, steam piping and air piping/ducts. Cleanliness of steam piping shall be ensured by target blowing.

c) Verification of inlet strainer for bypassing of debris across seating frame.

d) Verification of erection checklists.

e) Ensuring readiness of instrumentation and completion of loop checks.

f) Verification / Certification of correct functioning of alarms & trips/protections.

7.2.2 Preparation & Compliance with following Procedures

a) Equipment Start-up

b) Normal Operation

c) Normal and Emergency Shutdown

7.2.3 Deployment of Qualified, Trained and Competent personnel.

7.2.4 Readiness & functional verification of auxiliary systems

7.2.5 Equipment shall be commissioned as per startup procedures. All operating and machine parameters shall be verified for conformance with design values at various steps.

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Deviations, if any, from design values shall be recorded and corrective measures taken after evaluation.

A typical procedure for commissioning of new turbines is given at Annexure -3

8.0 OPERATION

Safe and reliable operation of turbines shall be ensured through the following:-

a) Use of Safe Operating Procedure (SOP). Safe Operating Procedures shall address start-up, normal operation and emergency shutdown.

b) Deployment of trained, qualified & skilled operators.

c) Periodic training and validation of operations personnel.

d) Operation of the equipment within the specified operating window.

e) Monitoring and protection systems shall be in place and operational. No protection shall be bypassed without approval from authorized personnel. (Refer to OISD-RP-126).

f) ‘Normal, Minimum and Maximum’ values of operating parameters shall be defined in the procedures or log sheets.

g) Continuous monitoring of inlet and exhaust conditions, equipment parameters like vibrations, bearing temperature etc and auxiliary systems like lubricating oil, etc. as defined in OISD-RP-124.

h) Ensure no leaks from Fuel, Steam and Oil piping.

i) Proper display boards detailing the precautions to be observed in handling the equipment including its safe start-up and shutdown procedure shall be displayed prominently near the equipment.

9.0 MAINTENANCE

9.1 To ensure good health and integrity of turbines, proper maintenance system shall be in place. Following shall be considered in finalization of the maintenance program:-

a) Condition of the Machine

b) Type of Machine

c) Criticality and Standby Availability

d) Running Hours

e) OEM recommendation

f) Opportunity

9.2 The maintenance systems shall comprise of the following:-

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a) Standard Maintenance Procedure (SMP)
b) Compliance to requirements like, Work Permit System, etc.
c) Deployment of competent and skilled personnel validated through training.
d) Use of tools, tackles and lifting equipment, which are periodically inspected, calibrated and certified fit for use by competent person.
e) Procedure shall be established to carry out monitoring of the equipment and process parameters in line with OISD-RP-124.
f) Procedures shall also detail the type and scope of the Predictive and Preventive activities being done based on standard practices and OISD-RP-124. Typical preventive maintenance schedules for gas turbines are attached at Annexure-4.
g) Overhauling of Steam turbines shall be based on Condition of the equipment, OEM recommendations or available
h) opportunities due to plant shutdowns (turnarounds).
i) Periodic Inspection and Overhauling of Gas Turbines shall be carried out in consultation with the OEMs and based on the fired hours and type of fuel used (equivalent fired hours).
j) Procedure shall be in place with regard to spare parts to be maintained in the inventory considering the criticality of the turbine and their availability shall be ensured.
k) Review and approvals shall be done for refurbishment of critical components.

10.0 CHANGE MANAGEMENT

a) Change management systems shall be in place as per OISD-RP-126.
b) Changes in the Process and Equipment related parameters or any related System shall be properly reviewed by all concerned and approved by designated authority and suitably documented.

11.0 DOCUMENTATION

Following documents shall be maintained for the turbines:-

a) Installation & Test Plan
b) Standard Maintenance Procedure
c) Equipment Failure History
d) Failure Analysis Report

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12.0 REFERENCES

This Standard shall be read in conjunction with the following standards, codes and publications.

