Guide for Source Inspection and Quality Surveillance of Rotating Equipment
Foreword

This guide has been developed to provide information for source inspectors for the purpose of providing a consistent method of Supplier/Vendor (S/V) quality surveillance for the oil, petrochemical and gas industries. It is intended as a resource for individuals studying to take the API Source Inspector Certification examination. Other references contained herein and in the published Body of Knowledge (BOK) will also be necessary for individuals to become familiar with in order to pass the examination and to perform satisfactorily in the source inspection job. This study guide is also intended as a draft from which an API Recommended Practice for Source Inspection could eventually be formulated and published utilizing the ANSI standardization process.
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Guide for Source Inspection and Quality Surveillance of Rotating Equipment

1.0 Scope/Purpose

This study guide covers the process of providing quality surveillance of materials, equipment and fabrications being supplied for use in the oil, petrochemical and gas industry, including upstream, midstream and downstream segments. This guide may be used as the basis for providing a systematic approach to risk-based source inspection in order to provide confidence that mechanical rotating equipment being purchased meet the minimum requirements as specified in the project documents and contractual agreements. The activities outlined in this study guide do not intend to replace the manufacturer’s own quality system, but rather are meant to guide source inspectors acting on behalf of purchasers to determine whether manufacturers own quality systems have functioned appropriately, such that the purchased equipment will meet contractual agreements.

This study guide focuses primarily on Mechanical Rotating Equipment including but not limited to: pumps, gears, compressors, turbines, etc. and associated appurtenances. This document assumes that suppliers/vendors (S/V) have been pre-qualified by a systematic quality review process of their facilities and quality process to determine if the facility has the ability to meet the requirements of the contractual agreements. That process generally leads to a list of pre-approved S/V’s deemed acceptable to the supply chain management of the purchaser and capable of meeting the requirements of the contract prior to it being placed. S/V’s on such a list will normally have an acceptable quality process already in place that meets the requirements of the contract. The purpose of source inspection in such a case is simply to verify that the S/V quality process is working as it should and to verify that certain vital steps in the inspection and test plan (ITP) have been satisfactorily accomplished prior to manufacturing completion and/or shipping.

The primary purpose of this study guide is to assist candidates intending to take the API source inspection examination to become certified source inspectors for mechanical rotating equipment. The study guide outlines the fundamentals of source inspection and may be useful to all personnel conducting such activities to perform their jobs in a competent and ethical manner. For more information on how to apply for Source Inspection Certification, please visit API website at http://www.api.org/certification-programs/icp/programs and follow the links as shown in chart below.

API website
(www.api.org) select Certification Programs select ICP Programs select Source Inspector Certification Exam

The Source Inspector Examination contains 100 multiple-choice questions targeting core knowledge necessary to perform source inspection of mechanical rotating equipment. The focus of the exam is on source inspection issues and activities rather than design or engineering knowledge contained in the reference standards. The exam is closed book and administered via computer based testing (CBT). The bulk of the questions address mechanical rotating equipment inspection/surveillance which are typically known by persons who have experience working as source inspectors or persons intending to work as source inspectors who have studied the material in this study guide and the associated reference materials.
2.0 Introduction

Like most business processes, the Source Inspection work process follows the Plan–Do–Check–Act circular process first popularized in the 1950’s by Edward Deming. The “Planning” part of source inspection is covered in Sections 6 and 7 of this study guide and involves the source inspection management systems, source inspection project plan and the Inspection and Test Plan (ITP). The “Doing” part is covered in Sections 8 and 9 and involves implementing the ITP, participating in scheduled source inspection work process events, filing nonconformance reports and source inspection report writing. The “Checking” part, covered in Section 8.7, involves looking back at all the source inspection activities that occurred in the Planning and Doing segments to see what went well and what should be improved based on the results of that look-back. And finally the “Act” part (sometimes called the “Adjust” part) covered in Section 8.8 involves implementing all the needed improvements in the “Planning and Doing” process before they are implemented on the next source inspection project.

3.0 References

The following standards or other recommended practices are referenced in this study guide and are the documents from which the SI exam has been developed.

API - American Petroleum Institute

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<td>Centrifugal Pumps for Petroleum, Petrochemical and Natural Gas Industries</td>
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<td>API 611</td>
<td>General-Purpose Steam Turbines for Petroleum, Chemical, and Gas Industry Services</td>
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<td>Lubrication, Shaft-Sealing and Control-Oil Systems and Auxiliaries for Petroleum, Chemical and Gas Industry Services</td>
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<td>API 617</td>
<td>Axial and Centrifugal Compressors and Expander-Compressors for Petroleum, Chemical and Gas Industry Services</td>
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<td>API 618</td>
<td>Reciprocating Compressors for Petroleum, Chemical, and Gas Industry Services</td>
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<td>API 619</td>
<td>Rotary Type Positive Displacement Compressors for Petroleum, Petrochemical and Natural Gas Industries</td>
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<td>API 677</td>
<td>General-Purpose Gear Units for Petroleum, Chemical and Gas Industry Services</td>
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<td>API 682</td>
<td>Pumps-Shaft Sealing Systems for Centrifugal and Rotary Pumps</td>
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ASME (ASME International; formerly known as American Society of Mechanical Engineers)

Boiler and Pressure Vessel Code (BPVC)

- Section II—Materials, Parts A, B, C, and D.
- Section V—Non-destructive Examination (Methods).
- Section VIII—Division 1 Appendices (Acceptance Criteria).
- Section IX-Qualification Standard for Welding and Brazing Procedures, Welders, Brazers, and Welding & Brazing Operators.
### Definitions, Abbreviations and Acronyms

For the purposes of this study guide, the following definitions, abbreviations and acronyms apply.

