Recommended Practice for Source Inspection and Quality Surveillance of Fixed Equipment

API RECOMMENDED PRACTICE 588
FIRST EDITION, JULY 2019

AMERICAN PETROLEUM INSTITUTE

Special Notes

API publications necessarily address problems of a general nature. With respect to particular circumstances, local, state, and federal laws and regulations should be reviewed.

Neither API nor any of API's employees, subcontractors, consultants, committees, or other assignees make any warranty or representation, either express or implied, with respect to the accuracy, completeness, or usefulness of the information contained herein, or assume any liability or responsibility for any use, or the results of such use, of any information or process disclosed in this publication. Neither API nor any of API's employees, subcontractors, consultants, or other assignees represent that use of this publication would not infringe upon privately owned rights.

API publications may be used by anyone desiring to do so. Every effort has been made by the Institute to assure the accuracy and reliability of the data contained in them; however, the Institute makes no representation, warranty, or guarantee in connection with this publication and hereby expressly disclaims any liability or responsibility for loss or damage resulting from its use or for the violation of any authorities having jurisdiction with which this publication may conflict.

API publications are published to facilitate the broad availability of proven, sound engineering and operating practices. These publications are not intended to obviate the need for applying sound engineering judgment regarding when and where these publications should be used. The formulation and publication of API publications is not intended in any way to inhibit anyone from using any other practices.

Any manufacturer marking equipment or materials in conformance with the marking requirements of an API standard is solely responsible for complying with all the applicable requirements of that standard. API does not represent, warrant, or guarantee that such products do in fact conform to the applicable API standard.

Foreword

Nothing contained in any API publication is to be construed as granting any right, by implication or otherwise, for the manufacture, sale, or use of any method, apparatus, or product covered by letters patent. Neither should anything contained in the publication be construed as insuring anyone against liability for infringement of letters patent.

The verbal forms used to express the provisions in this document are as follows.

Shall: As used in a standard, "shall" denotes a minimum requirement to conform to the standard.

Should: As used in a standard, "should" denotes a recommendation or that which is advised but not required to conform to the standard.

May: As used in a standard, "may" denotes a course of action permissible within the limits of a standard.

Can: As used in a standard, "can" denotes a statement of possibility or capability.

This document was produced under API standardization procedures that ensure appropriate notification and participation in the developmental process and is designated as an API standard. Questions concerning the interpretation of the content of this publication or comments and questions concerning the procedures under which this publication was developed should be directed in writing to the Director of Standards, American Petroleum Institute, 200 Massachusetts Avenue, Suite 1100, Washington, DC 20001. Requests for permission to reproduce or translate all or any part of the material published herein should also be addressed to the director.

Generally, API standards are reviewed and revised, reaffirmed, or withdrawn at least every five years. A one-time extension of up to two years may be added to this review cycle. Status of the publication can be ascertained from the API Standards Department, telephone (202) 682-8000. A catalog of API publications and materials is published annually by API, 200 Massachusetts Avenue, Suite 1100, Washington, DC 20001.

Suggested revisions are invited and should be submitted to the Standards Department, API, 200 Massachusetts Avenue, Suite 1100, Washington, DC 20001, standards@api.org.

Contents

Contents

Figures

Contents

Page

Tables

Introduction

This recommended practice has been developed to provide information for source inspectors (SI) 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 to pass the examination and to perform satisfactorily in the source inspection.

Recommended Practice for Source Inspection and Quality Surveillance of Fixed Equipment

1 Scope/Purpose

This recommended practice (RP) covers the process of specifying the necessary 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 RP may be used as the basis for providing a systematic approach to risk-based source inspection to provide confidence that materials and equipment being purchased meet the minimum requirements as specified in the project documents and contractual agreements. The activities outlined in this RP *are not* intended to replace the manufacturer's/fabricator's own quality systems, but rather are meant to guide SIs acting on behalf of the purchaser to determine whether manufacturer's/fabricator's own quality systems have functioned appropriately, such that the purchased equipment and materials will meet contractual agreements.

This RP focuses primarily on pressure-containing and structural equipment (fixed equipment), including but not limited to vessels, columns/towers, heat exchangers, piping, valves, pressure-relief devices, tubulars, and supporting structural fabrications. The principles of the document can be applied to other equipment disciplines. This document assumes that suppliers/vendors (S/V) have been pre-qualified by a systematic quality review process of their facilities and quality processes 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/Vs deemed acceptable to the supply chain management of the purchaser who are capable of meeting the requirements of the contract prior to it being placed. S/Vs on such a list will normally have an acceptable quality process already in place that meets the requirements of the contract. An approved S/V list may also indicate that S/Vs have the technical skills and can meet the SCM commercial terms and conditions. The purpose of source inspection in such a case is simply to verify that the S/V quality processes are working as they should and to verify that certain critical steps in the inspection and test plan (ITP) have been satisfactorily accomplished prior to fabrication completion and/or shipping.

The primary purpose of this RP is to summarize the basic body of knowledge that the source inspector typically needs to know to perform as a source inspector for fixed equipment. A secondary purpose is to assist candidates intending to take the API Source Inspection Examination to become certified source inspectors. This RP 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 the API website at www.api.org/si and follow the work process shown in Figure 1.

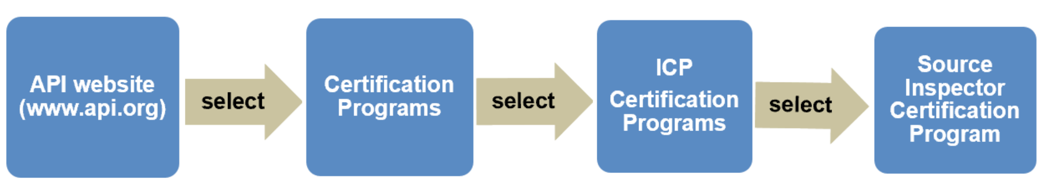


Figure 1—Work Process

2 Introduction

The source inspection work process follows the Plan–Do–Check–Act circular process first popularized in the 1950s by Edward Deming. The "Plan" part of source inspection is covered in Sections 6 and 7 of this RP and involves the source inspection management systems, source inspection project plan, and the inspection and test plan (ITP). The "Do" part is covered in Sections 8, 9, and 10, and involves implementing the ITP, participating in scheduled source inspection work process events, filing nonconformance reports (NCRs), and source inspection report writing. The "Check" part, covered in Section 9.7, involves reviewing all the source inspection activities that occurred in the "Plan" and "Do" parts to see what went well and what should be improved based on the results of that review. Finally, the "Act" part (sometimes called the "Adjust" part), covered in Section 9.8, involves implementing all the needed improvements in the "Plan" and "Do" parts before they are implemented on the next source inspection project.

3 Normative References

The most recent editions of these codes, standards, or other recommended practices are referenced in this RP and are the documents from which the SI exam has been developed.