a) API Standard 611 - General purpose steam turbine for Refinery Services.
b) API Standard 612 - Special purpose steam turbine for Refinery Services.
c) Project Specifications as specifically applicable to the installation.
d) Manufacturer’s instruction manuals
e) OISD-RP-123 Inspection and maintenance--Rotating equipment components.
f) OISD-RP-124 Predictive maintenance.
g) OISD-RP-126 Specific Maintenance Practices
h) API 613 - Special purpose Gear Units for Refinery Services.
i) API 614--Lubrication, Shaft--sealing and control oil system for special purpose applications.
j) API 615--Sound Control of mechanical equipment
k) API 616--Combustion Gas Turbine for General Refinery Services
l) API 670--Non contacting vibration and axial position monitoring system.
m) API 678--Accelerometer based vibration monitoring system.
n) ISO 3977--Gas Turbine Procurement
p) OISD-STD-152 on Instrumentation.
q) ISO 13691 :2001 - Petroleum and natural gas industries -- High-speed special-purpose gear units
r) ISO 10438 : 2003 - Petroleum, petrochemical and natural gas industries -- Lubrication, shaft-sealing and control-oil systems and auxiliaries

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# Annexure-1

## TYPICAL STEAM PURITY - LIMITS

<table>
<thead>
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<th></th>
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<td>Micromhos/cm at 25Deg c</td>
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<td><strong>Drum</strong></td>
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<td><strong>SiO, ppb, max</strong></td>
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<td><strong>Fe, ppb, max</strong></td>
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<td>50</td>
</tr>
<tr>
<td><strong>Cu, ppb, max</strong></td>
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<tr>
<td><strong>Na + K, ppb, max</strong></td>
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<td>10</td>
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<tr>
<td>Up to 800 Psi [55616 kpa (gauge)]</td>
<td>20</td>
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<tr>
<td>801 to 1450 psi [5517 to 9998 kpa (gauge)]</td>
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<tr>
<td>1451 to 2400 psi [9999 to 16548 kpa (gauge)]</td>
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<tr>
<td>Over 2400 psi [over 16548 kpa (gauge)]</td>
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A Typical List of Checks for Over-hauling

A. STEAM TURBINE

The following checks shall be carried out:

i) Couplings

Couplings are prone to sludge deposits; the problem being more acute in grease lubricated couplings. The couplings shall be checked for cleanliness. Condition of "O" rings shall also be checked. The coupling teeth and adjoining shaft portion near key-ways should be checked by D.P. for possible inner or hairline cracks, if required. Note1

ii) Oil Coolers

The oil coolers are prone to clogging on the waterside and hence shall be checked for cleanliness.

iii) Condenser

The condenser shall also be checked for cleanliness. Condition of electrodes, if any, provided for cathodic protection shall be inspected.

iv) Protective relays and trips

All relays and trips shall be checked for performance.

v) Bearings

a) Radial Bearings

The condition of the Babbit lining shall be checked. The oil seal shall be inspected to ensure proper clearances. The bedding of the bearing shell in housing shall also be checked. All clearances shall be as per manufacturer's recommendations.

b) Thrust Bearing

Condition of thrust collar and thrust pads shall be checked. All clearances shall be maintained as per manufacturer's recommendations.

c) Anti friction Bearing

Inspection of anti friction bearings shall be carried out as specified in OISD-Std-123 on Inspection of Rotating Equipment components.

vi) Gear Box

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The gear teeth shall be visually checked for wear and cracks. A magnifying glass shall be used to locate hairline cracks. If any deposits are noticed on gear teeth the source and type of deposits shall be investigated. All clearances shall be checked and maintained as per manufacturer’s recommendations. The matching gears should be checked for inner hairpin cracks by D.P. test, if required. Note1

**vii) Coupling and Alignment**

The coupling teeth shall be checked for deposits of sludge, wear, cracks etc., The oil sealing arrangement shall be inspected. The coupling bolts shall be inspected for elongation, wear or cracks. Alignment with the driven equipment shall be checked.

**viii) Steam Admission Valves**

All steam admission valves shall be inspected for wear and cracks. All valves shall be tested prior to use after repairs.

**ix) Main Stop Valve**

The main stop valve shall be visually inspected and hydraulically tested.

**x) Servo Motors**

Clearances shall be checked and maintained as per manufacturer’s recommendations.

**xi) Protection System**

All clearances and proper functioning of protection systems shall be checked.

**xii) Governing System**

The Governing system shall be checked for wear and clearances shall be checked and restored as per manufacturer's recommendations.

**xiii) Rotor**

The condition of the journals labyrinths, rotor blades and rotor discs shall be inspected. Labyrinth clearances shall be checked.

**xiv) Stator**

The condition of diaphragms, labyrinths, diaphragm flat springs and casing parting plane (flange) shall be inspected.