<table>
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<th>Title</th>
<th>Description</th>
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<tbody>
<tr>
<td>AARH</td>
<td>Arithmetic Average Roughness Height (a measure of surface roughness).</td>
</tr>
<tr>
<td>Alarm Point</td>
<td>Preset value of a parameter at which an alarm warns of a condition requiring corrective action.</td>
</tr>
<tr>
<td>Allowable Operating Region</td>
<td>Portion of a pump's hydraulic coverage over which the pump is allowed to operate, based on vibration within the upper limit of this International Standard or temperature rise or other limitation, specified by the manufacturer.</td>
</tr>
<tr>
<td>Amplitude</td>
<td>The magnitude of vibration. Displacement is measured in peak-to-peak. Velocity and acceleration are measured in zero-to-peak or root mean square (rms).</td>
</tr>
<tr>
<td>Anchor Bolts</td>
<td>Bolts used to attach the mounting plate to the support structure (concrete foundation or steel structure).</td>
</tr>
<tr>
<td>Annealing Heat Treatment</td>
<td>Heating an object to and then holding it at a specified temperature and then cooling at a suitable rate for such purposes as: reducing hardness, improving machinability, facilitating cold working, producing a desired micro-structure, or obtaining desired mechanical properties.</td>
</tr>
<tr>
<td>ANSI</td>
<td>American National Standards Institute.</td>
</tr>
<tr>
<td>API</td>
<td>American Petroleum Institute.</td>
</tr>
<tr>
<td>Title</td>
<td>Description</td>
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<tr>
<td>ASME</td>
<td>ASME International (formerly known as the American Society of Mechanical Engineers).</td>
</tr>
<tr>
<td>ASNT</td>
<td>American Society of Nondestructive Testing.</td>
</tr>
<tr>
<td>ASTM</td>
<td>ASTM International (formerly known as the American Society for Testing and Materials).</td>
</tr>
<tr>
<td>Axially (horizontal) Split</td>
<td>Split with the principal joint parallel to the shaft centerline.</td>
</tr>
<tr>
<td>Barrel Pump</td>
<td>Horizontal pump of the double-casing type.</td>
</tr>
<tr>
<td>Baseplate</td>
<td>A fabricated (or cast) metal structure used to mount, support, and align, machinery and its auxiliary components. Baseplates may be directly grouted to concrete foundations (after proper leveling) or bolted to pre-grouted chockplates.</td>
</tr>
<tr>
<td>Bellows Seal</td>
<td>Type of mechanical seal that uses a flexible metal bellows to provide secondary sealing and spring loading.</td>
</tr>
<tr>
<td>BEP</td>
<td>Flowrate at which a pump achieves its highest efficiency at rated impeller diameter.</td>
</tr>
<tr>
<td>BHP</td>
<td>Brake Horsepower. The actual amount of horsepower being consumed by the rotating equipment.</td>
</tr>
<tr>
<td>Blades</td>
<td>Rotating airfoils for both compressors and turbines unless modified by an adjective.</td>
</tr>
<tr>
<td>BOK</td>
<td>Body of Knowledge (in this case the BOK for the Source Inspector examination).</td>
</tr>
<tr>
<td>Booster Pump</td>
<td>Oil pump that takes suction from the discharge of another pump to provide oil at a higher pressure.</td>
</tr>
<tr>
<td>BPVC</td>
<td>Boiler and Pressure Vessel Code (published by ASME).</td>
</tr>
<tr>
<td>Buffer Fluid</td>
<td>Externally supplied fluid, at a pressure lower than the pump seal chamber pressure, used as a lubricant and/or to provide a diluent in an Arrangement 2 seal.</td>
</tr>
<tr>
<td>C</td>
<td>The chemical symbol for carbon which may appear on a MTR.</td>
</tr>
<tr>
<td>Certification</td>
<td>Documented and signed testimony of qualification. Certification generally refers to the confirmation of certain, specified characteristics of a product or confirmation of a person meeting requirements for a specific qualification.</td>
</tr>
<tr>
<td>Calibration</td>
<td>A comparison between measurements—one of known magnitude or correctness (the standard) compared to the measuring device under test in order to establish the accuracy of a measuring device.</td>
</tr>
<tr>
<td>Cartridge Seal</td>
<td>Completely self-contained unit (including seal/rings, mating ring/s, flexible elements, secondary seal, seal gland plate, and sleeve) that is preassembled and preset before installation.</td>
</tr>
<tr>
<td>Circulating Oil System</td>
<td>A system which withdraws oil from the housing of bearings equipped with oil rings and cools it in an external oil cooler before it is returned to the bearing housing.</td>
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<tr>
<td>Title</td>
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<tr>
<td>Cladding</td>
<td>A metal integrally bonded onto another metal (e.g. plate), under high pressure and temperature whose properties are better suited to resist damage from the process fluids than the underlying base metal.</td>
</tr>
<tr>
<td>Cold Working</td>
<td>Plastic deformation (forming, rolling, forging, etc.) of metals below the recrystallization temperature of the metal.</td>
</tr>
<tr>
<td>Coast Down Time</td>
<td>Period required after the driver is tripped for the equipment to come to rest.</td>
</tr>
<tr>
<td>Compressor Rated Point</td>
<td>The intersection on the 100% speed curve corresponding to the highest capacity of any specified operating point.</td>
</tr>
<tr>
<td>Console</td>
<td>Total system whose components and controls are packaged as a single unit on a continuous or joined baseplate.</td>
</tr>
<tr>
<td>Cr</td>
<td>The chemical symbol for chromium which may appear on an MTR.</td>
</tr>
<tr>
<td>Critical Equipment</td>
<td>Equipment that has been risk assessed and determined that if it were to fail in service, it would have an unacceptable impact on process safety, environment, or business needs and therefore deserves a higher level of source inspection attention to make sure the equipment being delivered is exactly as specified.</td>
</tr>
<tr>
<td>Critical Service</td>
<td>Critical service is typically defined as those applications that are unspared/single-train installations whereby loss of operation would result in significant loss of production, loss of primary process containment, or threat to personnel safety.</td>
</tr>
<tr>
<td>Critical Speed</td>
<td>Shaft rotational speed at which the rotor-bearing-support system is in a state of resonance.</td>
</tr>
<tr>
<td>Cu</td>
<td>The chemical symbol for copper which may appear on a MTR.</td>
</tr>
<tr>
<td>Datum Elevation</td>
<td>Elevation to which values of NPSH are referred.</td>
</tr>
<tr>
<td>Destructive Testing</td>
<td>Various tests that are performed on metals for the purposes of determining mechanical properties and which involve testing (usually breaking) of sample coupons. Examples of such tests include tensile testing, bend testing and Charpy impact testing. A destructive testing work process involves extracting samples / coupons from components and testing for characteristics that cannot otherwise be determined by nondestructive testing. The work process involves breaking and/or testing coupons / samples to failure, thus usually rendering the component from which the samples were extracted unfit for continued service.</td>
</tr>
<tr>
<td>Deviation</td>
<td>A departure from requirements in the contractual agreements or its referenced PO, engineering design, specified codes, standards or procedures.</td>
</tr>
<tr>
<td>DFT</td>
<td>Dry Film Thickness (of paint and coatings) which is measured by a DFT gauge.</td>
</tr>
<tr>
<td>Displacement</td>
<td>A vibration measurement that quantifies the amplitude in engineering units of mils (1 mil = 0.001 in.) or micrometers.</td>
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<tr>
<td>Double Casing</td>
<td>Type of pump construction in which the pressure casing is separate from the pumping elements contained in the casing.</td>
</tr>
<tr>
<td>Drive-Train Component</td>
<td>Item of the equipment used in series to drive the pump.</td>
</tr>
<tr>
<td>Dwell Time</td>
<td>The total time that the penetrant or emulsifier is in contact with the test surface, including the time required for application and the drain time.</td>
</tr>
<tr>
<td>Electrical Runout</td>
<td>A source of error on the output signal from a non-contacting probe system resulting from non-uniform electrical conductivity properties of the observed material or from the presence of a local magnetic field at a point on the shaft surface.</td>
</tr>
<tr>
<td>Elevation</td>
<td>The height of any point on a vessel, structure, or assembly as shown on a drawing e.g. nozzle, manway, or longitudinal weld as measured from a base plate or other reference line.</td>
</tr>
<tr>
<td>Employer</td>
<td>The corporate, public or private entity which employs personnel for wages, salaries, fees or other considerations e.g. the employer of the source inspector.</td>
</tr>
<tr>
<td>Engineered Equipment</td>
<td>Equipment that is custom designed and engineered by the client and/or EPC to perform a project-specific function. Engineered equipment will typically require more source inspection than non-engineered equipment.</td>
</tr>
<tr>
<td>EPC</td>
<td>Engineering/Procurement/Construction contract company.</td>
</tr>
<tr>
<td>Equipment Train</td>
<td>Two or more rotating equipment machinery elements consisting of at least one driver and one driven element joined together by a coupling.</td>
</tr>
<tr>
<td>Examiner</td>
<td>A person who performs specified nondestructive examination (NDE) on components and evaluates the results to the applicable acceptance criteria to assess the quality of the component. Typically NDE examiners (sometimes called NDE technicians) are qualified to ASNT NDE personnel qualification practices e.g. SNT-TC-IA or CP-189.</td>
</tr>
<tr>
<td>Fe</td>
<td>The chemical symbol for iron which may appear on an MTR.</td>
</tr>
<tr>
<td>Ferrous Materials</td>
<td>Alloys that are iron based, including stainless steels.</td>
</tr>
<tr>
<td>Flush</td>
<td>Fluid that is introduced into the seal chamber on the process fluid side in close proximity to the seal faces and typically used for cooling and lubricating the seal faces and/or to keep them clean.</td>
</tr>
<tr>
<td>Gear</td>
<td>Refers to either the pinion or gear wheel.</td>
</tr>
<tr>
<td>Gear Rated Power</td>
<td>The maximum power specified by the purchaser on the data sheets and stamped on the nameplate.</td>
</tr>
<tr>
<td>Gear-Service Factor (sf)</td>
<td>The factor that is applied to the tooth pitting index and the bending stress number, depending upon the characteristics of the driver and the driven equipment, to account for differences in potential overload, shock load, and/or continuous oscillatory torque characteristics.</td>
</tr>
<tr>
<td>Title</td>
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<tr>
<td>Gear Wheel</td>
<td>The lowest speed rotor in a gearbox.</td>
</tr>
<tr>
<td>Gearing</td>
<td>The pinion(s) and gear wheel combination(s). A gear mesh is a pinion and gear wheel that operates together. A gear wheel may mesh with more than one pinion, and therefore be part of more than one gear mesh.</td>
</tr>
<tr>
<td>General Purpose</td>
<td>Usually spared or in non-critical service.</td>
</tr>
<tr>
<td>HAZ</td>
<td>Heat Affected Zone, the area of base metal directly adjacent to the weld that has had its metal structure affected by the heat of welding.</td>
</tr>
<tr>
<td>Hot Working</td>
<td>Plastic deformation (forming, rolling, forging, etc.) of metals at a temperature above the metal recrystallization temperature.</td>
</tr>
<tr>
<td>Hunting Tooth Combination</td>
<td>Exists for mating gears when a tooth on the pinion does not repeat contact with a tooth on the gear until it has contacted all the other gear teeth.</td>
</tr>
<tr>
<td>Hydrodynamic Bearings</td>
<td>Bearings that use the principles of hydrodynamic lubrication.</td>
</tr>
<tr>
<td>ICP</td>
<td>Individual Certification Program (of the API) under which this source inspector certification program is administered.</td>
</tr>
<tr>
<td>Inlet Volume Flow</td>
<td>Flow rate expressed in volume flow units at the conditions of pressure, temperature, compressibility and gas composition, including moisture content, at the compressor inlet flange.</td>
</tr>
<tr>
<td>Inspection</td>
<td>The evaluation of a component or equipment for compliance with a specific product specification, code, drawing and/or standard specified in the contractual requirements, which may include the measuring, testing or gauging of one or more characteristics specified for the product to determine conformity.</td>
</tr>
<tr>
<td>Inspection Agency</td>
<td>An entity employed to provide competent, qualified and certified source inspection personnel for the purpose of performing source inspection. For example, and inspection agency can be an EPC company, an owner-user, or an inspection service company.</td>
</tr>
<tr>
<td>Inspection Coordinator</td>
<td>Individual who is responsible for the development of the source inspection strategy, coordination of the source inspection visits, and implementation of the source inspection activities on a project.</td>
</tr>
<tr>
<td>Inspection Waiver</td>
<td>Permission to proceed with production/shipment without having a purchaser source inspection representative present for a specific activity.</td>
</tr>
<tr>
<td>ITP</td>
<td>Inspection and Test Plan—A detailed plan (checklist) for the source inspection activities which will guide the source inspector in his/her quality assurance activities at the S/V site with reference to applicable technical information, acceptance criteria and reporting information. The supplier/vendor should also have their own ITP to guide their fabrication personnel and quality assurance personnel in the necessary quality steps and procedures.</td>
</tr>
<tr>
<td>Title</td>
<td>Description</td>
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</tr>
<tr>
<td>Lamination</td>
<td>A type of discontinuity with separation or weakness generally aligned parallel to the worked surface of a plate material. In a forging it can rise to the surface or occur internally; it is generally associated with forging at too low of a temperature or in plate material may be caused by the tramp elements that have congregated in the center of the plate during rolling.</td>
</tr>
<tr>
<td>Leakage rate</td>
<td>Volume or mass of fluid passing through a seal in a given length of time.</td>
</tr>
<tr>
<td>Levelness</td>
<td>The position of a surface of a component or structure that is horizontal (within tolerances) with the base plate and at 90 degrees to the vertical plumb line. Nozzle and attachment levelness tolerances are not addressed in ASME BPVC Section VIII, Division 1; however, in the pressure vessel handbook, a ½ tolerance is permissible. For levelness checking of a nozzle on a vessel, a level gauge is used. If the bubble is in the middle of the designated lines, the nozzle is level. A level gauge would be used for verification and measurement that the angle of a hill-side (tangential) nozzle is properly installed relative to the vessel centerline.</td>
</tr>
<tr>
<td>MAWP</td>
<td>Maximum Allowable Working Pressure maximum continuous pressure for which the manufacturer has designed the rotating equipment (or any part to which the term is referred) when operating on the specified liquid or gas at the specified maximum operating temperature (does not include mechanical seal).</td>
</tr>
<tr>
<td>Manufacturer</td>
<td>The organization responsible for the design and manufacture of the equipment.</td>
</tr>
<tr>
<td>Maximum Allowable Continuous Rod Load</td>
<td>The highest combined rod load at which none of the forces in the running gear (piston, piston rod, crosshead assembly, connecting rod, crankshaft, bearings etc.) and the compressor frame exceed the values in any component for which the manufacturer’s design permits continuous operation.</td>
</tr>
<tr>
<td>Maximum Allowable Speed</td>
<td>Highest speed at which the manufacturer's design permits continuous operation.</td>
</tr>
<tr>
<td>Maximum Allowable Temperature</td>
<td>Maximum continuous temperature for which the manufacturer has designed the pump (or any part to which the term is referred) when pumping the specified liquid at the specified maximum operating pressure.</td>
</tr>
<tr>
<td>Maximum Continuous Speed</td>
<td>The speed at least equal to 105% of the highest speed required by any of the specified operating conditions.</td>
</tr>
<tr>
<td>Maximum Discharge pressure</td>
<td>Maximum specified suction pressure plus the maximum differential pressure the pump with the furnished impeller is able to develop when operating at rated speed with liquid of the specified normal relative density (specific gravity).</td>
</tr>
<tr>
<td>Maximum Exhaust Casing Pressure</td>
<td>The highest exhaust steam pressure that the purchaser requires the casing to contain, with steam supplied at maximum inlet conditions.</td>
</tr>
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<td>Title</td>
<td>Description</td>
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</tr>
<tr>
<td>Mg</td>
<td>The chemical symbol for magnesium which may appear on an MTR.</td>
</tr>
<tr>
<td>Mn</td>
<td>The chemical symbol for manganese which may appear on an MTR.</td>
</tr>
<tr>
<td>Mo</td>
<td>The chemical symbol for molybdenum which may appear on an MTR.</td>
</tr>
<tr>
<td>Mechanical Runout</td>
<td>A source of error in the output signal of a proximity probe system resulting from surface irregularities, out-of-round shafts, and such.</td>
</tr>
<tr>
<td>Minimum Allowable Speed</td>
<td>Lowest speed at which the manufacturer's design permits continuous operation.</td>
</tr>
<tr>
<td>Minimum Allowable Suction Pressure</td>
<td>The lowest pressure (measured at the inlet flange of the cylinder) below which the combined rod load, gas load, discharge temperature, or crankshaft torque load (whichever is governing) exceeds the maximum allowable value during operation at the set pressure of the discharge relief valve and other specified inlet gas conditions for the stage.</td>
</tr>
<tr>
<td>Minimum Continuous Stable Flow</td>
<td>Lowest flow at which the pump can operate without exceeding the vibration limits imposed by this International Standard.</td>
</tr>
<tr>
<td>Minimum Exhaust Pressure</td>
<td>The lowest exhaust steam pressure at which the turbine is required to operate continuously.</td>
</tr>
<tr>
<td>Minimum Inlet Pressure</td>
<td>The lowest inlet steam pressure and temperature conditions at which the turbine is required to operate continuously.</td>
</tr>
<tr>
<td>Misalignment</td>
<td>The degree to which the axes of machine components are non-collinear, either in offset or angularity.</td>
</tr>
<tr>
<td>Mounting Plates</td>
<td>A structure (baseplate or a mounting plate), with machined surfaces, to allow the mounting and accurate alignment of items of equipment, which may or may not operate.</td>
</tr>
<tr>
<td>MSS</td>
<td>Manufacturers Standardization Society.</td>
</tr>
<tr>
<td>Maximum Static Sealing Pressure</td>
<td>Highest pressure, excluding pressures encountered during hydrostatic testing, to which the seals can be subjected while the pump is shut down.</td>
</tr>
<tr>
<td>MT</td>
<td>Magnetic Particle Testing (Examination).</td>
</tr>
<tr>
<td>MTR</td>
<td>Material Test Report or Mill Test Report—A document that certifies that a metal/material product is in conformance with the requirements (e.g. chemical and mechanical properties) of a specified industry standard—such as ASTM, ASME, etc.</td>
</tr>
<tr>
<td>Multistage Pump</td>
<td>Pump with three or more stages.</td>
</tr>
<tr>
<td>Nb</td>
<td>The chemical symbol for niobium which may appear on an MTR.</td>
</tr>
<tr>
<td>NCR</td>
<td>Nonconformance Report—A report filled out by the SI detailing an issue that has been discovered to be not in accordance with project contractual agreements such as the PO, engineering design, specified codes, standards or procedures.</td>
</tr>
<tr>
<td>Title</td>
<td>Description</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>NDE Map</td>
<td>A drawing which identifies specific locations where NDE has been conducted on a product/component.</td>
</tr>
<tr>
<td>NDE/NDT</td>
<td>Nondestructive Examination (the preferred terminology)/Non-destructive Testing (the outdated terminology). A quality process that involves the examination, testing and evaluation of materials, components or assemblies without affecting its functionality e.g. VT, PT, MT, UT, and RT.</td>
</tr>
<tr>
<td>NDT</td>
<td>Nondestructive Testing—Means the same as NDE, which is now the preferred terminology.</td>
</tr>
<tr>
<td>Ni</td>
<td>The chemical symbol for nickel which may appear on an MTR.</td>
</tr>
<tr>
<td>Nonconformance</td>
<td>A departure/deviation from project contractual agreements such as the PO, engineering design, specified codes, standards or procedures.</td>
</tr>
<tr>
<td>Non-engineered Equipment</td>
<td>Equipment that is designed and fabricated by S/V’s, which includes off-the-shelf items such as valves, fittings, as well as some skid units, instruments, pumps and electrical gear. Such equipment is usually purchased by catalog model numbers, etc. Non-engineered equipment will typically require less source inspection than engineered equipment.</td>
</tr>
<tr>
<td>Non-ferrous Materials</td>
<td>Alloys that are not iron based e.g. nickel and copper based alloys.</td>
</tr>
<tr>
<td>Normalizing Heat Treatment</td>
<td>A heat treating process in which a ferrous material or alloy is heated to a specified temperature above the transformation range of the metal and subsequently cooled in still air at room temperature. Typically normalizing heat treatments will refine the grain size and improve the impact properties of steels.</td>
</tr>
<tr>
<td>NPS</td>
<td>Nominal Pipe Size—A standard for designating pipe sizes (inches) and associated wall thickness (schedule) e.g. the nominal pipe size for a four inch pipe is normally shown as NPS 4.</td>
</tr>
<tr>
<td>NPSHa</td>
<td>NPSH determined by the purchaser for the pumping system with the liquid at the rated flow and normal pumping temperature.</td>
</tr>
<tr>
<td>NPSHr</td>
<td>NPSH that results in a 3% loss of head (first-stage head in a multistage pump) determined by the vendor by testing with water.</td>
</tr>
<tr>
<td>Normal Operating Condition</td>
<td>The condition at which usual operation is expected and optimum efficiency is desired. This condition is usually the point at which the vendor certifies that performance is within the tolerances stated in this standard.</td>
</tr>
<tr>
<td>Normal Operating Point</td>
<td>Point at which usual operation is expected and optimum efficiency is desired. This point is usually the point at which the vendor certifies the heat rate is within the tolerances stated in this standard.</td>
</tr>
<tr>
<td>Title</td>
<td>Description</td>
</tr>
<tr>
<td>-------------------------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Normal Transmitted Power</td>
<td>The power at which usual operation is expected and optimum efficiency is desired. The normal transmitted power may be equal to or less than the gear-rated power.</td>
</tr>
<tr>
<td>Nozzles</td>
<td>Turbine stationary (non-rotating) airfoils.</td>
</tr>
<tr>
<td>Oil Mist Lubrication</td>
<td>Lubrication provided by oil mist produced by atomization and transported to the bearing housing, or housings, by compressed air.</td>
</tr>
<tr>
<td>Observed Inspection (Observed test)</td>
<td>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, regardless of whether the purchaser or his representative is present.</td>
</tr>
<tr>
<td>Open Cycle</td>
<td>One which the working medium enters the gas turbine from the atmosphere and discharges to the atmosphere directly or indirectly through exhaust heat recovery equipment.</td>
</tr>
<tr>
<td>Operating Region</td>
<td>Portion of a pump's hydraulic coverage over which the pump operates.</td>
</tr>
<tr>
<td>Overhung Pump</td>
<td>Pump whose impeller is supported by a cantilever shaft from its bearing assembly.</td>
</tr>
<tr>
<td>P</td>
<td>The chemical symbol for phosphorus which may appear on an MTR.</td>
</tr>
<tr>
<td>Peak to Peak Value</td>
<td>The difference between positive and negative extreme values of an electronic signal or dynamic motion.</td>
</tr>
<tr>
<td>Pinion</td>
<td>The high-speed rotor(s) in a gearbox/gearset.</td>
</tr>
<tr>
<td>Piston Rod Drop</td>
<td>A measurement of the position of the piston rod relative to the measurement probe mounting location(s) (typically oriented vertically at the pressure packing on horizontal cylinders).</td>
</tr>
<tr>
<td>Piston Rod Runout</td>
<td>The change in position of the piston rod in either the vertical or horizontal direction as measured at a single point (typically at or near the pressure packing case) while the piston rod is moved through the outbound portion of its stroke.</td>
</tr>
<tr>
<td>Potential Maximum Power</td>
<td>Expected power capability when the gas turbine is operated at maximum allowable firing temperature, rated speed or under other limiting conditions as defined by the manufacturer and within the range of specified site values.</td>
</tr>
<tr>
<td>PQR</td>
<td>Procedure Qualification Record per ASME BPVC Section IX, QW 200.2.</td>
</tr>
<tr>
<td>Predicted Capacity Limit</td>
<td>The maximum volume flow capacity at the end of curve line which defines the manufacturer's capability to reasonably predict performance. This may or may not be an actual choke limit.</td>
</tr>
<tr>
<td>Preferred Operating Region</td>
<td>Portion of a pump's hydraulic coverage over which the pump's vibration is within the base limit of this International Standard.</td>
</tr>
<tr>
<td>Title</td>
<td>Description</td>
</tr>
<tr>
<td>---------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Pressure Casing</td>
<td>Composite of all stationary pressure-containing parts of the pump, including all nozzles, seal glands, seal chambers and auxiliary connections but excluding the stationary and rotating members of mechanical seals.</td>
</tr>
<tr>
<td>Procedure</td>
<td>A document detailing how a work process is to be performed e.g. a welding procedure.</td>
</tr>
<tr>
<td>Projection</td>
<td>A nozzle or attachment projection is the length from the nozzle or the attachment face to the vessel shell centerline.</td>
</tr>
<tr>
<td>Protractor</td>
<td>An instrument for measuring angles, typically in the form of a flat semicircle marked with degrees along the curved edge.</td>
</tr>
<tr>
<td>Proximity Probe</td>
<td>A non-contacting sensor that consists of a tip, a probe body, an integral coaxial or triaxial cable, and a connector and is used to translate distance (gap) to voltage when used in conjunction with an oscillator-demodulator.</td>
</tr>
<tr>
<td>PRV/PRD/PSV</td>
<td>Pressure Relief Valve/Pressure Relief Device/Pressure Safety Valve.</td>
</tr>
<tr>
<td>PT</td>
<td>Penetrant Testing (Examination).</td>
</tr>
<tr>
<td>QA</td>
<td>Quality Assurance—A proactive quality process that aims to prevent defects and refers to a program of planned, systematic and preventative activities implemented in a quality system that is intended to provide a degree of confidence that a product will consistently meet specifications. It includes the systematic measurement, comparison with a standard, monitoring of processes and an associated feedback loop that is intended to avoid deviations from specification.</td>
</tr>
<tr>
<td>QC</td>
<td>Quality Control—The specific steps in a QA process that aim to find potential defects in a product before it is released for delivery e.g. VT, PT, RT, UT, dimensional verification, etc. The QA process will specify the particular QC steps necessary during manufacture/fabrication of a product.</td>
</tr>
<tr>
<td>Qualification</td>
<td>Demonstrated skill, demonstrated knowledge, documented training, and documented experience required for personnel to perform the duties of a specific job e.g. a certified source inspector.</td>
</tr>
<tr>
<td>Quality Surveillance</td>
<td>The process of monitoring or observing the inspection activities associated with materials, equipment and/or components for adherence to the specific procedure, product specification, code or standard specified in the contractual requirements. For the purposes of this guide, quality surveillance and source inspection mean the same thing (see definition for source inspection).</td>
</tr>
<tr>
<td>Quenching</td>
<td>Rapid cooling of a heated metal for the purpose of affecting mechanical and/or physical properties.</td>
</tr>
<tr>
<td>Radially Split</td>
<td>Split with the principal joint perpendicular to the shaft center-line.</td>
</tr>
<tr>
<td>Title</td>
<td>Description</td>
</tr>
<tr>
<td>-------------------------------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Rated Input Speed of Gear Unit</td>
<td>The specified (or nominal) rated speed of its driver, as designated by the purchaser on the data sheets.</td>
</tr>
<tr>
<td>Rated Output Speed of Gear Unit</td>
<td>The specified (or nominal) rated speed of its driven equipment, as designated by the purchaser on the data sheets.</td>
</tr>
<tr>
<td>Rated Operating Point</td>
<td>Point at which the vendor certifies that pump performance is within the tolerances stated in this International Standard.</td>
</tr>
<tr>
<td>Rated Power</td>
<td>The greatest turbine power specified and the corresponding speed.</td>
</tr>
<tr>
<td>Rated Speed/100% Speed</td>
<td>Highest speed (revolutions per minute) of the gas turbine output shaft required of any of the operating conditions for the driven equipment and at which site rated power is developed.</td>
</tr>
<tr>
<td>RMS</td>
<td>Root Mean Square—A measure of surface finish on flanges.</td>
</tr>
<tr>
<td>Rotor</td>
<td>Assembly of all the rotating parts of a centrifugal pump.</td>
</tr>
<tr>
<td>RT</td>
<td>Radiographic Testing (Examination).</td>
</tr>
<tr>
<td>Rust Bloom</td>
<td>The term used to describe surface discoloration that occurs on the surface of steel that has been previously blasted e.g. near-white or white metal in preparation for coating. When rust bloom is found, the surface should generally be re-cleaned before coating using the same blast cleaning process.</td>
</tr>
<tr>
<td>S</td>
<td>The chemical symbol for sulfur which may appear on an MTR.</td>
</tr>
<tr>
<td>SDO</td>
<td>Standards Development Organization e.g. API, ASME, ASTM, NACE, MSS, TEMA, etc.</td>
</tr>
<tr>
<td>Seal Buffer gas</td>
<td>Clean gas supplied to the high-pressure side of a seal.</td>
</tr>
<tr>
<td>Seal Chamber</td>
<td>Component, either integral with or separate from the pump case (housing), which forms the region between the shaft and casing into which the seal is installed.</td>
</tr>
<tr>
<td>Seal Gas</td>
<td>Dry, filtered gas supplied to the high-pressure side of a self-acting gas seal.</td>
</tr>
<tr>
<td>Seal Gas Leakage</td>
<td>Gas that flows from the high-pressure side of the seal to the low-pressure side of the seal.</td>
</tr>
<tr>
<td>Shutdown Set Point</td>
<td>Preset value of a measured parameter at which automatic or manual shutdown of the system or equipment is required.</td>
</tr>
<tr>
<td>SI</td>
<td>Source Inspector or Source Inspection.</td>
</tr>
<tr>
<td>SME</td>
<td>Subject Matter Expert.</td>
</tr>
<tr>
<td>Sole Plates</td>
<td>Grouted plates installed under motors, bearing pedestals, gear-boxes, turbine feet, cylinder supports, crosshead pedestals and compressor frames.</td>
</tr>
<tr>
<td>Solution Anneal Heat Treatment</td>
<td>Heating an alloy to a specified temperature, holding at the temperature long enough for one or more elements to reenter into solid solution and then cooling rapidly enough to hold those elements in solid solution.</td>
</tr>
<tr>
<td>Title</td>
<td>Description</td>
</tr>
<tr>
<td>---------------------</td>
<td>------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>SOR</td>
<td>Supplier Observation Reports—Documents filled out by the SI indicating concerns or other factual descriptions of what was noticed during the course of product surveillance, but not necessarily issues that may be considered defects or requiring NCR’s.</td>
</tr>
<tr>
<td>Source Inspection</td>
<td>The process of providing quality surveillance of materials, fabrications and equipment being supplied by supplier/vendor (S/V) or manufacturer/fabricator for use in the oil, petro-chemical and gas industry, including up-stream, midstream and downstream segments. Source inspection largely consists of verifying that the S/V’s own quality assurance process is functioning as it should to produce quality products that meet the contractual agreements.</td>
</tr>
<tr>
<td>Source Inspector</td>
<td>Individual responsible for performing the actual source inspection activities at the S/V facilities in accordance with the applicable inspection and test plan (ITP).</td>
</tr>
<tr>
<td>Specification</td>
<td>A document that contains the requirements for the M&amp;F of specific types of equipment and components.</td>
</tr>
<tr>
<td>Special Purpose Application</td>
<td>Application for which the equipment is designed for uninterrupted, continuous operation in critical service and for which there is usually no spare equipment.</td>
</tr>
<tr>
<td>SSPC</td>
<td>Society for Protective Coatings (formerly-Steel Structures Painting Council).</td>
</tr>
<tr>
<td>Stall</td>
<td>The volume flow capacity below which an axial compressor becomes aerodynamically unstable. This is caused by blade drag due to non-optimum incidence angles.</td>
</tr>
<tr>
<td>Standby Service</td>
<td>Normally idle piece of equipment that is capable of immediate automatic or manual start-up and continuous operation.</td>
</tr>
<tr>
<td>Stage</td>
<td>One impeller and associated diffuser or volute and return channel, if required.</td>
</tr>
<tr>
<td>Subplate</td>
<td>A plate usually embedded in a concrete foundation and used to accurately locate and align a baseplate or mounting plate.</td>
</tr>
<tr>
<td>Surge</td>
<td>The volume flow capacity below which a centrifugal compressor becomes aerodynamically unstable.</td>
</tr>
<tr>
<td>S/V</td>
<td>Supplier/Vendor—The entity which is responsible for the actual manufacturing and fabrication (M&amp;F) of the material, equipment or components and which is responsible for meeting the contractual requirements.</td>
</tr>
<tr>
<td>TEMA</td>
<td>Tubular Exchanger Manufacturers Association.</td>
</tr>
<tr>
<td>Tempering</td>
<td>Reheating a hardened metal to a temperature below the transformation range to improve toughness.</td>
</tr>
<tr>
<td>Thermocouple</td>
<td>A temperature sensor consisting of two dissimilar metals so joined to produce different voltages when their junction is at different temperatures.</td>
</tr>
<tr>
<td><strong>Title</strong></td>
<td><strong>Description</strong></td>
</tr>
<tr>
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</tr>
<tr>
<td>Ti</td>
<td>The chemical symbol for titanium which may appear on an MTR.</td>
</tr>
<tr>
<td>TIR (Total Indicator Reading)</td>
<td>Difference between the maximum and minimum readings of a dial indicator or similar device, monitoring a face or cylindrical surface, during one complete revolution of the monitored surface.</td>
</tr>
<tr>
<td>Tolerance</td>
<td>Engineering tolerances refer to the limit (or limits) of specified dimensions, physical properties or other measured values of a component.</td>
</tr>
<tr>
<td>Training</td>
<td>An organized program developed to impart the skills and knowledge necessary for qualification as a source inspector.</td>
</tr>
<tr>
<td>Trip Speed</td>
<td>The speed at which the independent emergency overspeed device operates to shut down the turbine.</td>
</tr>
<tr>
<td>Turndown</td>
<td>The percentage of change in capacity (referred to rated capacity) between the rated capacity and the surge point capacity at the rated head when the unit is operating at rated suction temperature and gas composition.</td>
</tr>
<tr>
<td>Unbalance</td>
<td>A rotor condition where the mass centerline (principal axis of inertia) does not coincide with the geometric centerline, expressed in units of gram-inches, gram-centimeters, or ounce-inches.</td>
</tr>
<tr>
<td>UT</td>
<td>Ultrasonic Testing (Examination), generally for finding component flaws or measuring thicknesses.</td>
</tr>
<tr>
<td>Vanes</td>
<td>Compressor stationary (nonrotating) airfoils.</td>
</tr>
<tr>
<td>Velocity</td>
<td>The time rate of change of displacement. Units for velocity are inches per second or millimeters per second.</td>
</tr>
<tr>
<td>Verticle Inline Pump</td>
<td>Vertical-axis, single-stage overhung pump whose suction and discharge connections have a common centerline that intersects the shaft axis.</td>
</tr>
<tr>
<td>Vertical Suspended Pump</td>
<td>Vertical-axis pump whose liquid end is suspended from a column and mounting plate.</td>
</tr>
<tr>
<td>VT</td>
<td>Visual Testing (Examination).</td>
</tr>
<tr>
<td>Witnessed Test</td>
<td>Inspection or test for which the purchaser is notified of the timing of the inspection or test and a hold is placed on the inspection or test until the purchaser or his representative is in attendance.</td>
</tr>
<tr>
<td>WPQ</td>
<td>Welding Performance Qualification Record per ASME BPVC Section IX, QW 301.4.</td>
</tr>
<tr>
<td>WPS</td>
<td>Welding Procedure Specification per ASME BPVC Section IX, QW 200.1.</td>
</tr>
</tbody>
</table>
5.0 Training

5.1 General

Training and Certification for vendor/source inspection is unique to each organization. This study guide and supporting examination is designed to provide a minimum competency for a Mechanical Rotating Equipment Inspector.

6.0 Source Inspection Management Program

6.1 Employers or Inspection Agencies

Employers or inspection agencies tasked with the responsibility of performing source inspection coordination and/or source inspection activities should develop a management program in order to provide the individuals performing the specific source inspection functions the necessary information to accomplish their duties. These source inspection management programs are generic in nature in that they provide requirements and guidance of source inspection activities on all types of projects that will require source inspection. See Section 7 for the types of source inspection plans that are needed for each specific project.
6.2 Source Inspection Management Programs

Source inspection management programs should cover most of the generic activities identified in this study guide but also include company specific information like:

- What activities need to be accomplished.
- Who is responsible for accomplishing each of the activities, i.e. personnel titles.
- The training and competencies required for source inspectors.
- Schedule and/or frequency for each of the activities to be accomplished.
- How each of the activities will be accomplished i.e. specific work procedures.
- Application of acceptance criteria and industry standards.

6.3 These Management Programs May Reference

These management programs may reference many other company specific source inspection procedures, practices and policies with more details needed for specific types of source inspection activities, for example:

- How to prepare an overall Source Inspection Plan for an entire project and an Inspection and Test Plan (ITP) for each equipment item.
- How to conduct an equipment risk assessment in order to determine the level of source inspection activities that will be required.
- Guidance on the criteria to use for selecting source inspectors to match their skills and training with different types of equipment with different risk levels.
- Guidance on scheduling and conducting significant source inspection events like the pre-inspection (fabrication kick-off) meeting, the S/V quality coordination meeting, final acceptance testing, etc.
- Guidance on SI safety and professional conduct at S/V shops.
- How to review welding procedures and welder qualification documents.
- How to review inspection/examination records of the S/V.
- What inspections should be repeated by the source inspector to verify the results of S/V examinations and tests.
- How to handle change requests.
- How to handle deviations and nonconformances.
- How to write source inspection reports with specific forms to be filled out.
- What specific steps to take before approving product acceptance, etc.
- Interfacing with the jurisdictional authorized inspector.

7.0 Project Specific Source Inspection Planning Activities

7.1 General

From the Source Inspection Management Program documents, a Project Specific Inspection Plan should be developed by the inspection coordinator addressing the following activities.
7.2 Equipment Risk Assessment

7.2.1 Effective source inspection for each project begins with a risk-based assessment of the materials and/or equipment to be procured for the project. These risk based assessments are performed to identify the level of effort for source inspection activities during the M&F phase of a project at the S/V facility. Equipment identified as critical equipment will receive more intensive source inspection; while equipment identified as less critical will receive less intensive source inspection and thereby rely more on the S/V quality program.

7.2.2 Typically these risk based assessments occur early in the design stages of a project and identify the equipment risks into the following types of categories.

- Safety or environmental issues that could occur because of equipment failure to meet specification or failure while in service.
- Equipment complexity; the more complex the equipment, the higher level of source inspection may be required.
- Knowledge of S/V history and capabilities to deliver equipment meeting specifications on time i.e. newer S/V with relatively unknown history or capabilities may need closer scrutiny.
- Potential schedule impact from delivery delays or project construction impact from issues discovered after delivery i.e. long delivery items may require higher level of source inspection.
- Equipment design maturity level i.e. prototype, unusual or one-of-a-kind type equipment may require higher level of source inspection.
- Lessons learned from previous projects i.e. has the S/V had problems in the past meeting specifications on time?
- Potential economic impact on the project of S/V failure to deliver equipment meeting specifications on time.

7.2.3 The risked based assessment team typically consists of individuals from various company groups including: quality, engineering, procurement, construction, project management and source inspection. Input from those who will own and operate the equipment i.e. the client is also beneficial. This collaboration provides input from all parties that may be affected if material or equipment is delivered and installed with unacceptable levels of quality.

7.2.4 The risk assessment process takes into account the probability of failure (POF) of equipment to perform as specified, as well as the potential consequences of failure (COF) to perform in service e.g. safety, environmental and business impact. The ultimate risk associated for each equipment item is then a combination of the POF and COF assessments.