API 510, *Pressure Vessel Inspection Code: In-Service Inspection, Rating, Repair, and Alteration*

API Recommended Practice 572, *Inspection Practices for Pressure Vessels*

API Recommended Practice 577, *Welding Inspection and Metallurgy*

API Recommended Practice 578, *Guidelines for a Material Verification Program (MVP) for New and Existing Assets*

API Standard 598, *Valve Inspection and Testing*

ASME[1] Boiler and Pressure Vessel Code (BPVC), Section II—*Materials*, Parts A, B, C, and D

ASME Boiler and Pressure Vessel Code (BPVC), Section V—*Nondestructive Examination*

ASME Boiler and Pressure Vessel Code (BPVC), Section VIII—*Rules for Construction of Pressure Vessels*, Divisions 1 and 2

ASME Boiler and Pressure Vessel Code (BPVC), Section IX—*Welding and Brazing Qualifications*

ASME B31.1, *Power Piping*

ASME B31.3, *Process Piping*

ASME B16.5, *Pipe Flanges and Flanged Fittings*

ASNT[2]CP-189, *Standard for Qualification and Certification of Nondestructive Testing Personnel*

ASNT SNT-TC-1A, *Personnel Qualification and Certification in Nondestructive Testing*

AWS[3]D1.1, *Structural Welding Code*

AWS Committee on Methods of Inspection., *Welding Inspector Handbook*

SSPC,[4] PA 2, *Procedure for Determining Conformance to Dry Coating Thickness Requirements*

SSPC., *Surface Preparation Guide*

4 Definitions, Abbreviations, and Acronyms

For the purposes of this RP, the following definitions, abbreviations, and acronyms apply. Additional definitions that the source inspector needs to know and understand are included in the following documents:

---

1 American Society of Mechanical Engineers, 2 Park Avenue, New York City, New York, 10016, www.asme.org.
2 American Society for Nondestructive Testing, 1711 Arlingate Lane, Columbus, Ohio, 43228, www.asnt.org.
3 American Welding Society, 8669 NW 36th Street, #130, Miami, Florida, 33166, www.aws.org.
4 Society for Protective Coatings, 800 Trumbull Drive, Pittsburgh, Pennsylvania, www.sspc.org.

— API Recommended Practice 577, Section 3

— API Recommended Practice 578, Section 3

— ASME B31.3, 300.2

— ASME BPVC Section VIII, Division 1, Appendix 3

— ASME BPVC Section V, Subsection A, Article 1, Appendix 1

— ASME BPVC Section V, Subsection B, Article 30, SE-1316

— AWS D1.1, Annex K

4.1
AARH
Arithmetic average roughness height (a measure of surface roughness).

4.2
annealing heat treatment
Heating an object to and then holding it at a specified temperature, then cooling it at a suitable rate for such purposes as reducing hardness, improving machinability, facilitating cold working, producing a desired microstructure, or obtaining desired mechanical properties.

4.3
ANSI
American National Standards Institute.

4.4
API
American Petroleum Institute.

4.5
ASM
ASM International.

4.6
ASME
ASME International (formerly known as the American Society of Mechanical Engineers).

4.7
ASNT
American Society of Nondestructive Testing.

4.8
ASTM
ASTM International (formerly known as the American Society for Testing and Materials).

4.9
AI
Authorized inspector: the inspector responsible for confirmation to the recognized code.

4.10
BOK
Body of knowledge (in this case, the BOK for the SI examination).

4.11
BPVC
Boiler and Pressure Vessel Code (published by ASME).

4.12
causal analysis
A generic term for all types of investigative processes—from as simple as a 5-Why analysis to a full root cause analysis.

4.13
certification
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.

4.14
calibration
A comparison between measurements—one of known magnitude or correctness (the standard) compared with the measuring device under test to establish the accuracy of a measuring device.

4.15
cladding
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.

4.16
cold working
Plastic deformation (forming, rolling, forging, etc.) of metals below the recrystallization temperature of the metal.

4.17
continuity log
A document detailing the continuous history of a welder, the types of welds made, and that there has been no gap (i.e. no more than six months) in performing these processes.

4.18
critical equipment
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.

4.19
destructive testing
Various tests that are performed on metals for the purposes of determining mechanical properties and that involve testing (usually breaking) of sample coupons. Examples 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, and usually renders the component from which the samples were extracted unfit for continued service.

4.20
deviation
A departure from requirements in the contractual agreements or its referenced purchase order (PO), engineering design, specified codes, standards, or procedures.

4.21
DFT
Dry film thickness (of paint and coatings) that is measured by a DFT gauge.

4.22
elevation
The height of any point on a vessel as shown on a vessel drawing, e.g. nozzle, manway, or longitudinal weld, as measured from a base plate or other reference line, such as the bottom head tangent line.

4.23
employer
The corporate, public, or private entity that employs personnel for wages, salaries, fees, or other considerations, e.g. the employer of the source inspector.

4.24
engineered equipment
Equipment that is custom designed and engineered by the purchaser and/or EPC to perform a project-specific function. Engineered equipment will typically require more source inspection than non-engineered equipment.

4.25
EPC
Engineering/procurement/construction contractor.

4.26
examiner
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.

4.27
ferrous materials
Alloys that are iron-based, including stainless steels.

4.28
HAZ
Heat affected zone: the thin base metal area next to the weld that has had its metal structure affected by the heat of welding.

4.29
hot working
Plastic deformation (forming, rolling, forging, etc.) of metals at a temperature above the metal recrystallization temperature.

4.30
ICP
Individual Certification Program (of API) under which the SI certification program is administered.

4.31
inspection
The evaluation of a component or equipment for compliance with a specific product specification, code, drawing, and/or standard specified in the contractual requirements, that may include the measuring, testing, or gauging of one or more characteristics specified for the product to determine conformity.

4.32
inspection agency
An entity employed to provide competent, qualified, and certified source inspection personnel for the purpose of performing source inspection. For example, an inspection agency can be an EPC company, an owner-user, or an inspection service company.

4.33
inspection coordinator
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.

4.34
inspection waiver
Permission to proceed with production/shipment without having a purchaser source inspection representative present for a specific activity.

4.35
ITP
Inspection and test plan: a plan that summarizes minimum inspection, testing, and quality control requirements for a defined scope of work.

4.36
lamination
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.

4.37
levelness
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 $\frac{1}{2}^{\circ}$ 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 hillside (tangential) nozzle is properly installed relative to the vessel centerline.

4.38
management process
Management processes are the methods that aid the structuring, investigation, analysis, decision-making and communication of business issues.

4.39
MAWP
Maximum allowable working pressure: the maximum gauge pressure at the top of a pressure vessel allowed by code calculations for a designated temperature.

4.40
M&F
Manufacturing and fabrication: Refers to the various material working processes that are commonly used to produce a product, such as welding, joining, heat treatment, casting, forming, forging, bending, machining, assembly, etc.

4.41
manufacturer's record book
A document after completion of fixed equipment that contains all engineering documents outlined in the contractual agreement that confirms the FE met the engineering design. It contains all approved documents that confirm every inspection activity was satisfactorily completed.