**B. GAS TURBINES**

The following checks shall be carried out;

**a) Compressor Assembly**

"OISD hereby expressly disclaims any liability or responsibility for loss or damage resulting from the use of OISD Standards/Guidelines."
i) The compressor inspection shall be conducted to determine the mechanical and aerodynamic condition of the compressor.

ii) Holding bolts of stacked rotor shall be inspected for looseness.

iii) Both stator and rotor blades shall be cleaned and checked for cracks with dye penetrant.

iv) Blade roots shall be closely inspected for severe pitting as this may lead to structural failures.

v) Rotor blade tip clearance shall be measured and compared with manufacturer's recommended clearances.

vi) Rotor end float/thrust bearing axial clearance shall be checked.

vii) Labyrinth seals shall be inspected.

viii) Lateral clearance between the rotor and stator blades shall be checked.

ix) Inlet guide vanes shall be inspected for erosion and cracks.

b) **Combustion System**

i) All combustors shall be minutely inspected for cracks and deposits.

ii) Combustion liners shall be thoroughly inspected for cracks.

iii) Carbon deposits in flame failure viewing head and sight windows shall be removed and cleaned.

iv) The liquid and gas fuel burner shall be inspected.

v) The transition pieces shall be inspected for cracks and wear at the points of contact.

vi) Wear at the nozzle end of the transition piece shall be checked as it allows excessive vibration of the transition piece which might lead to cracking.

vii) Transition pieces shall be replaced if 50 per cent of inner or outer seal is reduced to half the original thickness.

viii) Ignitor plugs and leads shall be checked and replaced if necessary.

ix) Fuel valve and actuator settings shall be checked.

x) Combustor clearance with respect to fuel nozzle and igniters and baffles shall be measured and compared with manufacturer recommended figures.

xi) Thermocouple weld shall be checked for cracks.

c) **Turbine Section**

"OISD hereby expressly disclaims any liability or responsibility for loss or damage resulting from the use of OISD Standards/Guidelines."
i) Turbine rotor and stator blades for each stage shall be cleaned and closely inspected for erosion and cracks with non-destructive examination.

ii) Rotor/stator blade tip clearances shall be measured and compared with manufacturer's recommendation.

iii) Perpendicular distance between the trailing edges of each vane and the surface of the next vane shall be carefully measured to ensure equal gas distribution of gas flow to the rotating blading for elimination of blade vibration.

iv) Entire turbine rotating blades shall be replaced if several blades are fatigue cracked.

v) Condition of labyrinths shall be checked.

vi) It shall be ensured that diaphragm cooling air supply lines are clean.

d) **Bearings**

During inspection of journal bearings the following locations shall be checked for wear:

i) Babbited shoe surface
ii) Pivoting shoe surface and seat in retainer ring.
iii) Seal ring bore or end plates.

Clearance check of bearing shall be carried out as follows:

i) Housing outer diameter and inner diameter shall be measured to make sure it is even.

ii) Bore and face end plates shall be inspected for full contact.

iii) Pivoting surfaces of shoe and housing ring shall be checked for scratches, scoring, or erosion.

iv) For tilting pad bearings, blue shoe the pivot surface and check for contact area and positions. The contacting surface shall be in center only and at the bottom portion of the pivot bore in the retainer.

v) Check to ensure that pins do not bottom out in pads.

vi) Shaft clearance shall be checked.

e) **Balancing**

i) Rotor with assembled blades shall be dynamically balanced without the coupling, but with half key.

ii) Dynamic balancing shall be done at the operating speed range rather than at low speeds. However, in case it is not possible, the same should be done as per manufacturers’ recommendations.

iii) The maximum unbalance should not exceed: 2.0 mils on rotors with speed below

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4000 rpm 1.5 mils for speed between 4000-8000 rpm, 1.0 mils for speed between 8000-12000 rpm, 0.5 mils for speeds above 12000 rpm. These limits also include shaft run out (API 616)

f) **Lubricating oil system**

   i) Physical and chemical properties of the lube oil shall be tested.
   
   ii) Piping shall be inspected for clogging and corrosion.
   
   iii) Oil reservoirs and tanks shall be cleaned and inspected.
   
   iv) Oil coolers and accumulators shall be inspected, cleaned and hydrostatically tested at one and one-half times design pressure.
   
   v) Oil strainer should be inspected and cleaned.
   
   vi) Oil pressure control valves, relief valves and check valves shall be tested as per testing procedures.

g) **Gear Box**

   i) Gear teeth shall be checked for cracks and wear.
   
   ii) Backlash shall be measured and compared with manufacturer’s recommendation.
   