7.2.5 The risk assessment provides the information necessary for the inspection coordinator to specify a level of effort for source inspection of each S/V facilities commensurate with the agreed upon risk level. Typical levels of source inspection effort at the S/V facility commensurate with risk levels may include:

- No Source Inspection (lowest risk for equipment failure to meet specifications; rely solely on S/V quality).
Final Source Inspection (final acceptance) only just prior to shipment (lower to medium risk material or equipment; rely primarily on S/V quality with minimum source inspection).

Intermediate Source Inspection level (medium to medium high risk equipment; mixture of reliance on S/V quality with some source inspection activities at the more critical hold points). The number of shop visits may go up or down based on the performance level of the S/V.

Advanced Source Inspection level (higher risk equipment; significant amount of source inspection e.g. weekly to provide higher level of quality assurance). The number of shop visits may go up or down based on the performance level of the S/V.

Resident Source Inspection level [highest risk equipment; full time shop inspector(s) assigned, possibly even on all shifts].

7.3 Development of a Source Inspection Project Plan

7.3.1 A source inspection plan should be developed for projects that have materials or equipment which will be inspected for compliance to the contractual agreements, project specifications, drawings, codes and standards.

7.3.2 The project plan should consist of the project details, list of equipment to be inspected and the project specific details on how the inspection activities will be performed to meet the expected level of quality performance from the S/V and/or the equipment.

7.3.3 The plan should also be based upon the level of risk determined from the risk based assessment performed in the design stage of the project and the appropriate level of effort needed for the surveillance of the S/V that is commensurate with the risk level.

7.4 Development of Inspection and Test Plans

7.4.1 A detailed inspection and test plan (ITP) for each type of equipment to be inspected should be provided. This ITP should be specific to the type of equipment to be inspected, the associated risk level for each piece of equipment and should identify all the inspection activities necessary to be performed by the assigned source inspector. It should also include the appropriate acceptance criteria or reference theretofore.

7.4.2 The source inspector should follow the ITP and ensure that the fabrication and S/V quality activities performed meet the requirements specified in the contractual agreement, referenced project specifications, drawings, applicable codes and/or standards.

7.5 Selection of an Inspector

7.5.1 The source inspection coordinator should review the details of the project plan, location of the S/V and duration of the work and select the appropriate source inspector(s) for the assignment.

7.5.2 The source inspector(s) selected should have the necessary experience, training and qualifications to perform the inspection or surveillance activities referenced in the ITP.
7.6 Coordination of Inspection Events

Dates for source inspection scheduled work process events such as the pre-inspection meeting (manufacturing kickoff), key inspection events (factory acceptance, performance testing and final inspection) and anticipated shipping date should be identified in advance to allow coordination with other project members involved in the activity.

7.7 Report Review

Source inspection reports are important deliverables from the SI to the project team or client. The amount and type should be specified in the ITP. Each inspection report should be reviewed for content, completeness and technical clarity prior to distribution.

8.0 Source Inspection Performance

8.1 Inspector Conduct and Safety

8.1.1 Individuals tasked with the responsibility of performing source inspection activities should conduct themselves professionally while visiting an S/V facility as a representative of their employer and/or purchaser. If any conflict should arise during the inspection activity, the source inspector should notify their supervisor for resolution as soon as possible. It is important that the SI not be confrontational or argumentative regardless of the importance of the issue at hand; but rather simply indicate in objective terms how the S/V intends to proceed to resolve the issue.

8.1.2 Safety of the individual performing the source inspection activity is one of the most important aspects of their work. A safety program should be established which identifies specific safety hazards associated with the job. Source Inspectors should be adequately trained and knowledgeable in these safety programs in order to minimize the possibility of injury. The safety program should include:

- Potential travel safety issues specific to the job.
- Potential shop safety issues and hazard recognition.
- How to handle the observation of unsafe acts in the shop.

8.1.3 The SI should observe the safety procedures and policies of the S/V while on their premises or if more stringent, their own company safety requirements.

8.2 Review of Project Documents

General

8.2.1 Typical project documents include but are not limited to contractual agreements (purchase orders and/or subcontracts), source ITP, project specifications, engineering or fabrication drawings, data sheets, applicable codes, references or standards.

8.2.1.1 The source inspectors should familiarize themselves with all project documents applicable to the assigned scope of work and ensure that they have access to the specific edition/version of those documents specified in the contractual agreement at all times during their inspection visits.
Prior to commencing the quality surveillance specified in the ITP, the source inspector should confirm that the S/V has the most current documents, drawings, etc. specified in the engineering design. Later editions of industry codes and standards do not apply if the engineering design has specified an earlier edition of a specific standard. Additionally, the source inspector should confirm that all project documents have been reviewed/approved by the purchaser.

8.2.2 Contractual Agreements

The contractual agreements including the purchase order, all specified engineering design documents, specified company standards, and specified industry standards form the basis for the requirements for source inspection of the purchased products.

8.2.3 Engineering Design Documents

For engineered equipment, the SI needs to be familiar with the engineering design documents and drawings that are vital to quality of the purchased products.

8.2.4 Company and Client Standards

The SI needs to be familiar with all company and client standards that are specified in the contractual agreements. These standards typically augment or supplement industry standards for issues not sufficiently well covered in industry standards. All mandatory requirements i.e. “shall/must” statements, included in the company specifications must be met or become an issue for an NCR and handled in accordance with standard purchaser management NCR systems requirements. Other issues contained in the specified standards such as those suggested or recommended i.e. “should” statements which are expectations of the S/V, but not necessarily requirements may become an issue to be reported in Supplier Observation Reports (SOR’s) and handled in accordance with standard purchaser management systems. Company and client standards may cover engineered and non-engineered equipment.

8.2.5 Industry Codes and Standards

8.2.5.1 General

The SI needs to be familiar with all industry codes and standards that are specified in the contractual agreements to the extent that requirements and expectations in those codes and standards are part of the contractual agreements and therefore part of the source inspector duties. Those industry codes and standards are typically published by recognized industry standards development organizations (SDO’s), such as those in the following subsections.

8.2.5.2 API Standards

There are a wide variety of API Standards that may be included in the contractual agreements to specify and control the quality of products for the petroleum, gas, petrochemical, chemical process and energy industries. A few of those that the SI should be familiar with and apply when specified are shown in the following subsections; but this list is not all inclusive. Others that are specified in the contractual agreements may be equally important to the quality of the delivered product. The information contained in the following industry standards is generic to a wide variety of products and therefore should be general knowledge to the experienced SI.
API Std 610  Centrifugal Pumps for Petroleum, Petrochemical and Natural Gas Industries

API 610 specifies requirements for centrifugal pumps, including pumps running in reverse as hydraulic power recovery turbines, for use in petroleum, petrochemical, and gas industry process services. This Standard is applicable to overhung pumps, between bearing pumps, and vertically suspended pumps. Clause 9 provides requirements applicable to specific types of pumps. All other clauses of this International Standard apply to all pump types. Illustrations are provided of the various specific pump types and the designations assigned to each specific pump type. It does not cover sealless pumps.

This edition of API 610 is the adoption of ISO 13709:2009, Centrifugal Pumps for Petroleum, Petrochemical and Natural Gas Industries. NOTE: For sealless pumps, reference can be made to API Std 685. For heavy duty pump applications in industries other than petroleum, petrochemical and gas processing, reference can be made to ISO 9905.

Relevant industry experience suggests pumps produced to this International Standard are cost effective when pumping liquids at conditions exceeding any one of the following:

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>discharge pressure (gauge)</td>
<td>1 900 kPa (275 psi; 19.0 bar)</td>
</tr>
<tr>
<td>suction pressure (gauge)</td>
<td>500 kPa (75 psi; 5.0 bar)</td>
</tr>
<tr>
<td>pumping temperature</td>
<td>150°C (300°F)</td>
</tr>
<tr>
<td>rotative speed</td>
<td>3 600 r/min</td>
</tr>
<tr>
<td>rated total head</td>
<td>120 m (400 ft)</td>
</tr>
<tr>
<td>impeller diameter, overhung pumps</td>
<td>330 mm (13 in)</td>
</tr>
</tbody>
</table>

API Std 611  General-Purpose Steam Turbines for Petroleum, Chemical, and Gas Industry Services

API Std 611 specifies the minimum requirements for general-purpose steam turbines, including basic design, materials, related lubrication systems, controls, auxiliary systems and accessories. General-purpose turbines are horizontal or vertical turbines used to drive equipment that is usually spared, is relative small in size (power), or is in non-critical service. They are generally used where steam conditions will not exceed a pressure of 700 psig (48 bar) and a temperature of 750°F (400°C) or where speed will not exceed 6,000 rpm.

API Std 614  Lubrication, Shaft-Sealing and Oil-Control Systems and Auxiliaries for Petroleum, Chemical and Gas Industry Services

API Std 614 specifies the general requirements for lubrication systems, oil type shaft-sealing systems, dry-gas face-type shaft-sealing systems and control-oil systems for general-or special-purpose applications for equipment such as compressors, gears pumps and drivers. General purpose applications are limited to lubrication systems.

This edition of API 614 is the adaptation of ISO 10438:2007, Petroleum, petrochemical and natural gas industries – Lubrication, shaft-sealing and oil-control systems and auxiliaries.
API Std 617 Axial and Centrifugal Compressors and Expander-Compressors for Petroleum, Chemical and Gas Industry Services

API Std 617 specifies the minimum requirements for axial compressors, single-shaft and integrally geared process centrifugal compressors and expander-compressors. This standard does not apply to fans or blowers that develop less than 5 psi rise above atmospheric pressure. This standard also does not apply to packaged, integrally-geared centrifugal plant and instrument air compressors. Hot gas expanders over 500°F are not covered in this standard. Equipment covered by this standard are designed and constructed for a minimum service life of 20 years and at least 5 years uninterrupted operation.

API Std 618 Reciprocating Compressors for Petroleum, Chemical, and Gas Industry Services

API Std 618 specifies the minimum requirements for reciprocating compressors and their drivers for handling process air or gas with either lubricated or non-lubricated cylinders. Compressors covered by this standard are low to moderate speed machines. Also included in this standard are related lubrication systems, controls, instrumentation, intercoolers, aftercoolers, pulsation suppression devices and other auxiliary systems. This standard does not cover integral gas engines, compressors with single acting trunk-type pistons that also serve as crossheads, and plant or instrument-air compressors that discharge at or below 125 psig.

API Std 677 General-Purpose Gear Units for Petroleum, Chemical and Gas Industry Services

This standard covers the minimum requirements for general-purpose, enclosed single and multistage gear units incorporating parallel shaft helical and right angle spiral bevel gears for the petroleum, chemical, and gas industries. Gears manufactured according to this standard shall be limited to the following pitchline velocities. Helical gears should not exceed 60 m/s (12,000 ft/min), and spiral bevels shall not exceed 40 m/s (8,000 ft/min). Spiral bevel gearsets shall be considered matched sets. This standard is not intended to apply to gears in special-purpose service, which are covered in API Std 613; to gears integral with other equipment; to epicyclic gear assemblies; or gears with non-involute tooth forms.

API Std 682 Pumps-Shaft Sealing Systems for Centrifugal and Rotary Pumps

This Standard specifies requirements and gives recommendations for sealing systems for centrifugal and rotary pumps used in the petroleum, natural gas and chemical industries. It is applicable mainly for hazardous, flammable and/or toxic services where a greater degree of reliability is required for the improvement of equipment availability and the reduction of both emissions to the atmosphere and life-cycle sealing costs. It covers seals for pump shaft diameters from 20 mm (0.75 in) to 110 mm (4.3 in).

API Std 682 Shaft Sealing Systems for Centrifugal and Rotary Pumps

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Hydraulic Institute Standards

HI 14.6 Rotodynamic Pumps for Hydraulic Performance Acceptance Tests

This Standard is for centrifugal, sealless centrifugal and regenerative turbine pumps of all industrial types except vertical multistage diffuser type. It includes detailed procedures on the setup and conduct of hydrostatic and performance tests of such pumps.

8.2.5.3 ASME Codes and Standards

There are a wide variety of ASME Codes and Standards that may be included in the contractual agreements to specify equipment fabrication methods and control the quality of products for the energy industry. A few of those that the SI should be familiar with and apply when specified are shown in the following subsections; but this list is not all inclusive. Occasionally there may be other sections of the ASME BPVC that will be specified on different projects in which the SI will be involved.

- ASME BPVC Section II—Materials

This section of the BPVC is divided into four parts covering materials for the construction of piping and pressure vessels.

- Part A—Ferrous Material Specifications

This part contains the individual specifications for ferrous materials that are allowed in the construction of pressure vessels and piping designed to the ASME BPVC. Part A covers all forms of ferrous material products like wrought, castings, forgings, plates, piping valves, bolting, etc. The criteria addressed by each ferrous material specification vary based on the characteristics of the material and final use for which it is intended. Some examples of issues covered include: ordering information, heat treatment, chemical composition, mechanical properties, tests and examinations, dimensions and tolerances and the steel making practice. The source inspector should be familiar with the contents of whichever materials are specified in the contractual agreements. The specification covered in ASME BPVC Section II, Part A that the SI needs to be familiar with for purposes of the examination is:

- SA-370, Test Methods and Definitions of Mechanical Testing Steel Products.

- Part B—Nonferrous Material Specifications

This part contains the individual specifications for nonferrous materials that are allowed in the construction of pressure vessels and piping designed to the ASME BPVC. Part B covers all forms of nonferrous material products like wrought, castings, forgings, plates, piping valves, bolting, etc. allowed for in the construction of ASME BPVC equipment. The types of nonferrous material alloys included in Part B are: aluminum, copper, nickel, titanium, and zirconium. The criteria addressed by each nonferrous material specification vary based on the characteristics of the material and final use for which it is intended. Some examples of issues covered include: ordering information, heat treatment, chemical composition, mechanical properties, tests and examinations, dimensions and tolerances and the melting practice. The source inspector should be familiar with the contents of whichever materials are specified in the contractual agreements.
Part C—Specifications for Welding Rods, Electrodes and Filler Metals

Part C covers material specifications for the manufacture, acceptability, chemical composition, mechanical usability, surfacing, testing, operating characteristics and intended uses of welding rods, electrodes and filler materials. The material specifications are designated by SFA numbers derived from AWS specifications. The source inspector would typically reference these specifications for whichever welding materials are specified in the contractual agreements to ensure that the right materials are being used in fabrication.

Part D—Materials Properties

Part D provides tables for design stress values, tensile strength, yield strength, and other important chemical and physical properties for all the material specifications contained in Parts A and B. This section is primarily intended for designers of ASME BPVC equipment.

ASME BPVC Section V—Nondestructive Examination

This section of the BPVC contains requirements and methods for NDE techniques that are specified by other sections of the ASME BPVC and/or contractual agreements. Most of the common methods of NDE are covered in Section V including RT, UT, MT, PT, VT, and LT. Appendix A of Section V presents a listing of common imperfections and damage mechanisms and the NDE methods that are generally capable of detecting them. Section V also provides guidance on methods of evaluating NDE results. The source inspector should be thoroughly familiar with the contents of Section V for whichever NDE method is specified in contractual agreements and/or ITP. For the purposes of SI examination, some of the content covered in ASME BPVC Section V that applicants should focus on includes:

- All definitions in Subsection A, Article 1, Appendix I and Subsection B, Article 30, SE-1316.
- Article 1 on General Requirements for NDE.
- Article 2 on Radiographic Examination.
- Article 4 on Ultrasonic Examination Methods of Welds.
- Article 5 on Ultrasonic Examination Methods for Materials.
- Article 6 on Liquid Penetrant Examination.
- Article 7 on Magnetic Particle Examination.
- Article 9 on Visual Examination.
- Article 10 on Leak Testing.
- Article 23, Section 797 on UT Thickness Testing.

ASME Section VIII Division 1 Boiler Pressure Vessel Code

- UCS-56-57
- Appendix 7 - Examination of Steel Casting

ASME BPVC Section IX—Qualification Standard for Welding and Brazing Procedures, Welders, Brazers, and Welding and Brazing Operators

Section IX of the ASME BPVC Part QW covers the qualifications of welders, welding operators and the procedures that will be employed during fabrication. The primary subjects covered include: welding general requirements, welding procedure specifications and qualification, and welder performance qualification. Section IX does not cover acceptance criteria for production welds.
Section IX also covers fabrication by brazing (Part QB), so the SI inspector should be aware of that section, but will not need to be familiar with it until and unless assigned to a project that specifies brazed construction. The source inspector should be thoroughly familiar with the contents of Section IX Part QW with regard to the WPS, PQR and WPQ that are specified in contractual agreements and/or ITP. For the purposes of SI examination the applicants need to focus their attention on the following sections of ASME BPVC Section IX:

- Welding General Requirements QW 100 to 190.
- Welding Procedure Qualifications QW 200 to 290.
- Welding Performance Qualifications QW 300 to 380.
- Welding Data QW 400 to 490.
- Standard Welding Procedure Specifications QW 500 to 540.

### 8.2.5.4 ASNT Standards

- **ASNT SNT-TC-1A**
  
  This recommended practice establishes a general framework for a qualification and certification program for NDE technicians. In addition, the standard provides recommended educational requirements and training requirements for different test methods. The SI should be thoroughly familiar with this standard, including the duties and responsibilities for each of the 3 levels of NDE qualified technician.

### 8.2.5.5 SSPC Standards

- **SSPC-PA 2 Coating Applications Standard No. 2, Procedure for Determining Conformance to Dry Coating Thickness Requirements**

  This standard describes a procedure for determining conformance to a specified dry film thickness (DFT) range on metal substrates using NDE thickness gauges. The SI inspector should be familiar with Sections 1 to 8 of this standard.

- **SSPC Surface Preparation Guide**

  This guideline briefly describes the scope of the 7 different SSPC and NACE Surface Preparation Standards with application to source inspection. The source inspector should be familiar with the scope of the 7 standards listed below that are included in this guide, but need not be familiar with the details in the specific standards for examination purposes.

  - SSPC-SP1—Solvent Cleaning.
  - SSPC-SP3—Power Tool Cleaning.
  - SSPC-SP5 or NACE 1—White Metal Blast Cleaning.
  - SSPC-SP6 or NACE 3—Commercial Blast Cleaning.
  - SSPC-SP7 or NACE 4—Brush-Off Blast Cleaning.
  - SSPC-SP10 or NACE 2—Near-White Blast Cleaning.
  - SSPC-SP11—Power Tool Cleaning to Bare Metal.
8.2.6 Welding Procedures and Qualifications

Welding procedure qualifications are the responsibility of the S/V while it is the responsibility of the source inspector that they be verified as the ones approved by the purchaser. Prior to performing welding inspection, the SI should confirm that the version of the WPS in hand has been reviewed and approved by the responsible person e.g. engineer/WPS/PQR SME. ASME BPVC Section IX, is the appropriate references for knowledge and understanding of WPS/PQR's.

8.2.7 NDE Procedures

Development of NDE procedures are the responsibility of the S/V while it is the responsibility of the source inspector that they be verified as the ones approved for use. Prior to witnessing NDE, the SI should confirm that the version of the NDE procedure in hand has been reviewed and approved by the responsible person e.g. engineer/NDE SME. The AWS Welding Inspection Handbook, ASME BPVC Section V, AWS D1.1 and ASNT SNT-TC-1A are the appropriate references for knowledge and understanding of NDE procedures and required training and certification of NDE technicians.

8.2.8 Project Schedules

While the responsibility of establishing and monitoring the delivery is not generally in the purview of the SI and the responsibility of meeting the schedule remains with the S/V, the SI may be requested to report on fabrication status or slippage of milestone progress. The SI should notify the inspection coordinator if he/she believes that product quality may be compromised by schedule pressures.

8.3 Performing the Source Inspection

8.3.1 Individuals assigned to perform the source inspection activity must follow the ITP as specified by the purchaser. Visual inspection, welding inspection, dimensional inspections, observing NDE, and all other examinations and tests must be performed in accordance with the source ITP, project specification and applicable code and standards and meet the applicable acceptance criteria. See Section 9 for Examination Methods, Tools and Equipment.

8.3.2 One important step in the source inspection work process is to verify evidence that the S/V personnel conducting the fabrication and quality control steps during fabrication are properly trained, qualified and certified, as specified in the ITP or other contractual documents. This may include verification of such credentials as: S/V quality personnel qualifications per the specified standards, checking welder log books, and NDE technician certifications per the specified standards, such as ASNT SNT TC-1A, EPRI, or API Industry Qualified Examiners.

8.3.3 During the course of manufacturing and fabrication, the S/V may propose contract deviations that could impact cost, schedule and/or quality. In such cases, the source inspector should request that the S/V propose such changes in writing for review and approval by the purchaser and/or owner-user of the equipment.

8.4 Source Inspection Work Process Scheduled Planning Events

8.4.1 General

Typical source inspection scheduled work process events include the following:
8.4.2 Pre-purchase Meeting (Prior to Contract Placement)

The source inspector may or may not participate in a pre-purchase meeting. The purpose of such a meeting is to cover some specific design, fabrication, and/or QA/QC requirements expected of the S/V to make sure that their bid does not inadvertently overlook them and result in unanticipated surprises during fabrication and source inspection activities.

8.4.3 Pre-inspection Meeting (Prior to Start of Manufacturing)

The source inspector assigned to the S/V facility should participate in the pre-inspection meeting (PIM). The purpose of this meeting is to ensure that everyone at the S/V who will be involved in manufacturing, fabrication and monitoring the quality of the equipment fully understands specific requirements and details of the job, especially those requirements that may be non-routine or different relative to normal S/V quality surveillance. Advance preparation by the source inspector is important for the pre-inspection meeting to ensure the meeting covers all necessary issues requirements as specified in the contractual agreements and source inspector’s company policy/practices. Those requirements may include review of:

- PO and contractual agreements.
- Engineering, technical and material requirements and status.
- Fabrication schedules.
- Critical path and long-lead equipment/materials.
- Quality requirements e.g. ITP, NCR, inspection frequency, etc.
- Sub-suppliers and their quality requirements.
- Special requirements e.g. performance or functional testing requirements.
- Painting, preservation and tagging.
- Communication requirements e.g. inspection point notification, report distribution, proposed changes, hold points, schedule impacts, etc.
- Shipping and release plan.
- Final documentation requirements.
- Recording and reporting any observations, exceptions or deviations.

These source inspection work process events may also be observed or handled by others besides the source inspector including: project engineering, client representatives or third party inspection agency.