4.42
MOC
Management of change.

4.43
MSS
Manufacturers Standardization Society.

4.44
MT
magnetic particle testing (examination).

4.45
MTR
Material test report or mill test report: a quality assurance document used in the steelmaking industry that certifies a material's compliance with appropriate standards, including physical and chemical specifications, and applicable dimensions. The MTR also includes a date of production and testing and may include notation about method of fabrication. A mill test report is also known as a certified mill test report, certified material test report, mill test certificate (MTC), inspection certificate, certificate of test, and other names.

4.46
NB
National Board of Boiler and Pressure Vessel Inspectors.

4.47
NDE
Nondestructive examination (the preferred terminology): a quality process that involves the examination, testing, and evaluation of materials, components, or assemblies without affecting their functionality, e.g. VT, PT, MT, UT, RT.

4.48
NDT
Nondestructive testing: Means the same as NDE, which is now the preferred terminology.

4.49
nonconformance report
Also called an NCR. A form on which the non-conformance is recorded and registered for further handling and follow-up.

4.50
non-engineered equipment
Equipment that is designed and fabricated by S/Vs, that includes off-the-shelf items such as valves, fittings, 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.

4.51
nonferrous materials
Alloys that are not iron-based, e.g. nickel- and copper-based alloys.

4.52
normalizing heat treatment
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.

4.53
NPS
Nominal pipe size: a standard for designating pipe sizes (inches) and associated wall thickness (schedule); for example, the nominal pipe size for a four-inch pipe is normally shown as NPS 4.

4.54
orientation
The orientation of a nozzle or attachment is the number of degrees off from a vertical centerline (a circumferential degree line) of the attachment or nozzle on the plan view of a vessel. For example, orientation of a nozzle or attachment can be checked with a protractor or smart level.

4.55
out-of-roundness
A deviation from perfect roundness, e.g. ovality in a vessel circumference. ASME BPVC Section VIII, Division 1, UG 80 deals with out-of-roundness of a vessel shell. The maximum permitted ovality tolerance (D_{max} – D_{min}) shall not exceed 1 % of the nominal diameter of the vessel.

4.56
PDCA
Plan–Do–Check–Act (PDCA) cycle. Also known as the Deming cycle, Shewhart cycle, ISO 9001 Process approach.

4.57
PQR
Procedure qualification record per ASME BPVC Section IX, QW 200.2: a record of the welding data and variables used to weld a test coupon, and the test results used to qualify the welding procedure.

4.58
pressure vessel
A container designed to withstand a specified amount of internal or external pressure generally above 15 psig. This definition includes heat exchangers, air coolers, columns, towers, unfired steam generators (boilers), and other vapor-generating vessels.

4.59
procedure
A document detailing how a work process is to be performed, e.g. a welding procedure.

4.60
project quality plan
The plan for the project as a whole. Plans prepared by contractors or suppliers may be termed contractor or supplier quality plans.

4.61
protractor
An instrument for measuring angles, typically in the form of a flat semicircle marked with degrees along the curved edge.

4.62
PRV/PRD/PSV
Pressure relief valve/pressure relief device/pressure safety valve.

4.63
PT
Penetrant testing (examination).

4.64
QA
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 systematic measurement, comparison with a standard, monitoring of processes, and an associated feedback loop that is intended to avoid deviations from specification.

4.65
QC
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.

4.66
qualification
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.

4.67
quality surveillance
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 RP, quality surveillance and source inspection mean the same thing (see “source inspection” definition).

4.68
quenching
Rapid cooling of a heated metal for the purpose of affecting mechanical and/or physical properties.

4.69
RMS
Root mean square: a measure of surface finish on flanges.

4.70
RT
Radiographic testing (examination).

4.71
rust bloom
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.

4.72
SDO
Standards development organization, e.g. API, ASME, ASTM, NACE, MSS, TEMA, ISO, etc.

4.73
SI
Source inspector: the person responsible for confirming the work conforms to the contractual requirements.

4.74
SME
Subject-matter expert.

4.75
solution anneal heat treatment
Heating an alloy to a specified temperature, holding at the temperature long enough for one or more elements to reenter into solid solution, then cooling rapidly enough to hold those elements in solid solution.

4.76
SOR
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 that require NCRs.

4.77
source inspection
The process of providing quality surveillance of materials, fabrications, and equipment being supplied by supplier/vendor (S/V) or manufacturer/fabricator (M/F), including their subcontractors, for use in the oil, petrochemical, and gas industry, including upstream, 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 contractual agreements.

4.78
source inspector
Individual responsible for performing the actual source inspection activities at the S/V facilities in accordance with the applicable inspection and test plan (ITP).

4.79
source inspectors plan
A document specifying the requirements that the purchaser deems necessary for the SI to ensure adherence.

4.80
specification
A document that contains the requirements for the M&F of specific types of equipment and components.

4.81
SSPC
Society for Protective Coatings.

4.82
S/V
Supplier/vendor: the entity that is responsible for the actual manufacturing and fabrication (M&F) of the material, equipment, or components and that is responsible for meeting the contractual requirements.

4.83
surveillance
Monitoring of engineering, fabrication, and construction activities. Surveillance would increase or decrease based on observations of the work quality. A deliverable from surveillance would be a surveillance report or other document that identifies activities conducted and any corrective action needed.

4.84
traceability
Capability to show/prove the chain of custody or manufacturing of an asset until it is placed in service.

4.85
TEMA
Tubular Exchanger Manufacturers Association.

4.86
tempering
Reheating a hardened metal to a temperature below the transformation range to improve the toughness.

4.87
tolerance
The limit (or limits) of specified dimensions, physical properties, or other measured values of a component.

4.88
training
An organized program developed to impart the skills and knowledge necessary for qualification as a SI. May be formal or informal, i.e. OTJ.

4.89
UT
Ultrasonic testing (examination): generally used to find component flaws or measuring thicknesses.

4.90
VT
Visual testing (examination).

4.91
weld management process
A disciplined, controlled process that requires adherence to established weld processes to provide for a consistent and reliable outcome.

4.92
weld map
Set of construction drawings amended with the WPS reference used for each weld performed, the welder's ID reference, and the NDE reports reference for the welds subject to NDE.

4.93
weld mismatch
The deviation from perfect alignment between two pieces of metal welded together. ASME BPVC Section VIII, Division 1 specified tolerances for weld mismatch are in UW-33. It is important for the SI to measure weld mismatch with a welding gauge and to know that the limit for weld mismatch is stringent for a Category A weld (longitudinal joint and circumferential shell to hemispherical head). The concept behind this is that the longitudinal joint bears double the amount of stress, and inspectors should precisely check these joints.

4.94
weld reinforcement
The height of the weld cap. The longitudinal joint weld reinforcement limit is more stringent than that for circumferential joints. This is because the longitudinal joint bears double stress, and it is required that the stress concentration be minimized. Maximum weld reinforcement is specified in ASME BPVC Section VIII, Division 1.