   iii) Bearings shall be inspected as per procedure given in 4.3.2(d).
   
   iv) Gears shall be inspected for proper teeth contact.
   
   v) Gear element shall be dynamically balanced and maximum allowable residual unbalance shall be as per followings:

   $$\text{Max. unbalanced force} = \frac{56,347 \text{ (ounce inches)} \times \text{journal static weight load}}{\text{NMC}^2}$$

   where, NMC = Maximum continuous speed, revolutions per minute.

h) **Coupling and Alignment**

   i) Gear couplings shall be inspected for teeth breakage, scoring and pitting.
   
   ii) Disc couplings shall be checked for cracks by non-destructive test.
   
   iii) Continuous lubricated type coupling shall be inspected for corrosive wear and coupling contamination.
   
   iv) Cold alignment between shaft shall be checked and ensured that the readings are within the limits as prescribed by manufacturer.

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i) **Control System and Instrumentation**
   
   i) All pressure gauges, switches, temperature gauges, flow meters, vibration detectors, control valves, control loops, protection systems and transmitters shall be tested and calibrated once in a year.
   
   ii) All control systems shall be tested and calibration of alarm and trip points shall be done to control specifications.

j) **Starting System**
   
   i) Clearance of clutches jaws in engaged and disengaged position shall be checked.
   
   ii) Tubing connection and hydraulic hoses shall be checked for wear, leakage and abrasions.

k) **Fuel System**
   
   i. The following shall be checked while inspecting the liquid fuel forwarding system:
      
      1. Centrifugal pump shall be inspected as per the provisions of OISD-STD-119.
      
      2. Fuel valve heaters shall be checked for defective element.
   
   ii) Fuel oil system shall be inspected as per the following:
      
      1. Stop valve shall be checked for proper operation.
      
      2. Fuel nozzle selector valve shall be inspected for proper operation and worn diaphragm in valve actuator.
   
   iii) Gas control valve and control loop of Fuel Gas System shall be checked for proper operation, trip action and calibration.

l) **Inlet System**
   
   i) Air filter shall be ensured cleaned.
   
   ii) Inlet compartment, inlet duct and silencers shall be ensured cleaned.

m) **Control Oil System Hydraulic Supply**
   
   i) Hydraulic supply pump shall be checked for relief valve leakage at shaft and mounting flanges.

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ii) Air bleed valves shall be inspected for proper operation.

iii) Hydraulic system piping shall be inspected for corrosion and leakage.

n) **Cooling and Sealing Air System**
   i) Orifice plates and unions of piping shall be inspected.
   ii) Compressor bleed valves shall be checked for correct open/close condition.

o) **Compressor Cleaning System**
   i) Flow meter shall be calibrated.
   ii) Stop valve shall be checked for proper operation.

p) **Fire Detection System and Ultraviolet Detectors**
   i) Fire detectors shall be inspected for damage and proper operation.
   ii) Ventilation dampers shall be checked for free operation.
   iii) High pressure storage cylinders shall be checked for loss of cylinder weight.

q) **Water system**
   i) Water pump shall be inspected as per pump manufacturer's instructions.
   ii) System shall be checked for fouling condition.
   iii) All valves shall be checked for proper operation.
TYPICAL PROCEDURE FOR COMMISSIONING OF NEW TURBINES

1.0 PRESTART UP CHECKS

Manufacturers of turbines give detailed instruction for start up of turbines supplied by them. Services of their representatives are also available during first start up of a new turbine. Therefore, instructions supplied by them will over ride the general instructions applicable to all turbines given here. These requirements are meant to supplement requirements of the supplier and do not absolve the responsibility of the supplier's representative who commission the turbines. During start-up in addition to manufacturer's instructions the following checks shall also be carried out.

i) All pipe connections to the turbine shall be checked to ensure that they are as per drawing and are of proper rating.

ii) All valves and non return valves shall be checked for correctness with reference to direction of flow in the lines.

iii) It shall be ensured that blinds are removed and gaskets are provided in all joints.

iv) It shall be ensured that hydraulic test of all lines are conducted as per specifications and test certificates are signed by a competent authority.

v) All steam lines to the turbine shall be blown to remove foreign materials, electrodes, welding slag and mill scale from the line and the line shall be certified to be free from foreign material.

vi) All other lines shall be flushed with water and blown with steam/air to remove foreign particles.

vii) All lube oil lines shall be flushed, cleaned, pickled with acid to remove mill scale and other deposits in the line and treatment shall be given to make the line passive.