8.5 Report Writing

8.5.1 A key deliverable of source inspection is the progressive inspection reports detailing the documents reviewed, inspection activity performed, observed and/or witnessed during the source inspection visits. The report is normally on a standard format, and follows a consistent approach to reporting as specified by the purchaser.
8.5.2 The source inspector should reference the following minimum information in each report:

- Date of visit.
- Appropriate contract number and key information.
- Purpose of visit.
- Action items or areas of concerns.
- Results of inspection/surveillance.
- Reference drawings/data used (including drawing numbers) to perform inspection/surveillance.
- Revisions of referenced drawings/data.
- Reference to the applicable requirement in the ITP.
- Identification of nonconforming or deviating items/issues.

8.5.3 Photographs are frequently used in the inspection reports as they assist in the description of the inspection results. The SI should request permission from the S/V prior to taking any photographs. Care should be exercised to ensure that an appropriate number of photos are attached as too many can be detrimental to report issuance due to file size. Photos should be dated and labeled with description of area of interest or product tag reference so that they can be easily understood by those reading the SI reports.

8.5.4 Reports should be submitted to the inspection coordinator for review of content and technical clarity before they are distributed to the purchaser unless otherwise instructed.

8.6 Nonconformance/Deviations

8.6.1 When deviations to the contractual agreement or its referenced specifications, drawings, codes or standards are identified, the source inspector should identify them as nonconformances. The source inspector should notify the inspection coordinator as soon as practical once a nonconformance has been identified.

8.6.2 Nonconformance reports should reference the following minimum information:

- Date of inspection.
- Contract number and information.
- Description of nonconforming item and issue.
- Photo of discrepancy if possible.
- Specifications, drawings, codes or standards involved.
- Impact on the product.
- S/V recommended disposition of the nonconformance.

8.6.3 The source inspector should issue the nonconformance report to the inspection coordinator for review and distribution unless instructed otherwise.

8.6.4 In general, deviations from specifications must be approved by the responsible engineer/technical personnel.
8.6.5 Acceptable disposition of a nonconformance (as approved by the responsible engineer/technical personnel) may include:

- Use as is.
- Rework/repair per original contractual documents or approved repair procedure.
- Scrap the equipment/component involved and start over.

8.6.6 Once the disposition of the nonconformance has been agreed by all appropriate parties and implemented, the source inspector is normally responsible for determining if the nonconforming item currently conforms to the original or revised requirements based on the agreed disposition. It is SI responsibility to verify that NCR disposition has been properly implemented.

8.7 Source Inspection Project Continuous Improvement

At the completion of the source inspection activities at an S/V, the source inspector, inspection coordinator, and all others involved in the “planning and doing” processes should review the entire planning and implementation part of the "Plan–Do–Check–Act" continuous improvement (CI) cycle to determine which activities went well and where improvements/adjustments could/should be made. Determinations should be made if improvements are possible and necessary in the source inspection management systems; the source inspection project planning process: the creation and implementation of the ITP; and the implementation of the source inspection work process events. Any such improvements should be documented and made available to source inspection managers and coordinators to implement the improvements. This should include an evaluation of the performance of the S/V.

8.8 Source Inspector Continuous Improvement

The source inspector can/should also learn from the continuous improvement cycle how he/she can improve their performance on the job by answering such questions as:

- Are there some industry codes and standards that I should be more familiar with?
- Are there any safety and/or personal conduct improvements I can make?
- Can I improve the way I write the various SI reports?
- Do I need to improve my review of project documents before showing up at the S/V site?
- Can I improve the way I conducted the pre-fabrication meeting?
- Can I improve the timeliness of closing out my part of the source inspection project?

9.0 Examination Methods, Tools and Equipment

9.1 General

This section describes the typical examination methods, tools and equipment with which source inspectors should be familiar during the course of their surveillance at an S/V. Requirements for examinations from the purchaser or references in the contract agreement that may be more stringent than industry codes/standards or the S/V normal procedures should be included in the ITP.
9.2 Review and Confirmation of Materials of Construction

9.2.1 Ensuring that the S/V is using the correct material during the manufacturing of the equipment is a critical element of quality surveillance. Typical reviews should consist of the following:

- Material Test Reports (MTRs)—The information necessary for the source inspector to know and understand about MTRs is covered in ASME BPVC Section II, SA-370, and EN10204.

- Any reports e.g. MTRs that have been modified, corrected, or altered should be cause for further investigation as these could indicate the potential for the material or component being counterfeit material. All MTR’s must be legible.

- Confirming that the construction materials proposed are the actual materials used during construction is a typical source inspection activity. The source inspector should:
  - Confirm the correct material type and grade.
  - Confirm the origin of the material.
  - Check material size and/or thickness.
  - Verify traceability of the material to a certifying document.
  - Verify that the material complies with specific chemical and/or mechanical properties as specified in the contractual documents.
  - Verify compliance to NACE MR0175/ISO 15156 for equipment in sour service. Heat treat and hardness to be verified. Maximum hardness requirements for P-Numbered alloy steels are given in NACE MR0103, Table 2. Other alloy steels shall have a maximum hardness of 22 HRC (237 HBW) (NACE MR0103, 2.1.6. Ferrous materials not covered by NACE MR 0103-2007 or NACE MR 0175-2008 shall have a maximum yield strength of 620 N/mm2 (90,000 psi) and a maximum Rockwell hardness of HRC 22.
  - Check for evidence of specified heat treatment.
  - This is typically done by verifying that material grade, type and serial number match the material certifying document. Some S/V’s quality programs as well as purchasers’ have various methods for ensuring that the correct material is used in manufacturing with the use of positive material identification (PMI). The source inspector should be familiar with those methods and ensure compliance. API RP 578 is a good reference document for material verification and positive material identification.

9.2.2 The SI should be aware of the potential for counterfeit materials/documents slipping into the supply chain. Key issues to watch for include, but are not limited to:

- Generic documentation which is not product specific.
- Material or equipment containing minimal or no documentation.
- Markings or logos that are questionable or obliterated.
- Items that have inconsistent appearance.
- Documents that have been altered.
- Items that lack material traceability or product certification.
- ASME or ASTM stampings that may have been counterfeited.
9.3 Dimensional Inspections

9.3.1 The SI should be proficient in understanding and performing dimensional inspections. Equipment such as tape measures, dial indicators, calipers, micrometers, protractors, vibration gages, temperature gages, pressure gages, levels are all typical tools that are used for dimensional inspection. The SI should be familiar with proper usage and application of these tools along with calibration requirements. Tools used for precision measurement are typically calibrated in accordance with a S/V’s written calibration procedure in accordance with NIST, ISO Guide 99 and other industry standards for calibration. Calibration is a comparison between measurements, one of a known magnitude or correctness (the standard) compared to the measuring device under test in order to establish the accuracy of a measuring device. The main objective for performing calibration, it checks or verifies the accuracy and determines the traceability of the instrument. The accuracy of a measuring device can become suspect for various reasons. Some of the common causes of the loss of accuracy are:

- Normal wear during usage.
- Misuse of the instrument either in application or mishandling (i.e. dropping, incorrect storage etc.).
- Environmental issues such as extreme temperature changes, hazardous or corrosive conditions.

The S/V should have a calibration procedure that as a minimum addresses the calibration intervals, calibration tolerances, control of masters, traceability requirements, care of the instrument, records, and recalibration. Most companies establish a calibration interval based on multiple variables, including manufacturer’s recommendations, amount and type of usage, conditions of the unit, accuracy requirements, and established history of previous calibrations. Obviously the shorter the interval or more frequent the calibration the lower the risk concerning use of a device that does not comply with the calibration requirements and potential for unacceptable material to be inadvertently accepted. However calibration can be an expensive process, with potential serious ramifications for acceptance of product later found to be non-conforming. Therefore the S/V is required to take all potential parameters in consideration when establishing a calibration interval. S/V’s that do not perform a lot of detailed precision measurement may elect to establish a calibration requirement for the measurement device to be calibrated prior to each use.

The S/V should maintain adequate records addressing the method of controlling precision measuring devices that require calibration. The records should include, storage and handling requirements, calibration due dates, prevention of usage of devices past calibration due date, means to identify product verified using a specific measuring device, and determine optimal calibration interval based on an established history. Maintaining accurate calibration records will also provide the S/V with an indicator of a measuring device reaching the end of its lifetime in relation to ability to hold calibration or extent of re-calibration required each time it is subjected to calibration.
9.3.2 The S/V should include in the calibration procedure a method to recall material checked with a device that was later found to not be in calibration. Finding of a device that fails calibration at the established calibration interval will normally require the issuance of a non-conformance in the S/V’s quality system. When a device is found to be out of calibration, any measurements made since the last known calibration is suspect. The S/V must determine as part of the non-conformance resolution the extent of the calibration error, the criticality of product verified with the device, and ability to identify all potentially unacceptable product either in house or shipped. Depending on the level of error and criticality of the product the S/V may be able to re-measure or rework product still in house. The S/V may also need to contact customers that have received product to issue a recall or advise of the need for service to bring the product into specification requirements.

9.3.3 When performing dimensional inspections, the source inspector should be familiar with the dimensional requirements and the allowable tolerances. Actual dimensions should be recorded in the inspection reference drawing. Dimensions which exceed the tolerances should be reported as a nonconformance or deviation.

9.4 Visual Inspections

9.4.1 Adequate lighting is essential when performing visual inspection. The SI must be familiar with the minimum lighting requirements defined by the applicable code, standard or specification. If there is inadequate lighting available during the visual inspection which is not uncommon in some shops, the source inspector must address these concerns with the S/V and inspection coordinator to resolve. Portable lighting such as pen lights, high power flashlights, etc. are common tools that the source inspector may need with him/her in order to perform adequate visual inspection.

9.4.2 Source Inspectors who are performing visual inspections of welding, coatings, etc. should be appropriately trained, qualified and/or certified as required to perform those activities in accordance with the applicable codes or standards including the visual acuity requirements.

9.5 Nondestructive Examination (NDE) Techniques

9.5.1 General

9.5.1.1 The primary source for the specific NDE techniques to be applied during M&F by the S/V is included in the applicable project specifications. Those documents should reference other appropriate codes/standards for NDE methods such as ASME BPVC Section V & NDE technician qualifications such as ASNT SNT TC-1A. The source inspector should be familiar with the NDE qualification/certification processes described in ASNT SNT TC -1A, especially what NDE duties/responsibilities can be carried out by Levels I, II, and III NDE technicians.

9.5.1.2 The source inspector should be familiar with NDE terminology contained in ASME BPVC Section V, Subsection A, Article 1, Mandatory Appendix 1 and Subsection B, Article 30, SE-1316.
9.5.2 Penetrant Testing (PT)

ASME BPVC Section V, Article 6, T-620 cover most of what the source inspector needs to know about PT. Discontinuities revealed during PT are normally recorded on an NDE report.

9.5.3 Magnetic Particle Testing (MT)

ASME BPVC Section V, Article 7, T-750 cover most of what the source inspector needs to know about MT. Discontinuities revealed during MT are normally recorded on an NDE report.

9.5.4 Radiographic Testing (RT)

ASME BPVC Section V, Article 2, T-220 and E-94 or E1742 cover most of what the source inspector needs to know about RT. Discontinuities revealed during RT are normally recorded on an NDE report.

9.5.5 Ultrasonic Testing (UT)

ASME BPVC Section V, Article 4, and E 797 and Article 5, T-530 cover most of what the source inspector needs to know about UT. Discontinuities revealed during UT are normally recorded on an NDE report.

9.5.6 Positive Material Identification (PMI)

API RP 578 covers most of what the source inspector needs to know about material verification and PMI.

9.6 Destructive Testing

9.6.1 Destructive testing is defined as those tests that are performed on metals for the purposes of determining mechanical properties and which involve testing of sample coupons. Examples of such tests include tensile testing, bend testing and Charpy impact testing.

9.6.2 Tensile testing is performed to determine yield strength (point at which elastic deformation becomes plastic/permanent deformation) and ultimate tensile strength (fracture point) of an item.

9.6.3 Bend testing is commonly performed on weld coupons to check the ductility and integrity of welds.

9.6.4 Charpy impact testing is performed to determine toughness of metals and welds. It may be specified for a variety of reasons at a variety of different temperatures to show that the vessel or piping system has the ability to deform plastically before failing i.e. avoid catastrophic brittle fracture. For many construction codes, impact testing often becomes a requirement below temperatures of −20°F, but the engineering specifications may require impact testing at other temperatures as well.

9.6.5 Most of the information necessary for the source inspector to know and understand about destructive testing of metals is covered in ASME Section IX.
9.7 Pressure/Leak Testing

9.7.1 General

Pressure/leak testing is normally specified by the applicable codes/standards and contractual agreements.

9.7.2 Pressure/Leak Testing

9.7.2.1 Hydrotesting is conducted with water for the integrity of the equipment and a gas test is performed as a leak test. As the name indicates, pressure testing involves testing with elevated pressures, often above that at which the component will normally operate, so safety is of utmost importance when witnessing a pressure test. Pressure tests must be conducted in accordance with the construction code or standard to which the item was built e.g. ASME BPVC Section VIII for vessels or ASME B31.3 for process piping. API standards like API 610 also address minimum requirement to hydrotest pump pressure containing parts before further testing like performance or running tests. These codes generally indicate how to witness such a test safely after the pressure has equalized and stabilized. Whether testing by hydrotest, hydro-pneumatic or pneumatic, the pressure testing equipment should have the means to prevent overpressuring the equipment under test.

9.7.2.2 Hydrotesting is the most common method of pressure testing and involves the application of pressure using water. It’s very important that high point vents be opened during filling and before the application of pressure to ensure that there is no air left in the system. All connection welding to case should be completed prior to hydrotest. Verification that chloride content is less than 50ppm is to be conducted when hydrotesting austenitic stainless steels is a common requirement, the SI should be aware of this when austenitic stainless steel is tested. Verification of drying after hydrostatic testing is critical to prevent deposition of chlorides. S/V shop should have a safe area guarded by metal netting that would prevent pieces of metal from flying outside of the save compartment in case a tested part fails and disintegrates. The SI should verify a current lab analysis has been performed concerning the water quality in compliance with PO/Contractual requirements, including chloride content or other items as specified in these documents.

9.7.2.3 Pneumatic Testing is generally conducted with air though sometimes it’s conducted with a combination of air and water. There are significantly greater risks involved in higher pressure pneumatic testing, so it should never be conducted without the full knowledge and consent of the responsible engineer who has been satisfied that the potential for brittle fracture during test is negligible. The danger lies in pieces of the equipment that fail under pneumatic pressure being propelled with great force for long distances and thereby doing a lot of damage and/or inflicting severe injury. API 682 has more detail around pneumatic testing. The SI should be familiar with this requirement as it's a critical test.

9.7.2.4 Leak Testing is generally the term used to describe low pressure testing with air or gas just to see if the joints in a piece of equipment e.g. flanges and threaded connections are leak tight after assembly. Leak tests are usually done at low pressures which are substantially below equipment design pressures to minimize risk of injury. Specialized leak tests with helium or other gases have to be specified by contractual documents which will detail the leak test procedure and generally reference an industry standard that must be followed.
Performance/Functional Testing/Mechanical Run Test

Performance and functional testing is typically required for all rotating equipment. Prior to performance or functional testing, the S/V should provide a detailed functional test procedure which has been submitted for review and comment from the purchaser. This functional/performance test may also be attended by other interested parties in the project. Sufficient advance notice is necessary to ensure all interested parties are available and can attend this test.

The SI should be very familiar with the functional/performance test procedures and a detailed report that is expected at the end. SI should also verify that all attributes of the test are accurately reported in the final test report, provided by the S/V.

Following is an example of this functional testing, This could change based on customer requirements:

Example:

A performance curve is plotted to indicate the variation of pump differential head against volumetric flow (gpm) of a liquid at an indicated rotational speed or velocity, while consuming a specific quantity of horsepower (BHP). The performance curve typically consists of the following curves relating with each other on a common graph. These curves are:

1. The Head-Flow Curve. It is called the H-Q Curve.
2. The Efficiency Curve.
3. The Energy Curve. It records Brake Horsepower, BHP.

The purpose of pump performance test is to ensure that the actual performance of a pump is consistent with that set as adequate by the supplier.

Recorded test data usually consists of the following information:

− Test fluid temperature
− Test fluid specific gravity
− Torque (Power) reading
− Voltage at the driver
− Current to the driver
  ▪ Frequency of supply voltage
  ▪ Flowrates
  ▪ Discharge pressure
  ▪ Suction pressure
  ▪ Elevations corrections
  ▪ Vibration levels.
  ▪ Oil temperature
A minimum of five points are taken to cover the flow range from 0 to 120%, depending on the test standard. For API-610 pumps these normally are:

1. Shutoff (no vibration data required).
2. Minimum continuous stable flow (beginning of allowable operating region).
3. Between 95% and 99% of rated flow.
4. Between rated flow and 105% of rated flow.
5. Approximately the best efficiency flow (if rated flow is not within 5% of best efficiency flowrate).
6. End of allowable operating region.

The number of vibration readings taken depends also on the selected standard.

Once test is completed, all data have to be converted into suitable units, plotted on a chart and compared to the acceptance criteria.

Acceptance criteria usually cover tolerances on:
- Head, efficiency, flow rate, vibrations levels, brake horse power, speed and oil temperatures in bearing housings.

If specified, the pump should be run on the test stand at the rated flow until oil temperature stabilization has been achieved. If specified, the pump should be mechanically run at the rated flow for 4 h.

9.9 Equipment Disassembly Inspection

9.9.1 For certain kinds of rotating equipment, disassembly inspection is commonly performed to inspect the rotating equipment internals for contact during testing. **Example**, “disassembly due to the need to reduce impeller diameter by more than 5% to meet performance requirement requires a retest”.

9.9.2 If pump has anti-friction (ball or roller) bearings, oil should be drained from bearing housings and inspected on the subject of color change and foreign material inclusion. If pump has hydrodynamic bearings (sleeve and thrust), bearings should be removed and inspected after the test.

9.9.3 If it is necessary to disturb the mechanical seal assembly following the performance test, or if the test sealfaces are replaced with the job seal faces, the final seal assembly should be air-tested.

9.10 Surface Preparation/Coatings Inspections

9.10.1 Performance of coating systems typically depends on the how well the substrate or surface is prepared for coating applications. Typically on rotating equipment, visual inspection of surface preparation is recommended or required. Inspections typically consist of:
- Surface profile measurement.
- Visual surface comparison.
- Verification of blasting medium.
9.10.2 Coating systems are usually specified in the contractual and engineering documents and likely will involve single or multi coating applications. The method of inspection of these coating systems is by the use of a dry film thickness gauge (DFT) per SSPC-PA 2, which the SI should be familiar with.

9.10.3 The SI should also be aware of specific coating requirements such as stripe coating of welds, edges, corners, etc. which are performed to insure coating performance on rough or uneven surfaces.

9.10.4 In addition to purchase order requirements and company standards, coating manufacturer’s recommendations will provide the details for correct coatings application to be followed.

9.10.5 Prior to releasing the rotating equipment for shipment, the source inspector should inspect the external coated or lined surfaces for the following items: raised areas, pinholes, soft spots, disbondment, delaminations, blisters, holidays, bubbling, fish-eyes, runs and sags, uniformity, mechanical damage, orange peel, adhesion, mud flat cracking and proper color or shade. For internal or spare coating the inspector would check for anti-fouling testing prior to babalance or testing.

9.10.6 Any areas found in need of coating repairs should be properly identified and documented (NCR) by the source inspector as well as any testing and re-inspection performed after repairs have been made.

10.0 Final Acceptance

10.1 Prior to Final Acceptance of Rotating Equipment

Prior to final acceptance of rotating equipment, the source inspector should determine the following:

- All work specified in the contractual agreements is completed by the S/V.
- As-Built drawings, and datasheet have been completed and submitted to purchaser.
- All NCRs have been closed out and resolved by the S/V QC representative and owner’s QA representative.
- All punch list items have been completed.
- All Inspection related activities have been completed and documented.
- All S/V work has been deemed acceptable by the owner’s QA representative in accordance with the requirements of codes, standards and project specifications.

10.2 Shipping Preparations

Shipping Preparations may also be specified in the contractual and engineering documents. It is important that the SI confirm that all bracing, strapping, mounting, covering, packaging, marking, and protection from the weather, etc. is effectively completed before the equipment is released for shipment. These are typically defined in the purchase agreement or attached as a requirement, which may be different project to project.

10.3 Reviewing Final S/V Data

It is typical for the SI to perform a final review of the contractually required S/V data upon the completion of the manufacturing prior to shipment of the materials or equipment.
This review is to determine that all documents are complete, with the as built item with all supporting documents as identified in the contractual agreement. Such documentation may include but is not limited to:

- Final drawings/data sheets
- MTR’s
- Performance Test documentation
- NDE results
- Product specific QC checks
- NCR close outs
- Certification documents
- Code compliance documentation as applicable

11.0 Manufacturing and Fabrication Processes

11.1 General

11.1.1 The manufacturer/fabricator is responsible for the quality of all their products, which includes not only good workmanship, but also compliance with all codes, standards and specifications contained in the contractual agreements. The source inspector is responsible as defined in the inspection and test plan (ITP) for performing the source quality surveillance activities at the S/V facilities in accordance with the applicable ITP.

11.1.2 Specific processes that are commonly used include welding, heat treatment, casting, forming, forging, machining, assembly, etc. The source inspector needs to be familiar with those processes to confirm compliance with codes, standards and project document requirements. For all processes including rework and repair, the following information should be consistent and confirmed:

- Manufacturing and fabrication process has a documented method describing how to perform the work.
- Individuals required to perform the process have proof of training and qualifications.
- Individuals performing the work have immediate access to the relevant procedures.
- There is acceptance criteria documented to determine if the processes results are acceptable.
- The results of the processes are documented.

11.1.3 Rework and repair—should be approved by the purchaser and verified by the SI.

11.2 Welding Processes and Welding Defects

Different welding processes are susceptible to different types of welding defects. Hence it's important for the SI to know which welding processes will be applied to the equipment during manufacturing/fabrication and to be familiar with the typical defects for each welding process that can occur. The SI should revert to the purchase agreement and S/V welding procedures as applicable.
11.3  Casting

11.3.1 The casting process is used to create simple or complex shapes from any material that can be melted. This process consists of melting the material and heating it to a specified temperature, pouring the molten material into a mold or cavity of the desired shape, and solidification of the material to form the finished shape. An advantage of the casting process is that a single step process can be used to produce components that are characterized by one or more of the following attributes:
- Complex shapes e.g. fittings, flanges, valve bodies, pump cases.
- Hollow sections or internal cavities.
- Irregular curved surfaces.
- Very large sizes.
- Materials that are difficult to machine.

11.3.2 A disadvantage of castings for pressure components is that mechanical properties such as toughness may not be adequate. Typical defects associated with the casting process that the SI should be aware of include:
- Shrinkage voids.
- Gas porosity.
- Trapped inclusions.