4.95
WPQ
Welding performance qualification record per ASME BPVC Section IX, QW 301.4

4.96
WPS
A document that serves as a guide for the effective creation of a weld that meets all applicable code requirements and production standards

5 Training and Certification

5.1 General

Employers/inspection agencies providing inspection coordination and/or source inspection personnel or services should have an adequate training program for source inspection. The training should take into consideration the level of experience needed for the individuals performing the source inspection tasks. For instance, depending on the complexity and quality risks associated with any particular equipment, the purchaser may determine the requirement for a more- or less-experienced source inspector be appropriate for the job.

5.2 Levels of Training and Experience

5.2.1 General

Examples of different levels of training and experience for source inspectors include the following.

5.2.2 SI Level 1 (Entry/Awareness Level)

a) The inspector would be exposed to source inspection methods and technology on an initial introductory level and may act as a SI trainee following other more experienced SIs to learn on the job. Entry-level classroom training may also be provided.

b) The SI gains an awareness of the broad scope of SI activities, procedures, project documents, SI records, manufacturing processes, applicable codes and standards, etc. that they will eventually need to know and understand in greater detail as they become more experienced.

5.2.3 SI Level 2 (Basic Level)

a) The new SI would have been on the job full-time for about a year. They would have completed most of the awareness/entry level training, as well as on-the-job exposure, and should be competent to perform some basic SI duties on their own with adequate supervision.

b) The new SI should have passed the API SI entry-level exam and be gaining more knowledge and experience with a variety of SI issues and procedures.

c) The SI may start to become exposed to more complex and different types of SI issues and equipment.

5.2.4 SI Level 3 (Stand-alone Level)

a) The more experienced SI will have been on the job full-time for at least two to four years, have a good knowledge of all aspects of SI included in this document, as well as company procedures, and be able to perform most SI tasks competently with minimal supervision.

b) The experienced SI will have more detailed knowledge of applicable industry codes and standards, have a much better understanding of quality issues and risks, and be able to correctly handle different types of nonconformances and deviations without much direct supervision. Additionally, the stand-alone SI should be able to competently train less-experienced SIs.

c) The experienced SI will be able to handle more and different types of SI issues and equipment, including complex mechanical fixed equipment, packaged equipment, shop-fabricated piping, etc. The SI may also be competent with rotating equipment packages and electrical equipment depending on their area of expertise.

d) The experienced SI should be starting to obtain different types of certifications that will assist him/her in the performance of their job, and should be becoming a “go to” person for less-experienced SIs. Those certifications might include:

   1) API Welding Inspector Certification.

   2) NACE Coatings Inspector Certification.

   3) Positive material identification (PMI) training/certification.

   4) AWS Certified Welding Inspection (or equal).

   5) AWS Senior Certified Welding Inspector (or equal).

   6) API 510 for pressure vessels.

7) API 570 for piping.

8) API 653 for aboveground storage tanks.

9) Level II in film interpretation certification or qualification.

5.2.5 SI Level 4 (Master Level)

a) The experienced SI will have been on the job full-time for at least five to 10 years, have a broad and in-depth knowledge of all aspects of SI included in this document, as well as industry standards and company procedures, and be able to supervise and coordinate the activities of other SIs. As the title suggests, at this level, the SI has mastered the trade.

b) The master SI should be able to create and teach SI course materials, create on-the-job SI training programs, speak with confidence at source inspector conferences, improve the effectiveness and efficiency of SI procedures and work processes, and handle new and different SI assignments with higher-risk equipment.

6 Source Inspection Management Program

6.1 General

Employers or inspection agencies tasked with the responsibility of performing source inspection coordination and/or source inspection activities should develop a management program 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 plans that are needed for each specific project.

6.2 Activities

Source inspection management programs should cover most of the generic activities identified in this RP, but should also include company specific information, such as the following:

a) what activities need to be accomplished;

b) who is responsible to accomplish each of the activities, i.e. personnel titles;

c) the training, competencies, and, if necessary, certifications required for source inspectors;

d) when or how frequently each of the activities will be accomplished;

e) how each of the activities will be accomplished, i.e. specific work procedures;

f) application of acceptance criteria and industry standards.

6.3 Other References

These management programs may reference many other company-specific source inspection procedures, practices, and policies with more details that will be needed for specific types of source inspection activities. The following are provided as examples of those documents.

a) Project quality plan: Source inspectors would need to understand this plan and the sections applicable to covering source surveillance.

b) The SI should understand how to prepare a source inspection plan for an entire project and understand and follow an inspection and test plan (ITP) for each equipment item.

c) The SI should know how to conduct an equipment risk assessment to determine the level of source inspection activities that will be required and verify those source activities are reflected on the approved ITP.

d) Guidance on the criteria to use for selecting SIs to match their skills and training with different types of equipment with different risk levels.

e) Guidance on scheduling and conducting significant source inspection events, such as the pre-inspection (fabrication kick-off) meeting, the S/V quality coordination meeting, final acceptance testing, acceptance criteria, verifying documents, etc.

f) Guidance on SI safety and professional conduct at S/V shops.

g) How to review weld management processes, welding procedures, and welder qualification documents.

h) How to review inspection/examination records of the S/V.

i) What inspections should be repeated by the SI to verify the results of S/V examinations and tests.

j) How the management-of-change process is to be followed.

k) How to handle deviations and nonconformances, corrective actions, and preventive actions.

l) How to write source inspection reports and fill out specific forms.

m) What specific steps to take before approving product acceptance, documentation, etc.

n) Interfacing with the jurisdictional authorized inspector.

o) Project-specific source inspection planning activities.

p) Understanding continual-improvement processes.

7 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 that addresses the following activities.

7.1.1 The source inspector's plan describes the minimum level of detail required to effectively execute the work for the assigned SI. The plan should include:

— overseeing the supplier's approved quality assurance and quality control activities for achieving PO and/or contract compliance;

— using the proper reporting protocols to document quality concerns and the status of any re-work or outstanding action items;

— confirming the supplier's use of approved ITPs and applicable drawings, and specifications;

— providing sufficient advance notification to the purchaser and/or a procurement agent of any upcoming ITP hold and witness points, performance testing, and final inspections;

— confirming that the required documentation and the manufacturer's record book (MRB) content have been completed, reviewed, and approved prior to shipping.

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; equipment identified as less critical will receive less intensive source inspection.

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.

a) safety or environmental issues that could occur because of equipment failure to meet specification or failure while in service;

b) equipment complexity; the more complex the equipment, the higher level of source inspection may be required;

c) knowledge of S/V history and capabilities to deliver equipment meeting specifications; for example, newer S/V with relatively unknown history or capabilities may need closer scrutiny;

d) potential schedule impact from delivery delays or project construction impact from issues discovered after delivery; for example, long delivery items may require a higher level of source inspection;

e) equipment design maturity level; for example, prototype, unusual, or one-of-a-kind equipment may require a higher level of source inspection;

f) lessons learned from previous projects; for example, if the S/V has had problems in the past meeting specifications on time;

g) potential economic impact on the project of S/V failure to deliver equipment that meets specifications on time;

h) criticality of equipment should it not operate as designed; for example, shut down the plant, a section of the plant, a unit, etc.