viii) All auxiliary equipment such as condensate pump, vacuum system, auxiliary oil pumps shall be checked for satisfactory operation.

ix) Tripping of auxiliaries and automatic start up of stand by, if provided, shall be checked.

x) The operation of motor operated valves, their limit switches and remote operation shall be checked.

xi) The instruments mounted on the turbine, auxiliaries and turbine panel for proper operation and calibration shall be checked.

xii) Lube oil to the system shall be circulated after fine mesh strainers are installed in the turbine bearings and the quality of oil shall be monitored.

xiii) The oil shall be replaced after circulation.
xiv) The operation of bearing gear motor while circulating the oil through the bearing shall be checked.

xv) The emergency trip gear shall be checked for proper functioning, operating the knob or level at the trip gear and by remote operation. The responses of the emergency stop valve, extraction valve and servo valve shall be observed.

xvi) Open or close emergency stop valve by means of the starting device. The response shall be observed.

xvii) The operation of the spindles of control valves shall be checked to ensure easy and smooth operation.

xviii) The static characteristic of operation of the valve shall be compared with the test report.

xix) The oil strainers shall be replaced periodically during circulation of the lube oil if pressure drop exceeds limits prescribed by the manufacturer.

xx) The washers or belleville washers shall be used and gap spring bushes shall be easily movable. The play between the head of the bolt and the washers should amount to approximately 0.1 mm so that casing expansion takes place without obstruction.

2.0 STARTING OF THE TURBINE

The starting procedures as prescribed by the manufacturers of the turbine shall be followed. The following observations shall be made while starting the turbine, as these can contribute to major damage during start up:

i) Unusual expansion

iii) Vibrations

iv) Lack of lubrication

iv) Over speeding

v) Abnormal rubs.

3.0 SPARES

Only spares obtained from supplier of steam turbine shall be used for replacement in governing and protection system of steam turbine. However, in the case of obsolete turbines spares from other sources can be used but stringent inspection shall be carried out to ensure that safety is not compromised.

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Annexure 4

TYPICAL INSPECTION FREQUENCIES OF GAS TURBINES

<table>
<thead>
<tr>
<th>Sr.No</th>
<th>Type of Inspection</th>
<th>Inspection Frequency (Operating Hours)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Combustion Inspection</td>
<td>8000 Hours</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Combustion Inspection</td>
<td>16000 Hours</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Hot Gas path Inspection.</td>
<td>24000 Hours</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Combustion Inspection</td>
<td>32000 Hours</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Combustion Inspection</td>
<td>40000 Hours</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Major Inspection</td>
<td>48000 Hours</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Borescopic Inspection</td>
<td></td>
<td>See note 1</td>
</tr>
</tbody>
</table>

TYPICAL INSPECTION SCHEDULES OF GAS TURBINES

Note 1:
In addition to above inspections borescopic inspections of turbines is also suggested as per the following schedule.

<table>
<thead>
<tr>
<th>Sr.No</th>
<th>Fuels fired in gas turbine</th>
<th>Frequency of borescopic inspection</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Gas and distillate fuel oils</td>
<td>Annually or during combustion inspection whichever is earlier.</td>
</tr>
<tr>
<td>2</td>
<td>Heavy fuel oils (Crude/resid etc)</td>
<td>Semi annually or during combustion inspection whichever is earlier.</td>
</tr>
</tbody>
</table>

Combustion Inspection
The combustion section of the gas turbine is always removed, inspected, and reassembled during this inspection cycle. It is the first major step in each outage. Combustion inspection includes Fuel nozzles, liner, assemblies, and cross fire tubes. Transition pieces may be inspected at twice the values shown.

Hot / Gas Path Inspection
This inspection includes a combustion inspection along with the inspection of the turbine, the accessory compartment, inlet, oil tanks, oil coolers, and exhaust. Outage work will vary from plant to plant. Based on the actual condition of the parts corrective actions need to be decided.

Major inspection
A major inspection should be scheduled in accordance with the recommendations in the owner’s Operations and Maintenance Manual or as modified by the results of previous borescope and hot gas path inspection. The purpose of the major inspection is to examine all of the internal rotating and stationary components from the inlet of the machine through the exhaust. The work scope shown during this inspection involves inspection of all of the major flange-to-flange components of the gas turbine, which are subject to deterioration during normal turbine operation. This inspection includes previous elements of the combustion and hot gas path inspections, in addition to laying open the complete flange-to-flange gas turbine to the horizontal joints.

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