11.3.3 Castings are susceptible to the creation of voids during the casting process which could result in through wall leaks during service. ASTM grades of casting used in the petrochemical industry typically for pump casings and valve bodies are referenced in ASTM A703, *Standard Specification for Steel Castings, General Requirements for Pressure Containing Parts*. This standard prohibits peening, plugging and impregnating defects in castings to stop leaks, as opposed to making more permanent welding repairs. The SI should make sure that any casting repairs needed are brought to his/her attention so that adequate repair procedures can be prepared, approved by the purchaser and implemented. ASTM 703 also provides casting grade symbols that identify the type of material in the casting.

11.3.4 Grade symbols are required on castings (e.g. WCB, WC9, CF8M, and so forth) in order to indicate the type of casting material. The SI should verify that the casting grade symbol on products e.g. valve bodies matches the specified grade in the contractual documents.

11.3.5 MSS-SP-55, *Quality Standard for Steel Castings for Valves, Flanges and Fittings and Other Piping Components—Visual Method for Evaluation of Surface Irregularities* is the standard that is generally used to perform visual evaluation of surface irregularities that may have occurred during the casting process. The source inspector accepting cast products should be familiar with this standard.

11.4  Forging

11.4.1 Forging is the oldest known metal working process. It consists of a number of processes that are characterized by the use of localized compressive forces that are applied via hammers, presses, dies, or other forging equipment to induce plastic/permanent deformation. While forging may be performed in all temperature ranges, most forging is done above the recrystallization temperature of metal.
During the forging process the grain flow follows the general shape of the component and results in improved strength and toughness characteristics. Advantages of this change include:

- Increased wear resistance without increased hardness/loss of ductility.
- Stronger/tougher than an equivalent cast or machined component.
- Less expensive alloys can be used to produce high strength components.
- Components are not susceptible to common casting defects.

11.4.2 ASTM A788, Standard Specification for Steel Forgings, General Requirements covers a group of common requirements that may be applied to steel forgings for general use. Key elements of ASTM A788 include the following:

- The purchaser may specify additional requirements.
- Tension and hardness tests must be conducted to evaluate mechanical properties.
- Repair welding is not allowed unless permitted by the product specification.
- Supplementary general requirements may be performed by agreement between the supplier and the purchaser; these requirements are designated by an S followed by a number (e.g. S5).

11.5 Machining

11.5.1 Machining is any of several metal working processes in which a piece of raw material is cut into a desired final shape and size by a controlled material-removal process. Typical fixed equipment components that require machining include: flanges, valve components, and heat exchanger tube sheets. The three principal machining processes are turning, drilling and milling. Other machining operations include shaping, planing, boring, broaching and sawing.

11.5.1.1 Turning operations are operations that rotate the workpiece as the primary method of moving metal against the cutting tool. Lathes are the principal machine tool used in turning.

11.5.1.2 Milling operations are operations in which the cutting tool rotates to bring cutting edges to bear against the workpiece. Milling machines are the principal machine tool used in milling.

11.5.1.3 Drilling operations are operations in which holes are produced or refined by bringing a rotating cutter with cutting edges at the lower extremity into contact with the workpiece. Drilling operations are done primarily in drill presses but sometimes on lathes or mills.

11.5.2 Machining requires attention to many details for a workpiece to meet the specifications set out in the engineering drawings or blueprints. Besides the obvious problems related to correct dimensions, there is the problem of achieving the correct finish or surface smoothness on the workpiece such as a flange finish. Typically there is no in-process inspection by the SI for the machining operation; however, the SI may be required to check dimensional aspects and tolerances of machined components.
11.6 Assembly

Assembly generally has more to do with machinery, instrumentation, control systems, and electrical gear. However, for mechanical equipment such as skid units and other equipment that is to be assembled e.g. flanges or other connections, the SI should be looking for tight fit up of all connectors. This can be accomplished with torque wrenches or “pinging” bolts with a small hammer (like a slag or ball peen hammer). The SI should check to make sure that bolted flanges and screwed fittings are leak free when witnessing performance tests.

11.7 Metallurgy Issues Associated with Manufacturing and Fabrication Processes

11.7.1 The Structure and Metals

Metallurgy is a complex science in which many schools have degreed programs, but a general understanding of the major principles is important to the source inspector, due to the wide variety of metals and alloys that may be used in manufacturing and fabrication processes including welding.

11.7.2 Physical Properties of Metals

The physical properties of a metal or alloy are those, which are relatively insensitive to structure and can be measured without the application of force. Examples of physical properties of a metal are the melting temperature, the thermal conductivity, electrical conductivity, the coefficient of thermal expansion, and density.

11.7.3 Mechanical Properties of Metals

Engineers select materials of construction that provide adequate strength and toughness at operating temperatures and pressures. For the inspector, verification that mechanical properties meet the design requirements is essential. Inspectors should understand the underlying principles of mechanical properties and the nature of tests conducted to verify the value of those properties.

11.7.4 Hardness and Hardenability of Metals

Hardenability is defined as that property of a ferrous alloy that determines the depth and distribution of hardness induced by quenching. It is important to note that there is not a close relationship between hardenability and hardness, which is the resistance to indentation. Hardness depends primarily on the carbon content of the material, whereas hardenability is strongly affected by the presence of alloying elements, such as chromium, molybdenum and vanadium, and to a lesser extent by carbon content and alloying elements such as nickel, copper and silicon.

11.7.5 Weldability of Metals

The American Welding Society defines weldability as “the capacity of a metal to be welded under the fabrication conditions imposed, into a specific, suitably designed structure, and to perform satisfactorily in the intended service.”
11.7.6 Preheating and Post Weld Heat Treatment

11.7.6.1 Preheating

Preheating is defined as heating of the weld and surrounding base metal to a predetermined temperature prior to the start of welding. The primary purpose for preheating carbon and low-alloy steels is to reduce the tendency for hydrogen induced delayed cracking. It does this by slowing the cooling rate, which helps prevent the formation of martensite (a more crack prone microstructure) in the weld and base metal HAZ. According to B31.3, the pre-heat zone for welding of new process piping should extend at least one inch beyond the edge of the weld for piping.

11.7.6.2 Postweld Heat Treatment (PWHT)

Postweld heat treatment (PWHT) produces both mechanical and metallurgical effects in carbon and low-alloy steels that will vary widely depending on the composition of the steel, its past thermal history, the temperature and duration of the PWHT and heating and cooling rates employed during the PWHT. The need for PWHT is dependent on many factors including; chemistry of the metal, thickness of the parts being joined, joint design, welding processes and service or process conditions. The temperature of PWHT is selected by considering the changes being sought in the equipment or structure. PWHT is the most common form of fabrication heat treatment applied to fixed equipment. When PWHT is required by code, typical normal holding temperatures for carbon and some alloy steels is 1,100°F for one hour per inch of thickness with 15 minute minimum. When PWHT is required for equipment due to in-service process considerations, those requirements will most likely be found in company standards and specified in the project documents. Normally the appropriate PWHT for welded equipment and piping is specified in the welding procedure specification (WPS). Heating and cooling rates for PWHT may be specified in the construction code or project documents. Typically heating rates for pressure equipment and piping above 800°F must be controlled to no more than 400°F per hour with no variation permitted of more than 250°F in any 15 foot segment of the equipment. Thermocouples must be located in order to verify even distribution of temperature on components and to ensure that no component is over or under-heated during PWHT. Most of the information necessary for the source inspector to know and understand about PWHT is covered in ASME BPVC Section VIII, Division 1.

11.7.6.3 Other Heat Treatments

Other heat treatments include annealing, normalizing, solution annealing, and tempering. See Section 3 for definitions of those heat treatments.

12.0 250 to 1,000 Horsepower Pumps (Centrifugal Pumps)

12.1 General

Material of construction of the pump is specified on the Pump Data Sheet. API 610 Table G.1 provides a guide showing material classes that can be appropriate for various services. API Std 610, Section 8 Inspection, testing, and preparation (ITP) for shipment is the industry guidance document for all inspection and testing activities required for API 610 pumps.
SI Inspector should be familiar with all requirements in this section of API 610. The ITP specifies what level of inspection and documents review is required. Documents that are required to be submitted for Requisition Engineer (RE) review and approval are listed in the Purchaser’s Supplied Documents List (SDL). This document is mutually agreed between pump purchaser and the S/V.

Following is a list of documents typically required for purchase of centrifugal pumps:

12.1.1 API 610 Pump Data Sheet

Data Sheet is a part of Purchase Documents Package and issued by the purchaser. Data Sheet provides a general reference to material of construction, material certification & PMI requirements. Pump Data Sheet goes through three stages:
- As issued for P.O. (purchase) – part of P.O. package submitted by the purchaser and accepted by S/V.
- As sold – submitted by S/V as one of the first documents listed on SDL. Data Sheet is reviewed and approved for construction by purchaser RE.
- As built – submitted by S/V after final pump test and before final inspection. Reviewed and Approved by purchaser RE.

12.1.2 Inspection Requirements Form Issued by the Purchaser with P.O.

Each purchase package should include an Inspection Requirements Form. This form is issued by the purchaser during procurement process. It contains requirements for Inspection and actions that are to be conducted between the date of P.O. acceptance by supplier and the date of final inspection and shipment of the equipment.

12.1.3 Supplier’s Quality Plan (ITP)

One of the first documents supplied by S/V is a Inspection and Test Plan (ITP). The S/V ITP should address all activities required for manufacturing, inspection, assembly, test and shipment. S/V develops this plan based on Job Requirements specified in data sheets, IRF, technical notes, specifications and applicable industry standards such as API 610 or ASME. The ITP should be developed for each major component, sub-assembly and final package. Usually ITP’s feature a matrix, including each Activity, Inspection and Test requirements for this activity, Standard or other code reference on which this activity based, Specific area, place or characteristic of the part or stage in production where this activity takes place, supplemental documents that are required for this activity; and level of client involvement in this activity (Review Documents, Surveillance, Verify, Witness, Approve of activity, Hold Point).

12.1.4 Pump Cross Section with BOM (Bill of Materials)

BOM should list the part Name, Quantity, Identification Number, Part Number, and Material of Construction with ASTM codes for all major parts. Materials should be identified by reference to applicable International Standards such as ASTM, AFNOR, BS, DIN, EN, JIS, etc., including the material grade (Tables H.2 and H.3 of API 610 may be used for guidance). Pump Cross Section and BOM are reviewed and approved for construction by purchaser RE.
12.1.5 NDE procedures, Weld Maps, Hydro and Performance Test Procedure

S/V should submit for client approval NDE procedures, Weld Procedures, Weld Maps, PMI test procedure, Hydro and Performance test procedure according to approved SDL. In need for weld repair S/V should submit Weld Repair procedure for purchaser approval. For casting repairs made in the S/V shop, repair procedures including weld maps should be submitted for purchaser's approval. The purchaser should specify if approval is required before proceeding with repair. Repairs made at the foundry level should be controlled by the casting material specification (producing specification II).

12.1.6 Vendor Unpriced Quotes and Buy-outs for Major Parts

Usually, quotes and buy-outs are not required documents for review and approval by the purchaser. However, they should be reviewed by SI and have to be included in ITP as a “review” action. Such parts include but not limited to Pump Pressure Casing, Impellers, Diffusers, Shafts, Wear Rings, Sleeves, Bushings, Weld Fabrication, Pressure Bolting and Gaskets. The SI typically verifies that quotes and buy-outs have correct quantity, material, level of inspection and NDE based on the requirements of P.O. and ITP. Depending on S/V’s manufacturing structure and philosophy buy-outs can be for materials such as bars, sheets, pipes, casting, weld fabrication, forging, rough machined parts or final machined parts with all the required NDE and hydro testing completed at sub-vendor shops.

12.1.7 Material Certificates

The S/V should furnish material certificates that include chemical analysis and mechanical properties for the heats from which the material is supplied for pressure-containing castings and forgings, impellers and shafts. Unless otherwise specified, piping nipples, auxiliary piping components, and bolting are excluded from this requirement. Material Certificate should list part number, part name and reference to Pump Cross Section number for easy identification. In many cases parts such as castings, forgings and loose items for fabrication have different part numbers listed on material Certificates than those listed on Pump Cross Section. SI should always request that the final part number and assembly number are added to the Material Certificate. Material Certificates should be easily legible.

12.1.8 PMI and NDE Test Procedures

If specified by ITP, S/V should submit all PMI, NDE and other material tests procedures for purchasers review and approval for use. These procedures should be listed on purchaser's SDL and should be reviewed and approved by purchaser prior to the start of manufacturing.

12.1.9 PMI and NDE Test Reports

SI should verify if PMI and NDE test reports require submittal for purchaser’s review and comment. PMI and NDE test reports should be easily traceable to parts. They also should include a list of the approved procedures and industry standards such as ASME that were used for tests and test acceptance criteria. Tools, instruments and other equipment used for tests need to be listed and calibration records for such tool and instruments should be provided.
If SI observes a PMI or NDE testing, pictures should be taken and attached to the Inspection Report. Acceptance criteria for various NDEs can be found in ASME Section VIII, as follows:

- Mandatory Appendix 4 - Rounded Indications Charts Acceptance Standard For Radiographically Determined Rounded Indications In Welds.
- Mandatory Appendix 6 - Methods For Magnetic Particle examination (MT).
- Mandatory Appendix 8 - Methods For Liquid Penetrant Examination (PT).
- Mandatory Appendix 12 - Ultrasonic Examination of Welds (UT).

12.2 Design and Construction Standards

API Std 610, section .2.2 “Pump designations and descriptions” specifies various types of pumps. Pumps require two major assemblies: Stationary, that includes pressure casing and bearing housings and Rotating that includes Impeller(s), Shaft and Sleeves. Pressure casing is subject to hydrotesting.

All rotating elements are subject to balancing. Generally, Impellers are balanced individually. Rotor is balanced as an assembly with shaft, sleeves and impellers. For more information on balancing requirements refer to API Std. 610, section 6.9.4 “Balancing”. Pump data sheet specifies extent of balancing required.

All horizontal pumps and in-line pumps have anti-friction or hydrodynamic bearings or combination of both. Vertical pumps may have thrust bearings unless thrust bearing is provided in a pump driver. The following types of bearings’ lubrication are typically utilized: Oil Sump, Oil Mist, Forced Oil Lubrication or Grease. In some designs, Lubricated-for-Life bearings may be used.

Pump units are supplied with mechanical seal(s) (see API Std 682), drivers (i.e. electrical motors, steam turbines, diesel engines), couplings and coupling guards, piping (seal flush, cooling), and monitoring instrumentation. All equipment is usually installed on a single baseplate. Vertically suspended pumps are supplied with sole plate.

12.3 Materials of Construction/Pump Components

Major Pumps’ parts and assemblies that require SI activity if specified on ITP are the following:

12.3.1 Pressure Casing

Pressure casing parts may be subject to surface and subsurface examinations. Pressure casing material inspection requirements can be found in API 610, Table 14. Table 14 Inspection class 1 specifies minimum requirements for API 610 pumps pressure casing inspection. Job specific requirements are higher in most cases and involve MP or LP inspections as per class 2. Material Inspection Standards are listed in API 610 Table 15. These standards establish minimum acceptance criteria for casings. Job specific test requirements or supplier inspection procedures may exceed these requirements.
Listed below are the manufacturing methods of producing a Pressure Casing:
Casting, Forging, Weld Fabrication or a combination of any of three. Each of these
methods involves certain inspections and tests as specified on data sheets, IRF
and Quality Plan.

Casting

![Picture 1. Single Stage Pump](image)

**Cast Casing - Single Stage Overhung Pump**

The casting is a process used to create the parts by using melted metal and pouring it in
forms. Most widely used cast methods are green sand, ceramic, and investment casting.
For industry accepted practices of casting examination see ASME, Section VIII Mandatory
Appendix 7 - Examination of steel castings. Generally, NDE methods such as magnetic-
particle, liquid-penetrant, radio-graphic and ultrasonic examinations are the most frequently
performed at the casting producing foundries.

Casting should be heat treated and rough machined. Final machine surfaces are subject to
the examination at a machining facility after a hydro-test. Non-destructive examinations are
performed to ensure that casting is free from porosities, cavities and other surface or
internal defects and ready for final machining. Any defects that are found at a foundry may
either be fixed by approved weld repairs or else the casting has to be done over if weld
repair is not possible. Handling of the defects depends on the foundry procedures, material
and approved weld repair procedures. Casting quality can be affected by considerable
variations in material processing. Material standards, such as ASTM, provide minimum
requirements for the material itself, but castings can be subject to areas of shrinkage, gas
porosity, hot tears, sand inclusions, improper weld repairs, etc. In addition, some materials
are prone to grain boundary tears or cracks that can propagate under in-service stresses
causd by temperature, pressure, vibration and pipe strain.

Centrifugal Casting

Centrifugal casting is currently considered the preferable way for casting round shapes
such multi-stage pump casings, casing covers, nozzles and bearing brackets. This method
uses centrifugal force to pressure melted steel to avoid porosities, blow holes, gas holes
and other defect associated with casting.
Forging

Forging is a manufacturing process involving shaping of the metal using localized compressive forces. Forging inspection involves the same NDE methods as casting however the type of defects in a forged part is different than normally observed in cast parts. Since forging process involves a hot metal working, forging rarely produces such defects as porosities, blow holes, gas holes. Due to a possibility of uneven cooling forging may produce surface cracking, and therefore such NDE methods as magnetic-particle and liquid-penetrant are the most common tests used for the forged parts.

Fabrication

Pump casing almost always has parts attached by welding such as pipe attachments of casing connections. Multi-stage & Vertical Can pumps have pressure casing manufactured by fabrication. Forged or cast sections may be welded with forged or cast suction and discharge nozzles like shown in the picture above. Resulting weld assembly is rough machined. RT or UT test is typically required for the nozzle weld attachments before a part can be sent for rough machining. After the rough machining process, MT or LP inspections should to be done on the machined surfaces. Next operation is a weld attachment of auxiliary connections such as drains and vents. Connections’ welds are subject for an RT, MP or LP test before the part can be send for the final machining.

Suction Can pumps have a barrel that is generally fabricated from standard pipes and plates. Major NDE inspections for Vertical Can Pumps’ barrels and covers include weldments inspection. RT, MT or LP are most common NDE methods for weldments. In case if RT method is utilized, see ASME Section VIII.
The pattern tooling, casting process and cleaning process should be capable of producing the surface finishes specified on the Engineering drawing or, on the Purchase Order. Most foundries follow American Foundry Society surface standard shown below.

![American Foundry Society's C-9 Microfinish Comparator](image)

**Picture 3.** American Foundry Society's C-9 Microfinish Comparator shows surface finishes from 20 to 900 RMS.

Casting should not show discontinuities that exceed allowable as established in ASME Section VIII, MANDATORY APPENDIX 7 or in job specific requirements, or both.

![Pressure Casing Hydro test](image)

**Picture 4.** Pressure Casing Hydro test

**Hydro Test Pump Test Pac**

Pump Pressure casing hydrotests are performed per API 610, Section 8.3.2. The intent of a hydrostatic test of a centrifugal pump casing is to ensure that the pump pressure containing components and joints are leak-free. The test is performed in the full range of conditions: from ambient to the maximum operation conditions as defined on the data sheet.
SI should verify the part numbers of the items that are subject to the hydrotests. Casing Part numbers need to be stamped on the outside surface. Some pressure casing may be rated for dual (suction and discharge) rated pressure.

In some cases testing water should contain a wetting agent to reduce surface tension (See Section 8. of API 610). This requirement is typically listed in the S/V hydrotest procedure. Some hydrotest procedures also include a requirement that chloride content of liquids used to test should not exceed 50 mg/kg (50 ppm).

Pressure gauges used in the test should have current calibration dates shown on the permanently attached tags or located on a dial. The hydrostatic test should be considered satisfactory if neither leaks nor seepage through the pressure containing parts and joints occurs within 30 min or as defined by the purchaser.

![Impeller, Radial, Closed Type - Diffuser](image)

**Picture 5. Impellers and diffusers**

**Impeller, Radial, Closed Type - Diffuser**

Impellers and Diffusers are produced by casting process, sand cast or investment casting, depending on the criticality of pump design. Investment casting produces better dimensional and surface quality but is more expensive than sand casting. Impellers and Diffusers undergo the same type of basic NDE as pressure casing. RT or UT are not standard examination methods for these parts. First MT, LP and visual inspections are done at the foundry level. Then MT or LP examinations are performed on the final machined surfaces. In addition, impellers are balanced to the level specified on the Pump Data Sheets, technical Notes, Job Specifications or as a minimum as required per Section 6.9.4.1 of API 610. Impellers, balancing drums and similar major rotating components should be dynamically balanced to ISO 1940-1, grade G2.5.
12.3.2 Shafts, Wear Rings, Sleeves, Bushings, Thrust Balance Drums

Generally these parts are machined from bar stock. Large Sleeves, Wear Rings and Bushing can also be manufactured from Centrifugal casting raw material. Shafts of large multi-stage pumps often have UT inspection, otherwise Visual, Dimensional, MP, LP are examinations that are routinely used for these parts.

Visual examination includes also surface finish.

Below are Machining Finish Charts for different machining operation.

Picture 5. Surface Comparators (Typical)
Rotor Assembly

Rotor of Multi-Stage Pump

Pump Rotor is a major sub-assembly that requires separate examination. Rotor Assembly consists of Impeller(s), Shaft, Inter Stage Sleeves, Thrust Balance Drums, etc. Pump rotors need to be dynamically balanced per API 610 Section 6.9.4 (Parts) and Section 9.2.4.2 (Rotor assemblies). If a rotor needs to be disassembled for some reason, re-balancing is required after the re-assembly of the rotor.

For example, pumps’ rotors often need to be disassembled after first performance test for Impeller Trim adjustment. Pump S/V should supply the Balancing procedure for review by purchaser and provide a balance certificate upon completion.

Residual unbalance is the amount of unbalance remaining in a rotor after balancing. Although some balancing machines may be set up to read out the exact amount of unbalance, that measurement may be erroneous as it depends on the calibration. The only sure method of determining the residual unbalance is to test the rotor with a known amount of unbalance. See API 610 Annex J for procedure to determine residual rotor unbalance.

Picture 6. Rotor assembly

Picture 7. Mechanical Seal
Mechanical Seals

Mechanical seals are supplied by Seal Manufacturers. API 610 requires seals to be selected and designed per API 682. See API 610 6.8 for seal design requirements for pumps.

The main pressure containing part of mechanical seals is a Seal Gland that serves as a containing casing for mechanical seal parts and is bolted as an assembly to a pump Seal Chamber. Seal Gland is supposed to be hydro-tested to 1.5 times of seal MAWP. This pressure can be based on Pump Maximum Suction pressure, Pump MAWP, maximum applied pressure at seal static condition or any other specified on Pump Seal data sheet or other technical specifications included in the Purchase Order.