7.2.3 The risk-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 owner/user, 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 considers 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 a combination of the POF and COF assessments. An owner/user normally has a risk matrix based on these two parameters, and a guide as to what is very critical as opposed to not critical.

7.2.5 The risk assessment process should consider the volume of work being undertaken by one supplier. A manufacturer of multiple similar vessels, heat exchangers, or lower-pressure equipment types of FE may not warrant much inspection, but if that manufacturer has an order for 100 vessels, the risk increases because of the possible impact on the project if the schedule is not met.

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

a) No source inspection (lowest risk for equipment failure to meet specifications; rely solely on S/V quality).

b) Final source inspection (final acceptance) just prior to shipment (lower- to medium-risk material or equipment; rely primarily on S/V quality with minimum source inspection).

c) 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 and witness points). The number of shop visits may go up or down based on the performance level of the S/V.

d) Advanced source inspection level (higher-risk equipment; significant amount of source inspection, e.g. one or more days 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.

e) 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 that 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 on 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 by the S/V. This ITP should be specific to the type of equipment and the associated risk level for each piece of equipment, and should identify all the inspection activities necessary to be performed by the assigned SI. It should also include the appropriate acceptance criteria or reference thereafter.

7.4.2 The SI 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. The purchaser may have developed their own minimum requirements for inclusion in the ITP, and the SI should be familiar with these requirements. One of the purposes of the pre-fabrication meeting is to review and revise the ITP, if necessary.

7.4.3 The SI responsibilities are to verify that all acceptance criteria at each step in the ITP have been met.

7.4.4 Where a hold point or witness point are identified, and the SI has not been informed but the inspection is conducted without the SI being notified or present, a nonconformance should be issued against the S/V.

7.4.5 Although there may be different versions of ITPs, the following heading items at a minimum should be included:

a) description of task (i.e. material test certificate [MTR], hydro-test, PQRs, etc.);

b) the requirement (i.e. MTR meets specifications, hydro-test procedure is accepted, PQR details all essential variables in compliance with applicable code);

c) QA/QC method (is correct for the inspection to be conducted);

d) acceptance criteria (what must be met so that the QA/QC performed will satisfy that the work or process meets all requirements).

7.4.6 The following headings are normally used on an ITP.

a) description of activities, e.g. visual weld inspection, RT, UT, PWHT, etc.;

b) standard or requirement basis for activity; for example, the WPS should be listed as the standard for the activity of filler metal control;

c) responsibility for each party; typically, three parties would be listed for the ITP (manufacturer, third-party inspector, and client). The ITP should show the responsibilities for each party, e.g. hold point, witness point, review:

   1) hold point: hold on the production until the SI inspector performs inspection and supervises the required test;

   2) H1: work may proceed but activity must be complete before final acceptance;

   3) W (witness point): manufacturer shall notify the client and SI inspector, but there is no hold on the production; the client can waive this inspection based on his discretion and informs SI inspector accordingly;

   4) R (document review): the review document that includes material test certificates, WP, S, PQR, NDE, procedures, etc.;

   5) A (audit): QC system steps as defined in the quality plan; work in process or after completion;

   6) SW (spot witness): for items with a spot witness, the manufacturer shall notify the SI inspector fulfilling the monitoring; for example, one random visit for whole UT tests or one or two visits for whole surface preparation works for painting;

d) requirements for above activity: for welding, the supplier shall provide a WPS that describes all of the essential, nonessential, and, when required, supplementary essential variables for each welding process used as per ASME IX QW 200.1;

e) acceptance criteria, e.g. as per Section 5.2 ASME IX;

f) quality record, e.g. as per S/Vs quality program;

g) responsible, e.g. S/V, or S/V or purchaser;

h) verifying document, e.g. evidence that a task has been satisfactorily completed as specified, such as a heat treatment chart.

i) remarks or comments, e.g. the supplier must provide proof of QA program execution and it is recommended to retain documentation for a purchaser's audits, and WPS shall be made available to authorized inspectors at the fabrication site. WPS/PQRs to be submitted and approved prior to the start of any welding.

7.4.7 The source inspector should follow the approved S/V ITP and verify 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.

7.4.8 ITPs should include a place to sign off and date as each step is completed. ITPs should be signed off as the step is completed, not at the end of the fabrication, and not all at once.

7.4.9 Should a deficiency be identified, the SI shall follow the NCR process identified in 9.6.

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 SI(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 (fabrication 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 purchaser. The amount and type should be specified in the ITP. Each inspection report should be reviewed by the inspection coordinator for content, completeness, and technical clarity prior to distribution. The requirements for report writing are detailed in 9.5.

8 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 SI 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 and factual terms how the SI 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 that identifies specific safety hazards associated with the job. SIs should be adequately trained and knowledgeable in these safety programs to minimize the possibility of injury. A safety program should include:

a) potential travel safety issues specific to the job;

b) potential shop safety issues and hazard recognition;

c) 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 they are more stringent than their own company's safety requirements.

9 Review of Project Documents

9.1 General

9.1.1 Typical project documents include but are not limited to contractual agreements (purchase orders and/or subcontracts), the S/V ITP, project specifications, engineering or fabrication drawings, applicable codes, procedures, WPS, references, or standards.

9.1.2 The source inspectors should familiarize themselves with all project documents and verify 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.

9.2 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.

9.2.1 Engineering Design Documents

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

9.2.2 Company and Purchaser Standards

The SI needs to be familiar with all company and purchaser standards that are specified in the contractual agreements. These standards typically augment or supplement industry standards for issues not sufficiently covered in industry standards or that the company wants to be more stringent for several reasons. 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 the purchaser’s NCR system requirements. Other issues contained in the specified standards, such as those suggested or recommended (i.e. “should” statements that are expectations of the S/V, but not necessarily requirements), may become an issue to be reported in supplier observation reports (SORs) and handled in accordance with standard purchaser management systems. Company and purchaser standards may cover engineered and nonengineered equipment.

9.2.3 Industry Codes and Standards

9.2.3.1 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’s duties. Those industry codes and standards are typically published by recognized industry standards development organizations (SDOs), such as those in the following sections.

9.2.3.2 API Codes and Standards

There are a wide variety of API codes and standards that may be included in the contractual agreements to specify 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. However, 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 an experienced SI.

a) API 510, *Pressure Vessel Inspection Code: In-Service Inspection, Rating, Repair, and Alteration*

   Where repairs and alterations of used equipment are involved, it may be useful that, in addition to the certified SI, an API 510/570 certified inspector assist in the source inspection.

b) API RP 572, *Inspection Practices for Pressure Vessels*

This RP includes a description of the various types of pressure vessels and the materials and standards for their fabrication. The source inspector should be familiar with Sections 3 and 4 of this RP.

c) API RP 577, *Welding Processes, Inspection, and Metallurgy*

This RP provides guidance for the source inspector on welding fabrication inspection. Issues covered include welding processes and procedures, welder qualifications, metallurgical effects from welding, inspection techniques, welding terminology and symbols, how to review a welding procedure, and a guide to common filler metals. The source inspector should be thoroughly familiar with the contents of Sections 3 to 10 of this RP.

d) API RP 578, *Guidelines for a Material Verification Program (MVP) for New and Existing Assets*

The purpose of this RP is to provide guidelines for a material and quality system to verify that the nominal composition of piping alloy components is consistent with the material specifications. The primary topics covered include material verification test methods, evaluation of PMI test results, marking, and record-keeping. The source inspector should be thoroughly familiar with the contents of this RP, except for the sections that focus on material verification for existing systems that are already in operation in a plant.

e) API Standard 598, *Valve Inspection and Testing*

This standard covers the inspection, examination, and pressure test medium and requirements for various kinds of valves used in the energy industry. The various kinds of tests and examinations specified in this standard include shell test, backseat test, low-pressure closure test, high-pressure closure test, and visual examination of castings. The SI should look to the appropriate purchasing document and spec sheets for the required characteristics of each valve, such as type, size, materials, rating, trim, etc. The SI should be thoroughly familiar with the contents of API Standard 598 whenever specified in contractual agreements. The standard is mostly applied to the standard metallic valves (butterfly, gate, globe, ball, etc.) used in ASME B31.1 or B31.3 applications.

9.2.3.3 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.

a) ASME BPVC Section II—*Materials*

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

1) 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, such as wrought, castings, forgings, plates, piping valves, bolting, etc. The issues 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 SI should be familiar with the contents of whichever materials are specified in the contractual agreements. The only three specifications covered in ASME BPVC Section II, Part A that the SI needs to be familiar with for purposes of the examination are:

i. SA-20, *General Requirements for Steel Plates*.

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

iii. SA-6, *Thickness Tolerances for Steel Plate*.

2) 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, such as wrought, castings, forgings, plates, piping valves, bolting, etc. allowed 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 issues 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 steel-making practice. The source inspector should be familiar with the contents of whichever materials are specified in the contractual agreements.

3) Part C—*Specifications for Welding Rods, Electrodes, and Filler Metals*

This part 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 verify that the right materials are being used in fabrication. There will be no specific questions on the core examination out of Part C, but the SI should be familiar with what Part C covers.

b) 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.

c) 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 includes 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 Section V that applicants should focus on include:

1) All definitions in Subsection A, Article 1, Appendix 1 and Subsection B, Article 30, SE-1316.

2) Article 1 on General Requirements for NDE.

3) Article 4 on Ultrasonic Examination Methods of Welds.

4) Article 6 on Liquid Penetrant Examination.

5) Article 7 on Magnetic Particle Examination.

6) Article 9 on Visual Examination.

7) Article 10 on Leak Testing.

8) Article 23, Section 797 on UT Thickness Testing.

d) ASME BPVC Section VIII, Division 1—*Rules for the Construction of Pressure Vessels*

Division 1 contains the requirements, specific prohibitions, and non-mandatory guidance for standard-design unfired pressure vessel materials, design, fabrication, examination, inspection, testing, certification, and pressure-relief requirements. Division 1 is divided into three subsections, with mandatory and non-mandatory appendices. The source inspector should be thoroughly familiar with the contents of Division 1 with regard to the fabrication, examination, inspection, and testing that is specified in contractual agreements and/or ITP. Some of the content covered in ASME BPVC Section VIII, Division 1 that the SI should be familiar with include:

1) Subsection A covers the general requirements applicable to all pressure vessels.

2) Subsection B covers specific methods of fabrication of pressure vessels, e.g. welding

3) Subsection C covers the various classes of materials used in the fabrication of pressure vessels, e.g. steels, alloys, cladding, lining, low-temperature materials, etc.

The SI applicants should focus their attention on the following sections:

1) All definitions in Appendix 3.

2) Materials, UG 4 to 15.

3) Fabrication, UG 75 to 85.

4) Inspection and Testing, UG 90 to 103.

5) Marking and Reports, UG 115 to 120.

6) Welding General, UW 1 to 3.

7) Welding Materials, UW 5.

8) Fabrication, UW 26 to 42.

9) Inspection and Tests, UW 46 to 54.

10) Marking and Reporting, UW 60.

11) Postweld Heat Treatment, UCS 56.

12) Radiographic Examination, UCS 57.

i. ASME BPVC Section VIII, Division 2—*Rules for the Construction of Pressure Vessels—Alternative Rules*

Division 2 also contains the requirements, specific prohibitions, and non-mandatory guidance for advanced-design unfired pressure vessel materials, design, fabrication, examination, inspection, testing, certification, and pressure relief. Division 2 is divided into nine parts, each with mandatory and non-mandatory annexes. The source inspector need not be thoroughly familiar with the contents of Division 2 for the core examination, but should be familiar with what the standard covers.

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

Section IX 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 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 SI 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.

iii. ASME B31.3—*Process Piping*

B31.3 covers the requirements for the fabrication of process piping associated with pressure vessels typically used in the petrochemical industry. It covers design, materials, fabrication, welding, erection, testing, inspection, and examination of process piping, including flanges, fittings, gaskets, bolting, valves, and PRVs. The source inspector should be familiar with the contents of B31.3 with regard to examination, inspection, and testing procedures that are specified in contractual agreements and/or ITP. For the purposes of SI examination, some of the content covered in ASME B31.3 that the applicants should be familiar with includes:

— Chapter I, Scope and Definitions.

— Chapter III, Materials.

— Chapter IV, Standards for Piping Components.

— Chapter V, Fabrication, Assembly and Erection.

— Chapter VI, Inspection, Examination and Testing.

iv. ASME B16.5—*Pipe Flanges and Flanged Fittings*

B16.5 covers the requirements for materials, dimensions, tolerances, marking, testing of flanges, and flanged fittings, as well as flange bolting and gaskets. B16.5 covers flange class designations for 150, 300, 400, 600, 900, 1500, and 2500 systems for sizes from NPS ½ to NPS 24 made from cast or forged materials. These pressure classes have differing pressure and temperature ratings for different materials of construction. B16.5 also covers blind flanges and reducing flanges. The source inspector should use this standard to verify that flanges and flanged fittings specified in the contractual document have been correctly supplied. For the purposes of the SI examination, the applicants should be familiar with the following sections of ASME B16.5:

— Chapters 1 to 8, narrative information and associated tables referenced therein.

9.2.3.4 ASNT Standards

a) ASNT SNT-TC-1A

This recommended practice establishes a general framework for a qualification and certification program for NDE technicians. In addition, it 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 three levels of NDE-qualified technician.