Pump S/V typically issues a Purchase Order to the seal vendor with all the requirements and all process data documents available for proper seal design and material selection. Such documents include API 682 Data Sheet, Seal Chamber Drawing, API 610 Pump data sheet and related specifications. Seal vendor should prepare and submit for review and approval the Seal Assembly Drawing with detailed BOM and all dimensions that are required to check the seal design and proper fit to the pump. All documents should be listed on the purchaser’s SDL.

Only the contractually designed seals should be used in the pump for the performance test unless specified otherwise. However, some seals are not designed to run on the water, and in this situation the S/V may purchase a test seal from the same vendor that supplies a job seal and use this test seal for the performance test of the pump. Mechanical seals should not be used during the hydrostatic test but should be used during all the running or performance tests. There should be no visible leakage during running tests. If seals are removed from the pump after the test for any reason such as fixing the leak, installation of contract seals or any other reason, the seal should be retested with an air test of the pump. If specified, seal leakage during tests should require the assembled pump and seal to be rerun to demonstrate satisfactory seal performance.

There are two basic designs of mechanical seals, Single Seal that have one set of stationary/rotating elements and Double Seal that have two sets of stationary/rotating elements.

Seal Flush Piping and Accessories

Mechanical seals need to be lubricated and cooled for successful operation. This is achieved by providing flush liquid to contact surfaces between stationary and rotating sealing rings. Different arrangements of seal flush piping are described in API 682 Annex G. Some seal Flush plans have Heat Exchangers, Reservoirs, Flow Control Panels and other equipment and instrumentation. Pump and Seal vendor S/V have to submit drawings, schematic, ISA data sheets and BOM for piping, equipment and instrumentation for purchaser review and approval. All these documents should be available during the final inspection (see final inspection section for more detailed information).

Pump Drivers

Pumps are driven by Electrical Motors, Steam Turbines or Diesel Engines. When speed of the pump is different than the speed of the driver, a Gear is used for synchronization. In most cases Pumps and Drivers are installed on the same baseplate. There are some installations that have drivers installed on separate baseplate or a sole plate but they are not common and rather considered exceptions. A data sheet is provided for that driver or gear according to an applicable standard. Gears are generally purchased to conform to either API-677 for General Purpose Gear Units or to API-613 for Special Purpose Gear Units.
Couplings and Couplings Guards

Requirements for Couplings and Coupling Guards can be found in Section 7.2 of API 610. Pump data sheets include information such as coupling service factor, applicable standard, (for example if the coupling has to comply with API 671 or not), Coupling vendor, Model, Size, and Balancing requirements. Special attention should be paid to the requirements for coupling installation options such as tapered shaft or hydraulic fit design. Coupling guards should be constructed with sufficient stiffness (rigidity) to withstand a 900 N (200 lbf) static point load in any direction without the guard contacting moving parts. If specified, coupling guards should be constructed of an agreed spark-resistant material.

Baseplates and Sole Plates

Pumps and their drivers are installed on fabricated or cast baseplates. API 610, 7.3 specifies requirements for baseplates design and requirements. Job Specific requirements for a baseplate design options and inspection are listed on Pump Data Sheet. Baseplates may be with or without grout, cooling jackets, may have special anchor options, or special paint requirements. Inspection of baseplates involves visual inspection of all welds to make sure that welds are continuous and good quality, dimensional inspection, bolt hole/anchor bolt location and machined pedestal flatness check.

Lube Oil Piping

When forced lubrication is required for pump, gear and driver, the pump supplier provides Lube Oil Piping to connect the Pump Train and the Lube Oil System (LOS). LOS can be mounted on the same baseplate as Pump/Drive train or on separate baseplate. See API 610, Sections 7.5; 9.2.6 and Annex B for Lube Oil Piping and system requirements. Pump S/V should provide for purchasers review and approval a detailed drawing with BOM showing all parts, instrumentation, gaskets and fasteners used for Lube Oil Piping.

Lube Oil Piping, components, welding, configuration should be selected or designed according to API 614 Part 1 and related job specifications. The basic requirements for oil piping are listed in API 614, Part 1, 5.2. For more detailed information see the Lube Oil System Section. Lube Oil Piping is subject to Hydro-test 1.5 times Maximum Operating Pressure.

Cooling Water Piping

When required, the S/V provides Cooling Water Piping. Cooling Water Piping schematic can be found in API 610 Annex B. Piping material for cooling water piping and components are specified on Pump Data Sheet. Cooling Water Piping is subject to Hydro-test 1.5 times Maximum Operating Pressure.

Instrumentation

Instruments, Junction and Terminal boxes, and Wiring should be in full compliance with the job specifications and should conform to the Hazardous Area classification as specified. S/V typically are required to submit all engineering data such as process and instrument diagrams, Wiring diagrams and schematics, Instrumentation List and Instrumentation data sheets in a format requested in the Purchase Order. Each instrument should have an assigned Tag Number. SI should verify that all instruments, boxes and wires have proper tagging as shown in accompanying documents. All instruments should have a manufacturing name plate with at least a Serial number, Area Classification and latest Calibration date listed. Measurement ranges and units of measurements should be verified with data sheets and instrumentation list.
12.4 Testing

12.4.1 Pump Performance and Mechanical Run Test

Pump data sheet specifies process data such as Rated Flow, Rated Total Differential Head, Suction Pressure and NPSHA. Based on these requirements, S/V selects and submits a proposal for a pump that is the best fit for this application. Purpose of the Pump performance test is to confirm that pump performance is as specified on the purchase order and pump data sheet; to check for pump vibrations; & to verify trouble-free mechanical performance. Performance test requirements, tolerances and acceptance criteria are specified in API 610. Section 8.3.3. S/V should submit test procedure for purchasers review and approval.

This test procedure includes detailed information on:
- Pump test set up.
- Measurements schematic.
- Instruments being used.
- Test results collection.
- Interpretation and final presentation in a form of numerical tables.
- Collected data.
- Performance curve.
- Vibration reading presented in tables and graphs.
- Oil temperature rise VS time.
- Final visual inspection of oil and hydrodynamic bearings.

A sample of the test result curve can be seen below.

![Typical Pumps Performance Curve Report](image)

**Picture 8. Typical Pumps Performance Curve Report**
12.4.2 Performance Test Set Up

![Typical Pump Test setup schematic](image)

**Picture 9. Typical Pump Test setup schematic**

Performance test setup should include:

- Piping loop that includes Suction Tank, Suction Piping with suction Flow Control Valve, Suction Pressure control devices such as Vacuum Pump and Pressurized Suction Tank, Discharge Piping with Discharge Pressure Control valve, Minimum Flow By-pass line.
- Calibrated Shop motor.
- Coupling with Torque meter.
- Rigid test stand where Pump and Motor installed and aligned.
- Machine Monitor System consisting of Shop Accelerometers and digital data collecting system. Some shops use hand help Vibration analyzers.
- Performance collecting instruments such as Pressure Transmitters, Flow Meters, Power Meters (for motor), Temperature Collecting instruments (Thermometers, RTDS, Temperature Gauges etc.) for collecting temperature of the lubricating oil, bearings and test water.
- Noise Measurement microphone with digital reading device.
- All instruments that are supplied with the pump should be installed and used for test.

12.4.3 Pump Flow Rate

The flowrate Q is the usable flow (volume of liquid per unit of time) discharged by the pump through its outlet branch.

The common units are m³/s, m³/h and l/s in metric and GPM (Gallons Per Minute) in American Standard Units (ASU).

Instruments for flow measurement are:

- Flowmeters, turbine, electromagnetic, variable area, venture, pitot, ultrasonic, etc.
- Positive Displacement meter.
12.4.4 Total Differential Head (TDH)

Total Differential Head is defined as a difference between Pump Suction Pressure and Pump Discharge pressure converted to Static Pressure. Conversion is necessary to exclude specific weight (gravity) S.G. of the liquid being pumped by the pump. This will make the pump pressure building characteristic of the pump independent from an actual pumped fluid. For example, test water has S.G.=1.0 and actual liquid that pump is being intended to pump has S.G.=0.5. Pump will have the same TDH regardless of fluid pumped but Differential Pressure created by the pump when operating on water will be twice as high as when operating on liquid with S.G.=0.5.

12.4.5 Conducting the Test

S/V personnel starts the pump and brings the flow to a rated point. They should let the pump run for some time to establish a stable flow and pressure and to monitor pump’s mechanical performance. After that test personnel should collect performance data, and vibration and temperature readings for a minimum of 5 points on the performance curve as per API 610, Section 8.3.3.3. Stable suction pressure should be maintained at each point using vacuum pump or pressure air. For a small pump it may not be necessary. After the test data collection is concluded, and if specified on the pump data sheet, the pump is given a mechanical run until lubrication oil temperature becomes stable. See Pump Data Sheet for test requirements.

12.4.6 Submitting Results of the Test

S/V should prepare a Test Report that includes all collected data, performance curve as tested and if specified, vibration graphs. Results of the oil and bearing inspection should also be included. This report has to be submitted to purchaser for review and approval. Pump should not be released for final inspection unless all the documents including a test report have been approved by the purchaser.

12.5 Final Inspection

Final inspection should be conducted in two stages, at first, when the equipment is fully accessible for dimensional and visual inspection and also when the equipment is getting prepared for shipment.

12.5.1 Dimensional and Visual Inspection

Following is the list of documents that are typically required for final dimensional and visual inspection and actions required based on these documents:

- Data Sheets
- Pump Train General Arrangement
- Process & Instrument Diagram (P&ID)
- Electrical and instrumentation wiring diagrams
- Auxiliary Equipment GA, P&ID and BOM (seal reservoir, LOS, Seal, Driver, Junction Boxes)
- Packing List
During visual inspection the following areas of concern should be addressed:

- Piping assembly should be accessible for maintenance, disassembly, and gasket replacement.
- Valve handles should have enough space for safe open-close action by an operator according to OSHA requirements to prevent hand jamming and injury.
- All equipment should be mounted using secured methods without them being shaky or unsecured.
- Workmanship of installation, welding and wiring should be without visible defects and within industry standards.
- There should be no overhung equipment or piping extending beyond perimeter of the baseplate except those shown on the approved General Arrangement. Usually only main terminal boxes of large motors are allowed to overhang the baseplate.
- Painting and paint thickness should be inspected and verified.
- Quantity, condition, and packing for items shipped loose should be inspected and verified.

13.0 Drivers

13.1 General

Electrical Motors

API 610 Section 7.1 specifies requirements for selection and design of electrical motors for pumps. Applicable standards are listed in Section 7.1.5. Purchaser provides Motor Data sheet with the P.O. per applicable standard.

13.2 Design and Construction Standards

Electrical motors used in API services should comply with the standards listed in the purchase order and Pumps Data Sheet. The main criteria for selection of the type of motor and the appropriate standards to be used, are: Area Classification; where motor will be installed; type of the load, and specific purchaser requirements.

13.3 Materials of Construction

All major components of Electrical Motors (such as Stator, Stator Winding, Rotor, Shaft, Bearing Housings and Bearings) require similar NDE tests and Material certificates as the pump components and should be as requested on motor data sheets in addition to the mandatory requirements of API 541. Material certificates and NDE procedures are typically submitted for purchaser approval. Reports of all NDEs and material certificates should be submitted for purchaser’s review. Motor Rotors should be balanced and residual unbalance checked if requested on the data sheet. Balance reports should be submitted to purchaser for review.

13.4 Tests and Inspections

There are electrical/Insulation tests that are performed on motor parts such as Stator and Winding before the motor assembly; and tests that are performed on the assembled motors during motor Routine or Complete tests. Stator test is described in API 541 4.3.4 and includes tests on Stator core, Stator Winding and Visual Inspection before final assembly.
All these tests are optional but may be specified on the motor data sheet if required. The SI should be aware of these requirements and confirm their completion and acceptance if required as a part of the purchase requirements.

Motor Routine test is the mandatory test for each motor. API 541, Section 4.3.2. states: “Each machine shall be given a routine test to demonstrate that it is free from mechanical and electrical defects”.

Motor Complete test is an optional test that may be requested on the motor data sheet. See API 541, Section 4.3.5 for the detailed description of a Complete Motor test. The main purpose of the Complete Motor test is to determine accurate motor efficiency, power factor and torque values under different loads. If motor has antifriction (ball/roller) bearings, oil conditions should be checked after the test. Oil should be clean and should not change color when compared with same unused oil. If motor has hydrodynamic bearing, they have to be removed after the test and inspected for excessive or uneven wear, foreign material inclusions, hot spots and other signs of unsatisfactory performance.

13.5 Final Inspection and Shipping Preparations

Motor final inspection includes inspection of dimensions per motor General arrangements drawings, paint inspection per paint specification, instrumentation inspection per motor data sheets and P&ID, name tag and name plate inspection, main terminal box inspection and wire connections.

14.0 Gears: Reducers and Increasers

14.1 General

- Gears can serve two main purposes:
  - to reduce pump’s RPM from driver RPM
  - or increase pump’s RPM.
- Pumps’ RPM is designed for standard synchronous RPM of electrical motors.

If a pump needs to run with the fixed RPM that is above maximum synchronous RPM or is somewhere in between of lower synchronous RPMs, reducing gear is being employed. The other method to have non-synchronous RPMs is to use Variable Speed Motors.

Majority of the times when gears are used with pumps driven by electrical motors are the situations where pump TDH and Flow-rate need to be higher than it is possible with a maximum standard RPM of an electrical motor. Such situations require the use of Increasers. Also Increasers are used with Diesel Engines as drivers for pumps.

When a pump driver is a Steam Turbine, reduction of RPM may be required. Steam Turbines are designed for certain steam conditions and their performance and size depend on these conditions. Higher RPM steam turbines are more efficient and smaller in sizes.

Another application of gears with pumps is a Right Angle Gears, when the pump driver is a horizontal machine and the pump itself is vertical.
Usually, electrical motors are available in vertical design and a Right Angle gear is not needed. There are also steam turbines available in vertical design but they are more complicated and many end users prefer a Right Angle Gear to connect turbine and pump. Right Angle Gears can be found in Cooling Water Pumps for Cooling Water Towers and Basin applications.

**Picture 10. Right Angle 1: 1 Gear Set**

Gears must be designed for maximum Trip Speed. See API 677, Table 1 “driver trip speeds”.

Gears have slower and faster shafts. Slower shafts have the largest diameter and called Gear Wheel. Faster shafts have smaller diameter and are called Pinion.

**Picture 11. Gear-Pinion Set.**

Gear Boxes have many different combinations and orientation. See API 677, Table 2 and Figure 1 for all possible Gear Boxes designs and assembly variations.
14.2 Design and Construction Standards

API 677 is the main industry standard for the General Purpose Gear Units for Petroleum, Chemical and Gas Industry Services. See API 677 Appendix F for additional industry standards for Gear Design and Requirements.

Gears generally have the same level of instrumentation as the main equipment and driver. High speed shafts with hydrodynamic bearings have X-Y proximity probes for each side and embedded RTDS in each sleeve and thrust bearing. If low speed shafts have anti-friction (ball or roller) bearings, X-Y accelerometers can be specified. SI should check gear data sheets for instrumentation requirements. If forced lubrication is specified, generally a main lube oil pump is mounted on gear shafts (high or low speed).

Unless Lube Oil System is independently supplied, Gear casing can serve as an oil tank in some arrangements. Casing can have oil level gauges and switches, oil heater and other features that are installed on Oil Tanks.

14.3 Materials of Construction

Main Gear Parts are Casing (Gear Boxes), Gear Wheels, Pinions, Shafts and Bearings. Casing can be fabricated or cast. General requirements for material of construction and weld requirements are specified in API 677, Section 2.11.

Material of construction for fabricated Casing is carbon steel, material of construction for cast Casing can be either carbon steel or cast iron. Casing has a bottom half that serves as an oil sump and has mounting feet and an upper half that serves as the cover. Casing is horizontally split and upper half can be easily removed without disturbing couplings and alignment.

See API 677, Section 2.7.3 for gear shaft requirements. Shafts should be made of one-piece, heat-treated, forged, or hot-rolled steel.

See API 677 APPENDIX D—Material Specifications for General Purpose Gear units.
14.4 Internal Component Inspections

Inspection requirements for internal components are specified in API 677, Section 4.2 for. Gear manufacturer should provide an ITP/Quality plan based on API 677, as well as job specific inspection and test requirements. If specified, the gear casing should be given a fluid fill leak check to test for oil tightness. Gear pressure lube system components should be given a pressure (hydro) test as specified in API 677, Section 4.3.2.

API 677, Section 2.7.2 contains typical inspection and quality assurance requirements for gear mating pairs, checking gear contact area and axial movement of pinion relatively to gear. See API 677 Appendix G—Spiral Bevel Gear-Tooth Contact Arrangement Requirements for inspection, G.5 Tooth Contact for Bevel Gears.

Gear Rotors need to be balanced. If specified, residual unbalance check has to be performed. See API 677, Appendix H—Residual Unbalance Worksheets.

The SI may be required to observe the internal inspection after testing and should be familiar with these inspection activities.

14.5 Testing of Gears Increasers and Reducers

When required by the Purchaser, Run testing of the Gears may be performed by S/V and witnessed by the SI. In those instances, the SI should be completely familiar with the equipment, the purchase requirements and the Run Test procedure that the S/V intends to follow during testing.

Following are the pretest requirements as defined in API 677.

- Mechanical run testing shall be conducted by operating at the maximum continuous speed for not less than 1 hour after bearing temperature and lube oil temperatures have stabilized for 3 consecutive reading taken 5 minutes apart.
- The contract bearings shall be used in the machine for the mechanical run test.
- All oil flows, pressures, viscosities and temperatures shall be within the range of operating values recommended in the S/V operating manual.
- All joints shall be checked for tightness and any leaks corrected.
- All warning, protective and control devices used during the test shall be checked and adjusted as required.
- Testing with contract coupling or couplings is preferred.
- Mechanical run test shall be made with the job lube system, if purchased with unit.
- Following are the minimum requirements as defined in API 677 for run testing.
- During run test, the mechanical operation of all equipment being tested shall be within the defined limits as specified in the purchase agreement.
- Unfiltered vibration shall be recorded and not exceed the limits as defined in API 677 throughout the testing speed range.
- Vibration devices shall have been calibrated and operating within designed frequency range.
- Vibration probes, oscillation-demodulators shall meet the accuracy requirements of API 670.
S/V shall keep a detailed log of the final tests, making entries at 15 minute intervals for the duration of the test. Each entry shall record the following:

- Oil temperature and inlet pressures.
- Outlet oil temperature, when available.
- Vibration amplitude, unfiltered and filtered 1 time for operating speed of each rotor.
- Bearing temperatures.

The SI should confirm that the S/V correctly documents the conditions of the test and confirms that all readings were correctly recorded with devices that are within their calibration period and properly documented.

After run testing is complete, the tooth mesh shall be inspected for surface damage and proper contact pattern.

When spare gear elements are orders to permit concurrent manufacture, each spare element shall also be given mechanical run tests in accordance with the requirements of API 677.

Final acceptance of the Run Test is the responsibility of the Purchaser and not the SI.

14.6 Final Inspection and Shipment

Final inspection at the gear manufacturer facility should be performed in accordance with the purchase order, gear data sheet, general arrangement drawings & relevant documents.

Painting, tagging, final marking and cleanliness should also be checked per purchase order and specifications.

15.0 General Purpose Turbines

15.1 General

Single Stage Turbines

Picture 13: Single Stage Steam Turbine

Governing specification for Steam Turbines used in the Oil and Gas industry is API Std 611. See Appendix G of API 611 for corresponding international standards. The secondary and supplemental specification for Steam Turbines is NEMA SM23.
There are several reasons to use General Purpose Steam turbines as drivers for pumps. Depending on the reason for using the steam turbine as a driver, a steam turbine can be used on a main or spare pump.

Steam Turbine S/V should provide the following documents (where applicable). These documents also have to be used during the final inspection:

- General Arrangement, completed with all connections and nozzle loads.
- Steam Turbine Data Sheet.
- Steam Turbine Performance Characteristic Curve.
- Instrumentation and piping diagram.
- Condenser and Ejector General Arrangement.
- Turbine and T&T valve cross sectional drawing.
- Manual and Mechanical Trip Linkage.
- Gauge Board Assembly.
- Electronic Governor operation and installation instruction.
- T&T Valve General Arrangement if supplied separately.

Each Steam turbine has an emergency trip mechanism to protect it from over speeding. A pin or a ball is held in place by a spring that has a manual regulator to set up the tension. When shaft rotates with an RPM above the setting, pin or ball come out from the holding cavity in the shaft and push the level to trip the Steam Turbine.

### 15.2 Design and Construction Standards

Steam turbines may be classified by several different design options:

- By exhaust pressure - Back pressure when exhaust pressure is higher than atmospheric pressure, or Atmospheric when exhaust pressure is slightly higher than atmospheric.
- By casing design - Vertically split casing or horizontally split casing.
Steam turbines covered in this guide should comply with API 611. Major parts of steam turbines are Pressure Casing, Rotor, Bearing Housings, Governor, Speed Control mechanism, Seals or packing, over speed trip mechanism, and Condensate control system.

15.3 Materials of Construction

Requirements for Material of Construction for Steam Turbines are described in API 611, Section 4.11. Generally, minimum requirements for material of construction is a manufacturer’s standard, however purchaser can also specify the material for each major part on a Steam Turbine data sheet. For piping material used for steam turbine steam piping, cooling water piping and lube oil piping see API 611, Table 3.

Turbine Casing

Casing of steam turbines consists of two parts, high pressure casing and lower pressure exhaust casing. Both parts are made out of casting and the most commonly used material is carbon steel ASTM A216 WCB. Casing is the subject to testing during the manufacturing process, from a foundry to a machining and hydro-test. See API 611, Section 6.2.2 for a detailed description of all NDE and other required inspections.

Rotating Elements

See API 611, Section 4.6 for the requirements for shafts and blading. Most common material for shafts is steel carbon steel alloy 4340, for Blade Wheel - 4140 and 403SS for Blades.

Seals and Packing

Outer glands should be sealed at the shaft by a carbon ring, a replaceable labyrinth packing, a combination of both, or by non-contacting end face mechanical seals.
Bearing Housings and Bearings

Steam Turbine Bearings and bearing housings are cast parts usually made out of carbon steel. Cast Iron bearing housings are not that common. Depending on the bearing, the bearing housings can be axial split when a hydrodynamic sleeve bearing is selected, or for an anti-friction ball bearing, the bearing housings are radially split.