9.2.3.5 AWS Standards and References

a) *The Welding Inspection Handbook*

This handbook provides information to assist welding inspectors and supervisors in the technology and application of visual and nondestructive examination associated with welding. The SI should be thoroughly familiar with the contents of this handbook.

b) AWS D1.1, *Structural Welding Code*

This code covers the welding requirements for any type of welded structure made from the commonly used carbon and low-alloy constructional steels. The SI should be familiar with the following sections:

1) Scope and Application.

2) Requirements for the Welding Inspector.

3) Welding Inspection Operations.

4) Inspection Safety Considerations.

5) Preheating and Postweld Heat Treating.

6) Weld and Weld Related Discontinuities.

7) Destructive Testing of Welds.

8) NDE Methods.

9) Qualification of NDE Personnel.

9.2.3.6 SSPC Standards

a) 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 should be familiar with Sections 1 to 8 of this standard.

b) *SSPC Surface Preparation Guide*

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

1) SSPC-SP1—*Solvent Cleaning*.

2) SSPC-SP3—*Power Tool Cleaning*.

3) SSPC-SP5 or NACE 1—*White Metal Blast Cleaning*.

4) SSPC-SP6 or NACE 3—*Commercial Blast Cleaning*.

5) SSPC-SP7 or NACE 4—*Brush-Off Blast Cleaning*.

6) SSPC-SP10 or NACE 2—*Near-White Blast Cleaning*.

7) SSPC-SP11—*Power Tool Cleaning to Bare Metal*.

9.2.4 Welding Procedures and Qualifications

For fixed and mechanical equipment and materials, 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 engineering. Source inspectors should verify that welders qualified per the approved WPS are being used or have been used for all welding operations. Source inspectors should verify that the approved WPS meets the welding configuration/joint noted on the WPS/PQR. 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. an engineering or welding SME. Source inspectors should verify the continuity log for welders that will or have worked on the fabrication. The *AWS Welding Inspection Handbook*, ASME BPVC Section IX, AWS D1.1, and API RP 577 are the appropriate references for knowledge and understanding of WPS/PQRs.

9.2.5 NDE Procedures

Development of NDE procedures is 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. an engineer or 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.

9.2.6 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. It is recommended that the job of expediting and inspection be separate functions performed by different people. These two functions may be in conflict, and have an adverse impact on the S/V to meet quality requirements. The SI should notify the inspection coordinator if he/she believes that product quality may be compromised by schedule pressures.

9.3 Performing the Source Inspection

9.3.1 Individuals assigned to perform the source inspection activity must follow the S/V ITP as approved by the purchaser. Visual inspection, welding inspection, fit-ups, dimensional inspections, observing NDE, and all other examinations and tests must be performed in accordance with the ITP, project specification, and applicable code and standards, and meet the applicable acceptance criteria. See Section 10 (Examination Methods, Tools, and Equipment).

9.3.2 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.

9.3.3 During the course of manufacturing and fabrication, the S/V may propose work process changes 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 by the purchaser and/or owner-user of the equipment. The SI also should not accept any changes or deviations to approved project documentation without written evidence of purchaser acceptance.

9.4 Source Inspection Work Process Scheduled Planning Events

9.4.1 General

Typical source inspection scheduled work process events include the following.

9.4.2 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 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 surprises during fabrication and source inspection activities.

9.4.3 Pre-inspection Meeting (Prior to Start of Fabrication)

The source inspector assigned to the S/V facility should participate in the pre-inspection meeting (also called the pre-fabrication meeting). 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. Although materials may be ordered in advance of this meeting, no actual fabrication should occur until the pre-inspection meeting has been completed and any concerns or comments have been resolved. Advance preparation by the SI is important for the pre-inspection meeting to ensure the meeting covers all necessary issues and requirements as specified in the contractual agreements and the SI's company policy/practices. This meeting is used to review manufacturing or fabrication readiness of the engineered equipment and materials against the expectations of the work scope. Those requirements may include review of:

a) safety: discuss S/V internal safety requirements and PPE during shop visits;

b) PO and contractual agreements;

c) procedural status;

d) engineering, technical, and material requirements and status;

e) fabrication schedules;

f) critical path and long-lead equipment/materials;

g) role, responsibilities, and limitations of SI;

h) quality requirements, e.g. review of S/V ITP, NCR, process, inspection frequency, etc.;

i) amount of advanced notice required for hold point notification;

j) sub-suppliers and their quality requirements;

k) S/V purchaser, EPC, and third-party inspection;

l) special requirements, e.g. performance or functional testing requirements;

m) painting, preservation, and tagging;

n) communication requirements, e.g. hold point and witness point notification, report distribution, proposed changes, hold points, schedule impacts, etc.;

o) shipping and release plan;

p) final documentation requirements;

q) recording and reporting any observations, exceptions, or deviations;

r) communication channels between SI, S/V, purchaser, EPC and third-party inspection agencies.

These source inspection work process events may also be observed or handled by others besides the SI, including project engineers, purchaser representatives, or a third-party inspection agency.

9.5 Report Writing

9.5.1 A key deliverable of source inspection is the progressive inspection reports detailing the documents reviewed and inspection activity performed, observed, and/or witnessed during the source inspection visits. The report is normally in a standard format and follows a consistent approach to reporting as specified by the purchaser.

9.5.2 The source inspector should reference the following information at a minimum in each report:

a) vendor name;

b) date of visit;

c) equipment tag number and service description;

d) appropriate contract number and key information;

e) purpose of visit;

f) action items or areas of concern;

g) results of inspection/surveillance, including NDE results, accepted/rejected);

h) equipment testing results, including factory acceptance test (FAT), pressure test, pneumatic test, etc.;

i) reference drawings/data used (including drawing numbers) to perform inspection/surveillance;

j) revisions of referenced drawings/data;

k) reference to the applicable requirement in the ITP;

l) identification of nonconforming or deviating items/issues.

9.5.3 Photographs are common in inspection reports as they assist in the description of the inspection results. The SI should request permission from the S/V prior to taking 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.

9.5.4 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.

9.6 Nonconformances/Deviations

9.6.1 Nonconformances are instances where there is objective evidence that the work does not comply with either the requirements of governing technical documents (standards, drawings, specifications, software parameters, technical procedures, etc.) or is not processed in accordance with governing management system documents (e.g. project control procedures). Any deficiencies against the quality management system process should be reported on a nonconformance report. Failure to notify the SI of a hold point or witness point should also result in an NCR.

9.6.2 An NCR is the means to identify and document quality issues. The NCR process should have been discussed at either the engineering meeting and/or the pre-inspection meeting. As S/Vs may differ in format and process for NCRs, the details of how the purchaser requires their NCR process to work should be reviewed in detail at these meetings with the inspectors and engineers.