Condenser

For some applications, a purchaser may order condenser and ejector as parts of a package with the Steam Turbine. Stainless Steel units are most common. Condensers are essentially heat exchangers and have to follow all the requirements for design and inspection of the heat exchangers.

![Picture 15. Condenser](image)

A Steam Turbine Gland vacuum system with Ejector mounted on the top of the condenser is shown in a picture below is shown.

![Picture 16. Steam Turbine Gland Vacuum system](image)
15.4 **Internal Component Inspections**

See API 611, Section 6 for Inspection and Testing and APPENDIX F—Inspector’s Checklist. Turbine S/V should provide a Quality assurance plan listing all the requirements for Inspection and testing. Steam Turbine components’ inspection includes the following:

1. Pressure casing, Blade Wheel, blading, piping welds, and shaft NDEs and visual inspection.
2. Material certifications and PMI review.
3. Rotor balancing and determination of residual unbalance.
4. Hydro-Test of Turbine Casing.
5. Cleanness Inspection of assembled Steam Turbine, including bearing housings.
6. Auxiliary equipment inspection (Condensers, Ejectors).

The SI should be familiar with the referenced code and ensure that the S/V has completed these internal component inspections by witness or reviewing S/V documentation ensuring that these inspections have been completed.

15.5 **Testing of Steam Turbine**

Steam Turbines should have a Mechanical Run test per API 611, Section 6.3.3. Prior to the Mechanical Run Test, the SI should confirm that the Test Procedure is properly documented and should be submitted for review by the Purchaser.

During the mechanical run test, if requested as part of the purchase agreement, the S/V should demonstrate the following functionality and/or perform the following:

- Selected running speed is controlled by the Governor and the Turbine holds the speed at a selected (rated) RPM. Turbine is tripped when the running speed exceed the maximum (trip) RPM.
- Hand level trips the Steam Turbine as per API 611, Section 5.4.2.8 with maximum inlet steam flow and pressure. The personnel running the test should reset the Manual Trip back to its operating position under maximum inlet steam pressure.
- If the Turbine has Hydraulic Actuators and minimum oil pressure switch or transmitter, turbine will trip on low, low oil pressure level.
- Check Relieve and Sentinel Warning Valves operation.
- Job vibration and temperature instruments should be used during the Mechanical Run test.

The SI should confirm that the S/V performed the Mechanical Run test in strict accordance with the procedure and that the test results were correctly detailed in the final run test report. The acceptance of the test rests with the Purchaser and not the SI.

15.6 **Final Inspection**

The following documents are typically required for the Steam Turbine Final inspection:

- API 611 data sheet
- P&ID
- Bill of materials
- Instruments list
- ISA data sheets for all instruments and orifices
- General Arrangement
- Packing List
- Shipment and preservation procedure

Typical Final Inspection points:
- SI should verify that all dimensions are as shown on the Steam Turbine GA
- SI should check that all flanged/screwed customer connections are as shown on General Arrangements drawings.
- SI should check flanges’ sizes, face type, rating and protection for shipping. All NPT connections need to be plugged for the shipment.
- SI should verify Tagging of equipment and instruments per drawings.
- Verify that all testing and final documentation is correct.

16.0 Lube Oil Systems

16.1 General

Lube Oil Systems for pumps and their drivers should be designed per API 614. API 614 has 4 chapters:
- Part 1: General requirements.
- Part 2: Special-purpose oil systems.
- Part 3: General-purpose oil systems.
- Part 4: Self-acting gas seal support systems.

Picture 17. Mounted Lube Oil System
16.2 Design and Construction Standards

Lube Oil Systems (LOS) have two basic configurations:

− when LOS is mounted on the same baseplate as a pump and a driver
− when LOS is a separate skid mounted next to the main Pump/Driver train.

Each LOS consists of: Lube Oil Tank, Lube Oil Pump(s), Oil Cooler(s), Filters, connecting piping, pressure controlling valves (PCV), pressure safety valves (PSV), temperature control valve (TCV), pressure, temperature and oil level measurement instruments and indicators, gauge panel, terminal boxes and mounting baseplate. Client specifies the equipment scope of supply on the API 614 data sheet. Requirements for LOS design, functionality and scope of supply are covered in API 614 and API 610, Section 9.2.6 and Annex B.

16.3 Materials of Construction

See API 614, Table 3 - Minimum requirements for piping materials — Cooling water.

See API 614, Table 4 - Minimum requirements for piping materials — Lubricating, control and seal oil.
Lube Oil Tank

Lube Oil tank stores the lubricating oil and is completed with Lever Gauge, Level Switch or Transmitter, Separation Screen between “clean” and “return” oil sections, Oil heater with thermostat, Temperature gauge, and Temperature Transmitter. For requirements for Lube Oil tanks see API 614, Part 3. 4.4.

Typical Inspection Points for Lube Oil Systems

Following are the recommended inspection points that the SI should be familiar with during inspection of Lube Oil Systems. Note that the SI should follow the ITP for actual Inspection Points if documented:

− SI should check the Actual Oil tank with LOS Data sheet for all options.
− SI should open the Service access and make sure that there is a separating screen with its bottom sloping away from the pump suction.
− SI should check if the minimum and maximum oil levels are shown on the level gauge indicator.
− SI should verify that all return pipes enter reservoir above the maximum operating level.
− SI should verify that the Oil heater hot section is located at least 2” below minimum oil level.
− SI should Check for grounding clips.

Lube Oil Pumps

Depending on the LOS class there may be one or two pumps.

For API 610 pumps LOS should be class 2 or 3 only, and should have two Lube Oil Pumps. Majority of Pumps have a Lube Oil System Class 2 with a Main Lube Oil pump driven by a shaft of the Main Pump or Gear (if provided) and an Auxiliary Lube Oil Pump is driven by an electrical motor or steam turbine. See API 614, Section 4.5 for the requirements for pumps and pump drivers.

Typical Inspection Points:

− SI should verify that the motor name plate is in compliance with area classification.
− SI should verify the setting of pump oil pressure relive valves.
− SI should make sure that pump casing is made of steel if the pump is located outside of oil tank. Pump casing may be Cast Iron when pump is installed inside of the oil tank.

Coolers

See API 614, Section 3. 4.6 and LOS data sheet for the coolers requirements. Coolers should be a bundle removable type. SI should check whether the code compliance and stamping is required.

Typical Inspection Points:

− SI should compare the Cooler with the LOS Data sheet to verify all options.
SI should verify the name plate and stamping if required.
- SI should verify that bundle can be removed without obstructions.
- In case of dual coolers design, SI should verify that the switch valve is easily accessible and operates without obstructions.

**Mounting baseplate**

The Lube Oil system may be designed as a separate console or to be integral with the baseplate of the equipment it serves. If LOS is installed as a separate console, a weld fabricated baseplate should be supplied. See API 614, Section 3.4.3 for the requirements for baseplates.

Typical Inspection points:
- SI should verify that all welds are continuous.
- SI should verify that drainage from the baseplate is unobstructed by the installed equipment.
- SI should verify that each closed compartment of the baseplate has a grout hole and vent holes for grouting.
- SI should verify that a Leveling screw is provided next to the anchor bolt holes.

**Instrumentation and Electrical Systems**

See API 614, Section 3.6 for Instrumentation and Electrical Systems requirements. See Table 3 for minimum instruments required alarms and shutdowns.

Typical Inspection Points:
- SI should check the name plates to make sure that instruments match their description, power requirements, units of measurements, and areas classification.
- SI should verify that pressure and temperature indicator ranges are selected in a manner that the normal operating pressure is in the middle of their range.
- SI should verify that indication instruments are located in such positions that their dials easily accessible for reading.
- Actual Inspection Points are defined in the Inspection and Test Plan.

**16.4 Inspection and Testing of Lube Oil System**

Following are the typical tests performed on Lube Oil Systems. All tests should be conducted to a detailed and documented procedure or written practice. The SI’s responsibility is to confirm that the S/V performed the tests and documented them correctly.

**Hydro-test**

The hydrostatic test is to be performed in accordance with API 614, Section 1.7.3.2. The LOS S/V should provide a test procedure for the piping hydrotest. SI should check the hydro test reports for coolers and filters since they are supplied by sub-vendors and normally are a standard equipment. Piping should be tested while fully assembled. Alternatively, and by prior agreement, the piping spools may be tested individually instead of during the assembled hydrotest.
Performance Test

− See API 614, Section 3, 7.3.3 for Operation and Performance Test requirements.

Typical Inspection Points:

− SI should verify that oil-pressure limiting valves (PLV) operate smoothly, without chattering and without causing a drop in a supply pressure to the equipment. Pressure-limiting valve piping should be sized for the full flow of each pump; the valves should not chatter and not produce excessive noise.

− SI should verify that all instruments show reading in required units.

− SI should verify that calibrated shop flowmeters are used for oil flow control.

− A Run Test should be conducted while each of the pumps, main and stand-by are running. A shop-calibrated pump with the identical flow/pressure characteristics as the Main Lube Oil Pump should be used instead of the main Lube Oil Pump.

− A Run Test also should be conducted when both pumps are running at the same time. SI should confirm that the system supplies the rated flow regardless of which pump is operated and if both pumps operate at the same time.

− SI should confirm that the S/V conduct a system cleanliness test as required per API 614, Section 3, 7.3.3.8.

− After all run tests are completed, filter elements should be replaced with the new ones.

16.5 Final Inspection and Shipment

The following documents supplied by the LOS manufacturer are typically required for final inspection:

− API 614 LOS data sheet
− P&ID
− Bill of material
− Instrument list
− ISA data sheets for all instruments and orifices
− LOS General Arrangement
− Packing List
− Shipment and preservation procedure

Final inspection of an LOS should confirm that:

− Oil filters were replaced after the run test.
− All open flanges have face protecting covering with gaskets.
− All dimensions were verified per GA.
− All connections have tags.
− Piping arrangement allows easy access to all control and safety valves.
- Handles of valves have enough clearance to allow a safe opening/closing without risk of jamming the hand.
- There is no overhung of any equipment or piping over the baseplate perimeter.
- All loose items should have tags and should be listed in a packing list. Final packing should be done per an approved preservation and packing procedure.

17.0 Reciprocating Compressors

17.1 General

The reciprocating compressors (known also as “piston-type” compressors) are the best compressors for any service with a relatively low capacity and a relatively high differential pressure. They can be single-or multi-head compressors driven by a single driver.

Scope of supply typically includes Driver, Suction and Discharge Pulsation Suppressors (bottles), Flywheel, Cylinder and Packing Lubricator Systems, Frame Lubrication Systems, Cylinder/Packing Jacket Coolant System, Instrumentation, Control system and Auxiliary piping and manifolds.

Equipment can be designed for console mounting or be baseplate-mounted depending on the scope of supply and the size of the equipment. Compressors should comply with requirements of API 618.

Picture 19. Six throw reciprocating compressor

17.2 Design and Construction Standards

Reciprocating Compressors should comply with the requirements of API 618 - Reciprocating Compressors for Petroleum, Chemical, and Gas Industry Services.

All instruments, piping, coolers, filters, and electrical equipment should comply with the requirements of API 614, part 1.

Lube Oil System also should comply with API 614, Part 1 and 3. In some cases LOS should comply with API 614 Part 2 instead of part 3.
Electrical Motors should comply with NEMA MG1, IEEE841 or API 541 for North America or equivalent standards for IEC specification. Suction and Discharge dampeners (bottles), Heat Exchangers and Filters should comply with ASME Section VIII. Welding should comply with ASME Section IX.

Gear units should be either special purpose units or general purpose units conforming to API 677, as specified. Machine Monitoring System (MMS) (instrumentation) should comply with API 670.

17.3 Materials of Construction

Reciprocating compressors are used mostly with process gases. As stated in API 618, Section 6.15.1.1 “Unless otherwise specified by the purchaser, the materials of construction shall be selected by the manufacturer based on the operating and site environmental conditions specified”. API 618, Annex H lists general material classes for compressors. Special attention should be paid to materials if compressor parts will be exposed to H2S. Components are expected to comply with NACE MR0175 and should include, as a minimum:

- All pressure-containing cylinder parts (such as the cylinder, heads, clearance pockets, valve covers) and all fasteners directly associated with those parts.
- All components within the cylinder (such as piston, piston rod, valves, unloaders and fasteners).
- Components within the outboard distance piece (such as packing box, packing, and fasteners).

There is a pressure limitation for pressure-containing parts such as cylinders. See API 618, Table 3 for Maximum Gauge Pressures for Cylinder Materials. See API 618, Section 6.15 for material selection, quality requirements, welding, NDE and repair of pressure containing parts and piping. API 618 provides a compressor data sheet which contains the information about the material selection and Inspection requirements.

Supplier has to submit material certificates for all major compressor components as specified on API 618 data sheet. Below are some special requirements for the material of some parts as required per API 618:

- **Crankshafts** - For compressors above 150 kW (200 hp), crankshafts should be forged in one piece and should be heat-treated and machined on all working surfaces and fits.
- **Piston Rods** - all piston rods, regardless of base material, should be coated with a wear resistant material (see API 618, Section 6.10.4.1 for clarification and exceptions).
- **Connecting Rods** - For compressors above 150 kW (200 hp), connecting rods should be made of forged steel with removable caps. For compressors equal to or less than 150 kW (200 hp), other materials, such as ductile iron, steel plate, or cast steel connecting rods are acceptable.
- **Crossheads** - For compressors above 150 kW (200 hp), crossheads should be made of steel. For compressors equal to or less than 150 kW (200 hp), ductile iron is acceptable for crossheads.
17.4 **Internal Component Inspections**

See Compressor Data Sheet, IRF and S/V submitted quality plan (ITP) for the inspection requirements.

API 618, Section 8 provides information on documents requirements, notifications and list of codes that should be used for Material inspection, Certification and NDE. Refer to API 618, Annex K for Inspector’s check list. Below is the list of Main components that are subject to NDE, hydro- and leak tests as specified:

Crankcase Group:
- Crankcase
- Crankshaft
- Connecting Rod
- Bearing
- Crosshead Pins
- Crosshead
- Crosshead Extensions

Cylinder Group:
- Cylinder
- Cylinder Head
- Piston
- Piston Rod
- Distance Piece
- Suction Cylinder Valves
- Discharge Cylinder Valves

Accessory Equipment and Components include:
- Drivers
- Intercoolers, Aftercoolers, and Separators
- Suction and Discharge dampeners (bottles)
- Lube Oil System
- Instrumentation and Control System
- Process Piping
- Cooling Water piping and equipment
- Lube Oil Piping
- Baseplate

The SI should be familiar with the ITP and drawings to observed inspections made by the S/V during assembly of the compressor. It should be noted that the S/V is responsible for the quality and inspections of the work, the S/V should focus on verifying that the S/V inspections are done properly and results are documented correctly.
17.5 Testing of Reciprocating Compressors and Associated Equipment

S/V should submit a Test Procedure that is in full compliance with API 618, Section 8.3 Testing. Test procedure should be reviewed and approved by the purchaser. The following is the list of tests usually specified by purchaser:

- PMI test on major pressure containing parts and parts that are in contact with process gas.
- Visual inspection of major castings, weld fabrications and piping.
- Hydrostatic test for pressure containing part and piping.
- Leakage test for cylinders, Suction and Discharge valves.
- Mechanical run test of compressor and associated equipment. Driver trip speed should be as per API 618 table 2.
- The power required by the compressor at the normal operating point should not exceed the stated power by more than 3%. (API 618, Section 6.1.18).

Control System Factory Acceptance Test

Purpose of a mechanical run test is to verify the assembly integrity as being free from rubs, excessive vibration and noise, lubricant leaks and overheating. The SI should confirm that the run test was performed in accordance with the S/V’s written procedure and that results of the test are correctly documented.

17.6 Final Inspection and Preparation for Shipment

Purpose of a final inspection is to verify that:

- Dimensions are as shown on Compressor GA.
- Compliance with standards.
- Instruments and connection tagging.
- Piping compliance to P&I.D.
- Proper piped support.
- Electrical and instrumentation wiring is in compliance with the drawings.
- Junction/Terminal boxes are mounted and correct per drawings.
- Name Plates contain correct information and are in compliance with API 618, Section 6.16.

The SI should follow these typical Inspection points unless the Inspection and test plan is more specific.

API 618, Section 8.4 specifies procedure and requirements that should be adhered to in preparation for shipment. All documents submitted by the S/V should be reviewed and approved by the purchaser. Compliance with preservation procedure should be verified. Packing list should clearly list the shipped items’ tag numbers, names, quantity and box numbers where they are located. Parts that don’t have separate tag numbers should have references to assembly or GA drawings such as balloon numbers, part numbers, etc.
18.0 Rotary-Type Compressors

18.1 General

A rotary screw compressor is a type of gas compressor which uses a rotary type positive displacement mechanism. Rotary screw compressors combine the advantages of positive displacement compressors and centrifugal/axial flow compressors and are used in a wide range of applications. Another advantage of the rotary screw (positive displacement) compressor is that this type of compressor cannot surge and, therefore, any complex control schemes and unloading by-passes are avoided.

There are two different types of Rotary Screw Compressors, oil flooded compressors and oil-free compressors. The screw compressor is characterized by high volumetric and good adiabatic efficiencies, stepless capacity modulation with sliding valve, wide compression range, and valveless, pulsation-free operation. Compressors can be single-stage or multi-stage with two or more sets of screws. Rotary Screw Compressors should comply with API 619.

![Oil-Free Rotary Compressor]

**Picture 20. Oil-free Rotary Compressor**
Multi Stage Oil Flooded compressor

It is easy to identify the difference between Oil-Free and Flooded Rotary compressors. Oil-Free compressors have timing gears that drive the idle rotor. There is no mechanical contact between rotors. Flooded compressors don’t have timing gears and a coupled screw drives the idle screw by mechanical contact with flooding oil providing cooling, lubrication and seal between screws. Flooded Type Screw Compressors have fluid injection and fluid separation systems with cooling and storage tank.

18.2 Design and Construction Standards

Rotary Screw Compressors should comply with the requirements of API 619. All instruments, piping, coolers, filters, and electrical equipment should comply with the requirements of API 614, part 1.

Lube Oil System also should comply with API 614, Part 1 and 3. In some cases LOS should comply with API 614 Part 2 instead of part 3.

Electrical Motors should comply with NEMA MG1, IEEE 841 or API 541 for North America or equivalent standards for IEC specification. Suction and Discharge dampeners (bottles).

Heat Exchangers and Filters should comply with ASME Section VIII. Welding should comply with ASME Section IX.

Gear units should be either special purpose units conforming to ISO 13691 or API 613, or general purpose units conforming to API 677, as specified.

Machine Monitoring System (MMS) (instrumentation) should comply with API 670.

18.3 Materials of Construction

General requirements for material selections and NDE tests are specified in API 619, Section 5.11. API 619 Annex F, Table F1 serves as a guide for Rotary Compressors material selection. Special attention should be paid to the materials if compressor parts will be exposed to H2S.
See API 619, Section 5.11 for material selection, quality requirements, welding, NDE and repair of pressure containing parts and piping. API 619 Compressor data sheet contains the information about material selection and Inspection requirements. S/V typically submits material certificates for all major compressor components as specified on the API 619 data sheet. Below are some special requirements for material of some parts as per API 619:

− Shafts should be forged steel unless otherwise approved by the purchaser.
− Timing gears should be made of forged steel.

18.4 Internal Component Inspections

See Compressor Data Sheet, IRF and S/V submitted quality plan (ITP) for the inspection requirements. API 619, Section 7 provides information on documents requirements, notifications and list of codes that should be used for Material inspection, Certification and NDE. Refer to API 619, Annex H for Inspector’s check list. Below is the list of Main components that are subject to tests, NDE, visual inspection, hydro-and leak tests as specified:

The SI should be familiar with these internal inspection points so they are capable of observing during construction of the equipment.

**Compressor**

− Pressure Containing Parts
− Rotary Screws

**Accessory Equipment and Components**

− Suction Filter
− Oil Separators and oil coolers
− Oil Filters
− Interstage and after coolers
− Piping (oil, cooling water, gas)

18.5 Testing of Rotary Screw Compressors and Associated Equipment

S/V maybe required to should submit a Test Procedure that is in full compliance with API 619, Section 7.3 Testing. Test procedure should be reviewed and approved by the purchaser.

Following is the list of tests usually specified by purchaser:

− PMI test on major pressure containing parts and parts that are in contact with process gas.
− Visual inspection of major castings, weld fabrications and piping.
− Hydrostatic test for pressure containing part and piping.
− Dynamic balance test.
− Leakage test.
Mechanical run test of compressor and associated equipment.

- Driver trip speed should conform to API 619, Table 2.
- The power at the certified point should not exceed 104% of the quoted value with no negative tolerance on required capacity. (API 619, Section 5.1.15).

Control System Factory Acceptance Test

Purpose of the mechanical run test is to verify the assembly integrity as being free from rubs, excessive vibration and noise, lubricant leaks and overheating. The SI should will typically observe the run test in accordance with the S/V test procedure or written practice and observe that the test was completed in strict accordance with the procedure. The SI should verify that the results of the test are correctly reported.

18.6 Final Inspection and Preparation for Shipment

All S/V documents are typically submitted according to SDL, reviewed and approved by purchaser.

Purpose of the final inspection is to verify:

- Dimensions are as shown on Compressor GA.
- Compliance with standards.
- Instruments and connection tagging.
- Piping compliance to P&ID.
- Proper piping support.
- Electrical and instrumentation wiring is installed per the approved drawings and areas classifications.
- Junction/Terminal boxes are correctly mounted per the approved drawings and areas classification.
- Name plates contain correct information and are in compliance with API 619, Section 5.12.

API 619 Section 7.4 specifies procedures and requirements that should be adhered to in preparation for shipment. All documents submitted by S/V should be reviewed and approved by purchaser.

19.0 Axial/Centrifugal Compressors

19.1 General

Axial Compressor and Centrifugal Compressors are covered in API 617. Although they are grouped in the same API code and have mechanical features that look alike, they compress gas by using different physics. Axial compressors use principle of airfoil, same principle which is used in wing design for airplanes.
Rotor blades drive the gas in axial direction through stator blades where kinetic energy converted in static pressure. Adding diffuser design, which is reduction in the passage area, to rotor blades increase compressing effect.

Principle of operation of Axial Compressor

Centrifugal Compressors generate pressure increase in gas using the same principle as Centrifugal Pumps. Impeller turn the flow from axial direction to centrifugal increasing gas speed in the process. Then gas enters in diffuser area where part of velocity head (energy) converted to static head (energy). Higher gas pressure leads to gas compression. Then gas enters in the suction eye of next stage impeller and process repeats until final stage.

Multi-Stage Centrifugal Compressor

Axial Compressor and Centrifugal Compressors are widely used for process gases in Refining, Chemical and Gas Industries. They use wide variety of material of constructions. Large units are driven by Steam and Gas Turbines. Their power can be in the range of tens of thousands of HP. Major Components of compressors are Pressure Casing, Rotor, Stationary Blades assembly or Diffusers, Seals, Bearing housings (oil lubricated or magnetic bearings). Major components of Compressor trains are Drivers, Control System, Lube Oil Systems, Gas Seal Modules, Cooling equipment (heat exchangers), Interstage Injection Equipment (oil and water), Seal Filters.
19.2 Design and Construction Standards

As stated in 19.1, API 617 for Axial and Centrifugal compressors specifies minimum requirements and gives recommendations for axial compressors, single shaft and integrally geared process centrifugal compressors, and expander-compressors for special purpose applications that handle gas or process air in the petroleum, chemical, and gas industries. Following are parts of API 617:

Part 1 - General Requirements

This part describes basic principles & philosophy of compressors operation, responsibilities of compressor manufacturer and purchaser, major industry standards that shall be applied in compressor design, manufacturing and test, auxiliary equipment design. Part 1 also specifies requirements for material selection, certification, NDE, PMI, selection material for Low temperature Service, casting, forging, welding, inspection, testing and preparation for shipment, requirement for technical documentation. Part 1 has Annexes that provide detailed information on design and requirements for Determination of Residual Unbalance, Typical Shaft End Seals, Lateral and A Torsional analysis Reports, Magnetic Bearings, Dry Gas Seal Testing at Manufacturer's Shop, Guidelines for Anti-surge Systems, Full-load/Full-pressure/Full-speed Testing.

Part 2 - Nonintegrially Geared Centrifugal and Axial Compressors

This type of compressors are conventional single shaft machines that have all rotating parts mounted on single shaft.

Part 3 - Integrally Geared Centrifugal Compressors

This type of compressors have multiple shafts that have one impeller on each of them that are running at certain speed and where shafts are connected by means of gear pairs with first stage driven by a driver (electrical motor or turbine).

Part 4 - Expander-Compressors

Expander-compressors are two-ended rotating machines that use high pressure gas at Expander side to generate rotating torque on common shaft and drive Compressor on the other end. These machines mostly used in cooling cycles to save great amount of energy by using chilling of the gas during expansion in Expanders to drive Compressor on the other side of the common shaft.

19.3 Materials of Construction

General requirements for material of constructions described in Part 1, 4.5 and in same chapters in each following Parts of API 617. Purchaser responsibilities to specify any corrosive agents (including trace quantities) present in the motive and process fluids in the site environment, including constituents that may cause corrosion. The purchaser can specify additional optional tests and inspections—especially for materials used for critical components or in critical services.

Selection of materials is a joint effort between manufacturer and supplier. Based on provided information on compressors’ data sheets, manufacturer shall propose material of construction for each major component of the compressor and submit for purchaser review and approval during proposal stage. Special consideration shall be given to materials for Low temperature service and service where hydrogen sulfide has been identified in the gas composition.
Unless otherwise specified, if hydrogen sulfide has been identified in the gas composition, materials exposed to that gas shall be selected in accordance with the requirements of NACE MR 0103-2007 and where applicable, the referenced NACE SP 0472-2008.

All carbon and low alloy steel pressure-containing components for low temperature service including nozzles, flanges, and weldments shall be impact tested in accordance with the requirements of Section VIII, Division 1, Sections UCS-65 through 68 of the ASME Code or equivalent standard. High alloy steels shall be tested in accordance with Section VIII, Division 1, Section UHA-51 of the ASME Code or equivalent standard.

All repairs that are not covered by ASTM specifications shall be subject to the purchaser’s approval. All repairs that are not covered by ASTM specifications shall be subject to the purchaser’s approval.

Paragraphs 4.6.2 Casing Repairs and Inspections and 4.6.3 Material Inspection of Pressure-containing Parts describe suppliers’ responsibility for submitting repair procedures to obtain purchaser approval weld procedures and inspection of weld repair of pressure containing parts. See Table 3 for ASME Materials Inspection Standards and Table 4 for Maximum Severity of Defects in Castings.

### 19.4 Component Inspection

The SI should be able to identify major components & understand requirements for their inspections, NDE, balancing, PMI and Material Certification, level of test and requirements. Following is a typical table that list major components that normally listed in ITP and sample of level of inspection they normally see:

- explanation of abbreviation for extent of inspection.
- “Typical Inspection and Test Plan for Compressor”.

<table>
<thead>
<tr>
<th>Part Name</th>
<th>Inspection and Certification</th>
<th>Level of Involvement</th>
<th>Area of Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cast pressure casing, Forged pressure casing, fabricated pressure casing, internal cast and fabricated parts, bearing housings</td>
<td>Visual &amp; Dimensional</td>
<td>RI/R</td>
<td>SI visit supplier/sub supplier to visually inspect internal and external surfaces as cast. Major dimensions checking, wall thickness verification.</td>
</tr>
<tr>
<td></td>
<td>NDE</td>
<td>RI / RV /R</td>
<td>NDE of surfaces as cast, weld repairs, weld attachments, machined surfaces. Checking technician level of qualification, follow of approved procedure, use of proper equipment and test materials.</td>
</tr>
<tr>
<td></td>
<td>PMI</td>
<td>RI / RV /R</td>
<td>Checking technician level of qualification, follow of approved procedure, use of proper equipment and test materials.</td>
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<td>Hardness Test</td>
<td>RI / RV /R</td>
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</tr>
<tr>
<td>Part Name</td>
<td>Inspection and Certification</td>
<td>Level of Involvement</td>
<td>Area of Verification</td>
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</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>approved procedure, use of proper equipment and test materials.</td>
</tr>
<tr>
<td>Material Certificate</td>
<td>RV / R</td>
<td></td>
<td>Verify that parts have proper tagging to trace them to Material Certificates.</td>
</tr>
<tr>
<td>Casing Bolt and Nut</td>
<td>Visual &amp; Dimensional</td>
<td>RI/R</td>
<td>Major dimensions checking</td>
</tr>
<tr>
<td>NDE</td>
<td>RI / RV /R</td>
<td></td>
<td>NDE of surfaces as cast, weld repairs, weld attachments, machined surfaces. Checking technician level of qualification, follow of approved procedure, use of proper equipment and test materials.</td>
</tr>
<tr>
<td>PMI</td>
<td>RI / RV /R</td>
<td></td>
<td>Checking technician level of qualification, follow of approved procedure, use of proper equipment and test materials.</td>
</tr>
<tr>
<td>Material Certificate</td>
<td>RV / R</td>
<td></td>
<td>Verify that parts have proper tagging to trace them to Material Certificates.</td>
</tr>
<tr>
<td>Casing Assembly</td>
<td>Pressure Test / Hydrostatic Test</td>
<td>W / R</td>
<td>Verify test set up per approved procedure, pressure gauges' calibration records, chlorine content in water. Check gaskets before and after test; check bolts torque sequence and value.</td>
</tr>
<tr>
<td>Shaft, Impellers, Spacers, Rotor Assembly</td>
<td>Visual &amp; Dimensional</td>
<td>RI/R</td>
<td>Major dimensions checking</td>
</tr>
<tr>
<td>NDE</td>
<td>RI / RV /R</td>
<td></td>
<td>NDE of surfaces as cast, weld repairs, weld attachments, machined surfaces. Checking technician level of qualification, follow of approved procedure, use of proper equipment and test materials.</td>
</tr>
<tr>
<td>PMI</td>
<td>RI / RV /R</td>
<td></td>
<td>Checking technician level of qualification, follow of approved procedure, use of proper equipment and test materials.</td>
</tr>
<tr>
<td>Material Certificate</td>
<td>RV / R</td>
<td></td>
<td>Verify that parts have proper tagging to trace them to Material Certificates.</td>
</tr>
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<td>Balancing Test</td>
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<td>Component and assembly balancing. Follow procedure,</td>
</tr>
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<td>Low Speed Balance</td>
<td>W/RV/R</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Part Name</td>
<td>Inspection and Certification</td>
<td>Level of Involvement</td>
<td>Area of Verification</td>
</tr>
<tr>
<td>-------------------</td>
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<td>--------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>verify technician qualification</td>
</tr>
<tr>
<td></td>
<td>Total Combined Electrical &amp; Mechanical Runout</td>
<td>W/RV/R</td>
<td>Follow procedure, verify technician qualification, check instrument calibration</td>
</tr>
<tr>
<td></td>
<td>Balancing Test High Speed Balance</td>
<td>W/RV/R</td>
<td>Component and assembly balancing. Follow procedure, verify technician qualification</td>
</tr>
<tr>
<td>Compressor assembly</td>
<td>Assembly Inspection Clearance</td>
<td>RI</td>
<td>During the random visits observe measurements and review records of measurements of clearances done by shop personal. Compare them to design clearances.</td>
</tr>
<tr>
<td></td>
<td>Performance test, Mechanical Running Test</td>
<td>W</td>
<td>See next paragraph for detailed description of inspector involvement</td>
</tr>
<tr>
<td></td>
<td>Coupling Fit Check (Match Mark Check)</td>
<td>W/RV</td>
<td>See next paragraph for detailed description of inspector involvement</td>
</tr>
<tr>
<td></td>
<td>Gas Leakage Test</td>
<td>W</td>
<td>See next paragraph for detailed description of inspector involvement</td>
</tr>
</tbody>
</table>

19.5 **Testing of Axial/Centrifugal Compressors**

Testing of Axial and Centrifugal compressors consist of following tests:

- Performance Test.
- Mechanical Run test including vibration data collection, sound level test, oil temperature monitoring.
- Impeller Overspeed Test.
- Control panel Factory Acceptance test (FAT).
- Coupling Fit test.
- Gas leakage test.
- After test disassembly inspection.
- Unbalanced Rotor Response Verification Test per API617 7th Chapter 1 para.2.6.3.
Performance Test

Purpose of performance test is to verify guaranty performance of the compressor. See API 617, Parts 2 and 3, 6.3 for detailed description of performance test. API 617 based Performance Test requirements on ASME PTC 10-1997 Performance Test Code on Compressors and Exhausters. Supplier cannot typically use the exact specified gas. Most often it is a gas blend of local pipeline gas with commercially available gases such as propane, carbon dioxide and nitrogen. Vendor provides a comparison table between design condition and test condition at guarantee point. Following quantiles are subject to performance test verification:

(a). quantity of gas delivered
(b). pressure rise produced
(c). head
(d). shaft power required
(e). efficiency
(f). surge point
(g). choke point

Below is the sample performance curve of Centrifugal Compressor. One of the most important results of the performance test is confirming the surge points at the different compressor speeds.

Compressor performance data shall be compared to acceptance criteria during and after test. Results shall not vary from ASME PTC 10-1997 Table 3.1 for Type 1 test, Table 3.2 for Type 1 and Type 2 tests.
Mechanical Run Test

During the mechanical running test, the mechanical operation of all equipment being tested and the operation of the test instrumentation shall be satisfactory.

Seal flow data shall be taken during the compressor mechanical running test.

Lube-oil and seal-oil inlet pressures and temperatures shall be varied through the range specified in the compressor operating manual.

At the beginning of the test compressors the compressor is operated at slow speed about less than 1,000 rpm to check any abnormal conditions.

Then the compressor will be operated at speed increments of approximately 10% from zero to the maximum continuous speed and run at the maximum continuous speed until the bearing metal temperatures and shaft vibrations have stabilized.

The speed will be increased to the trip speed and the compressor will be run for a minimum of 15 minutes, when the operating data including vibration data will be measured and recorded.

The compressor will be operated at the maximum continuous speed for 4 hours. While the compressor is operating at the maximum continuous speed.

Impeller Overspeed Test

Overspeed test requirements described in API 617, 6.3.3. Each impeller shall be subjected to an overspeed test at not less than 115% of MCS for a minimum duration of 1 minute. Impeller dimensions identified by the manufacturer as critical (such as bore, eye seal, and outside diameter) shall be measured before and after each overspeed test.

Control Panel Factory Acceptance Test (FAT)

API 617 compressors supplied with control panels that house instruments that record compressor performance, PLC that control safe operation, HMI for visual presentation and control, power units, set of I/O terminals. Control panels shall undergo FAT where logic and operation of the all system components verified. Input/Output signals are simulated to achieve system respond. Depend on contract requirements, Control Panel may be or may be not used during compressor performance and mechanical run test. Part of FAT shall be wiring and panel layout check. All tagging shall match supplied documentation.

Coupling Fit Test

After the running tests, hydraulically mounted couplings shall be inspected by comparing hub/shaft match marks to ensure that the coupling hub has not moved on the shaft during the tests.

Gas Leakage Test

The assembled compressor (including end seals) shall be pressurized, with an inert gas to the maximum sealing pressure or the maximum seal design pressure, as agreed by the purchaser and the supplier; held at no less than this pressure for a minimum of 30 minutes, and subjected to a soap bubble test, or alternate method, to check for gas leaks.
Unbalanced Rotor Response Verification Test per API617 7th Chapter 1 para.2.6.3

If specified or when the first critical speed is less than 127% of Nmc, an unbalanced rotor response test shall be performed as part of the mechanical running test. Purpose of the test is to verify the analytical model. See API 617, Part 1, 4.8.3 for specific information on Unbalance Rotor response. Generally, results shall be as follow:

1). The actual critical speeds shall be within ±5% of the predicted critical speeds by analysis.
2). The actual peak amplitude shall not exceed the predicted values.

After Test Disassembly Inspection

After completion of the mechanical running test, bearings will be removed, inspected, and reassembled. After completion of the mechanical running test, seals will be removed, inspected, and reassembled without an overhaul of Dry Gas Seal assembly. The compressor shall be dismantled, inspected, and reassembled after satisfactory completion of the mechanical running test. The gas test shall be performed after the post-test inspection.

19.6 Final Inspection and Preparation for Shipment

All S/V documents are typically submitted according to SDL, reviewed and approved by purchaser.

Purpose of the final inspection is to verify:
- Dimensions are as shown on Compressor GA.
- Compliance with standards.
- Instruments and connection tagging.
- Piping compliance to P&ID.
- Proper piping support.
- Electrical and instrumentation wiring is installed per the approved drawings and areas classifications.
- Junction/Terminal boxes are correctly mounted per the approved drawings and areas classification.

19.6.1 Dimensional and Visual Inspection

Following is the list of documents that are typically required for final dimensional and visual inspection and actions required based on these documents:

- Data Sheets
- Compressor Train General Arrangement
- Process & Instrument Diagram (P&ID)
- Electrical and instrumentation wiring diagrams
- Auxiliary Equipment GA, P&ID and BOM (seal reservoir, LOS, Seal, Driver, Junction Boxes)
- Packing List
During visual inspection the following areas of concern should be addressed:

- Piping assembly should be accessible for maintenance, disassembly, and gasket replacement.
- Valve handles should have enough space for safe open-close action by an operator according to OSHA requirements to prevent hand jamming and injury.
- All equipment should be mounted using secured methods without them being shaky or unsecured.
- Workmanship of installation, welding and wiring should be without visible defects and within industry standards.
- There should be no overhung equipment or piping extending beyond perimeter of the baseplate except those shown on the approved General Arrangement.
- Painting and paint thickness should be inspected and verified.
- Quantity, condition, and packing for items shipped loose should be inspected and verified.

### Annex A

**Photos of various types of tools for use by the Source Inspector**

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Picture</th>
<th>Typical Usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flash Lights (Krypton)</td>
<td><img src="image" alt="Flash Light" /></td>
<td>Supplemental light source for visual inspection.</td>
</tr>
<tr>
<td>Tape Measures 5'</td>
<td><img src="image" alt="Tape Measure" /></td>
<td>Dimensional inspection</td>
</tr>
<tr>
<td>Bridge Cam Gages</td>
<td><img src="image" alt="Bridge Cam Gage" /></td>
<td>Multi-purpose welding inspection gage</td>
</tr>
<tr>
<td>Equipment</td>
<td>Picture</td>
<td>Typical Usage</td>
</tr>
<tr>
<td>---------------------------</td>
<td>---------</td>
<td>-------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Hi LO Gages</td>
<td><img src="image" alt="Hi LO Gages" /></td>
<td>Measures internal alignment for components to be welded.</td>
</tr>
<tr>
<td>Radiograph Viewer 4” x 17”</td>
<td><img src="image" alt="Radiograph Viewer" /></td>
<td>Light source for reviewing radiographic film</td>
</tr>
<tr>
<td>Radiograph Film Densitometer</td>
<td><img src="image" alt="Radiograph Film Densitometer" /></td>
<td>Tool designed to measure the degree or density of darkness of radiographic film.</td>
</tr>
<tr>
<td>Digital Calliper</td>
<td><img src="image" alt="Digital Calliper" /></td>
<td>Instrument used to measure distance between opposite sides of an object. Typically used for close tolerance dimensions on machined parts.</td>
</tr>
<tr>
<td>OD Micrometer</td>
<td><img src="image" alt="OD Micrometer" /></td>
<td>Instrument used to measure outside diameters/dimensions. Typically used for close tolerance dimensions on machined parts.</td>
</tr>
<tr>
<td>Pit gage</td>
<td><img src="image" alt="Pit gage" /></td>
<td>Measures the depth of weld undercut or other surface discontinuities.</td>
</tr>
<tr>
<td>Inspection Mirrors</td>
<td><img src="image" alt="Inspection Mirrors" /></td>
<td>Tool designed to support visual inspection in limited and/or obscured areas.</td>
</tr>
<tr>
<td>Equipment</td>
<td>Picture</td>
<td>Typical Usage</td>
</tr>
<tr>
<td>---------------------------------</td>
<td>---------</td>
<td>-------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Temperature Indicator</td>
<td><img src="image1" alt="Image" /></td>
<td>Used for reading temperatures by changing from solid to liquid at a specific temperature.</td>
</tr>
<tr>
<td>Laser Thermal Gun</td>
<td><img src="image2" alt="Image" /></td>
<td>Tool for measuring surface temperature.</td>
</tr>
<tr>
<td>Clamp on Amp Meter</td>
<td><img src="image3" alt="Image" /></td>
<td>Tool designed to measure electric current in amperage and voltage. May be used for checking welding machine settings.</td>
</tr>
<tr>
<td>Digital Surface Profile Gage</td>
<td><img src="image4" alt="Image" /></td>
<td>Tool designed to measure the surface roughness for material that is about to be coated.</td>
</tr>
<tr>
<td>Surface Profile Replica Tape</td>
<td><img src="image5" alt="Image" /></td>
<td>Tool designed to replicate surface profile and measure surface roughness.</td>
</tr>
<tr>
<td>Wet Gauge</td>
<td><img src="image6" alt="Image" /></td>
<td>Tool for measuring un-cured thickness of coating.</td>
</tr>
<tr>
<td>Camera</td>
<td><img src="image7" alt="Image" /></td>
<td>Tool for photographic record keeping.</td>
</tr>
<tr>
<td>Equipment</td>
<td>Picture</td>
<td>Typical Usage</td>
</tr>
<tr>
<td>-------------------------------</td>
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<td>---------------------------------------------------------------------</td>
</tr>
<tr>
<td>Magnifying Glass</td>
<td></td>
<td>Tool for enhanced visual inspection.</td>
</tr>
<tr>
<td>Positive Material Identification Tool</td>
<td></td>
<td>Tool designed to verify or measure chemical content.</td>
</tr>
<tr>
<td>Ferrite Meter</td>
<td></td>
<td>Tool to measure the ferrite (iron phase) content in stainless steels.</td>
</tr>
<tr>
<td>Portable Brinell Tester</td>
<td></td>
<td>Tool for measuring surface hardness.</td>
</tr>
<tr>
<td>Vibration Meter</td>
<td></td>
<td>Tool designed to measure mechanical oscillations.</td>
</tr>
<tr>
<td>Borescope</td>
<td></td>
<td>Designed for remote visual inspection.</td>
</tr>
<tr>
<td>Equipment</td>
<td>Picture</td>
<td>Typical Usage</td>
</tr>
<tr>
<td>------------------------------------</td>
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<td>-------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Liquid Penetrant Kit</td>
<td><img src="image1" alt="Picture" /></td>
<td>NDE technique for finding discontinuities open to the surface.</td>
</tr>
<tr>
<td>Ultrasonic Thickness Meter</td>
<td><img src="image2" alt="Picture" /></td>
<td>Tool commonly used for measuring metal thickness.</td>
</tr>
<tr>
<td>Vacuum Box</td>
<td><img src="image3" alt="Picture" /></td>
<td>Tool for measuring leakage in welded components</td>
</tr>
<tr>
<td>Ultrasonic Flaw Detection</td>
<td><img src="image4" alt="Picture" /></td>
<td>Volumetric NDE method for finding weld flaws.</td>
</tr>
<tr>
<td>Inside Micrometer Set</td>
<td><img src="image5" alt="Picture" /></td>
<td>Used for measuring inside diameters.</td>
</tr>
<tr>
<td>Equipment</td>
<td>Picture</td>
<td>Typical Usage</td>
</tr>
<tr>
<td>-----------------------------------</td>
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<td>-------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Depth Micrometer</td>
<td>![](Depth Micrometer.png)</td>
<td>Used for measuring depth.</td>
</tr>
<tr>
<td>Precision Gage Blocks</td>
<td>![](Precision Gage Blocks.png)</td>
<td>Used for callibration of precision measurement equipment.</td>
</tr>
<tr>
<td>Bore Gage</td>
<td>![](Bore Gage.png)</td>
<td>Measures inside diameter of components.</td>
</tr>
<tr>
<td>Magnetic Particle Testing</td>
<td>![](Magnetic Particle Testing.png)</td>
<td>Tool designed to detect surface and near surface discontinuities in ferrous materials.</td>
</tr>
<tr>
<td>Level</td>
<td><img src="Level.png" alt="" /></td>
<td>Device used to determine horizontally level and/or vertically plumb</td>
</tr>
<tr>
<td>Equipment</td>
<td>Picture</td>
<td>Typical Usage</td>
</tr>
<tr>
<td>---------------------------------------------------------</td>
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</tr>
<tr>
<td>Machinists’ Level with Ground and Graduated Vial</td>
<td><img src="image" alt="Machinists’ Level" /></td>
<td>Device used for precision verification of level of machines and components</td>
</tr>
<tr>
<td>Coordinate Measuring machine (CMM)</td>
<td><img src="image" alt="CMM" /></td>
<td>Device for measuring the physical geometrical characteristics of an object. This machine may be manually controlled by an operator or it may be computer controlled. Measurements are defined by a probe attached to the third moving axis of this machine. Probes may be mechanical, optical, laser, or white light, amongst others. A machine which takes readings in six degrees of freedom and displays these readings in mathematical form is known as a CMM.</td>
</tr>
</tbody>
</table>