9.6.3 There are two types of NCRs.

a) Product NCR

A product-related nonconformance occurs when an installed or received item is found to be damaged or not in compliance with a specified design or code criteria.

b) Process NCR

A process-related nonconformance occurs when a work process does not meet defined criteria. An example is a procedure that has not been completely followed, resulting in incomplete or untimely outputs of the procedures. Another example is not following a procedure for the control of weld consumables, resulting in the cutout and rework of welds.

9.6.4 NCRs may be applied in several situations, including (but not limited) to the following:

a) when product quality or functionality differs from the specified requirements and cannot be brought in compliance with immediate means;

b) when replacement materials or parts are required or when technical analysis must be done;

c) where a repair proceeded without either an approved repair procedure or the repair procedure was not correctly followed;

d) when standard repair procedures are not adequate;

e) when a serious cost or schedule impact is foreseen;

f) when concerns with procedural understanding (training) exist;

g) failure of communications, interface, MOC, and reporting procedure;

h) when minor, repeat infractions occur that could impact cost or schedule;

i) when the quality deficiency is requested to be accepted;

j) when the quality deficiency may affect others or require an MOC;

k) when breakdowns occur in the S/V's quality system.

9.6.5 Nonconformance reports should reference the following information at a minimum:

a) date of inspection;

b) contract number and information;

c) description of nonconforming item and issue, including references to standards, specifications, plans, work processes, regulatory and/or code requirements detailing the section/paragraph, document, and revision;

d) objective evidence in the form of photos of discrepancy, if possible;

e) impact on the product;

f) product-related NCR materials that are segregated/isolated and clearly identified to prevent inadvertent use or further processing until the NCR has been successfully dispositioned;

g) NCR shall have item tag number or serial numbers listed on report;

h) S/V recommended disposition of the nonconformance;

i) signatures indicating resolution of the NCR.

9.6.6 The SI should notify the inspection coordinator and the S/V as soon as practical once a nonconformance has been identified. In general, deviations from specifications must be approved by the responsible engineer/ technical personnel.

9.6.7 Acceptable disposition of a product nonconformance (as approved by the responsible engineer/SME) may include:

a) use as is;

b) rework/repair per original contractual documents or approved repair procedure;

c) scrap the equipment/component involved and start over;

d) return to supplier, or (sub)contractor for an acceptable replacement component; may require application of a contract amendment process.

9.6.7.1 Acceptable disposition of a process nonconformance (as approved by the responsible engineer/SME) may include:

a) use as is;

b) conforms to requirements (update documents to comply with requirements);

c) revise process (to match current practices);

d) scrap process (void or delete process).

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

9.6.8 Corrective Action Request (CAR)

The CAR process is initiated when one or more of the following situations are realized:

a) repeated NCRs related to products or services from the same origin;

b) significant NCRs that require a root cause analysis;

c) evidence of significant quality problems related to the purchaser's requirements with S/Vs, contractors, or third-party providers.

9.6.8.1 The SI should not initiate a CAR, but take direction from their technical staff as to when a CAR is required.

9.6.8.2 The corrective action plan should be derived from a causal analysis. The listings will include the corrective actions to be taken to prevent recurrence of the problems. Once the verifications of the short-term actions are confirmed, the long-term actions may be implemented. Verifications are again required to establish the effectiveness of the corrective actions.

9.6.8.3 The CAR process may also require changes to the standards, specifications, work practices, and contract documents. Such changes need to follow the change management process of the impacted functions.

9.6.8.4 Preventive actions (PAR) are identified where there are extremely serious or systemic defects occurring, such as a recurring defect in a particular weld. Normally, an intensive investigation (even a root cause analysis) is undertaken. The analysis normally identifies and corrects more than the area originally identified.

9.7 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 "Plan" and "Do" 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.

9.8 Source Inspector Continuous Improvement

Continuous improvement is a requirement to improve the work process. The SI should learn from the continuous improvement cycle how they can improve their performance on the job by answering such questions as:

a) Are there some industry codes and standards that I should be more familiar with?

b) Are there any safety and/or personal conduct improvements I can make?

c) Can I improve the way I write the various SI reports?

d) Do I need to improve my review of project documents before showing up at the S/V site?

e) Can I improve the way I conducted the pre-fabrication meeting?

f) Can I improve the timeliness of closing out my part of the source inspection project?

g) Do I communicate quickly and clearly enough when defects are uncovered?

10 Examination Methods, Tools, and Equipment

10.1 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.

10.1.1 In-process Inspection

The SI plan identifies overall surveillance activities that can be planned during the normal course of work progress. For ongoing work that requires in-process inspections, the SI should:

a) perform source surveillance activities consistent with the PO and/or contractual surveillance requirements;

b) verify the suppliers' use of drawings with applicable revision levels;

c) ensure that hold, witness, and review points are verified against the ITP requirements;

d) monitor and perform ITP activities according to the scheduled frequency; this includes any performance testing, pressure tests, factory acceptance tests (FAT), and other activities;

e) notify the purchaser of their required involvement during work scope completion;

f) review and approve quality control (QC) documentation as activities are completed;

g) witness regulatory/jurisdictional acceptance and signoff;

h) comply with all reporting requirements, using the purchaser's templates, as available and directed;

i) comply with all site-specific safety rules and regulations.

10.2 Review and Confirmation of Materials of Construction

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

a) Material test reports (MTR): The information necessary for the source inspector to know and understand MTRs is covered in API RP 577 and ASME BPVC Section II, SA-370.

b) Any reports, e.g. MTRs that have been modified, corrected, or obliterated, should be cause for immediate rejection, as these could indicate the potential for the material or component being counterfeit. All MTRs must be legible.

c) Where identified in the ITP, verify PMI has been conducted in accordance with the contractual specification (i.e. API RP 578, purchaser-specific specification, etc.). Correct traceability is important to prevent incorrect, rogue, or counterfeit material from being used. The SI should recognize that materials from certain countries have a higher risk of not meeting specification.

d) Confirming that the construction materials proposed are the actual materials used during construction is a typical source inspection activity. The SI should verify the segregation for release of materials. The SI should also verify the security of materials identified as nonconforming to the specifications so that inadvertent use cannot occur. If it is determined that the security is not adequate, additional vigilance is necessary to verify correct materials are being used in the correct place. The source inspector should:

    1) confirm the correct material type and grade;

    2) confirm the origin of the material;

    3) check material size and/or thickness;

    4) verify traceability of the material to a certifying document;

    5) verify that the material complies with specific chemical and/or mechanical properties, as specified in the contractual documents;

    6) check for evidence of specified heat treatment;

    7) verify that material grade, type, and serial number match the material certifying document. One way of verifying material to the MTR is by comparing the "heat number" on the base material with that listed on the MTR. Some S/Vs' quality programs, as well as purchasers' quality programs, have various methods

for ensuring that the correct material is used in manufacturing with the use of PMI. The source inspector should be familiar with those methods and verify compliance.

10.2.2 The SI should be aware of the potential for counterfeit materials/documents to exist within the supply chain. Key issues to watch for include but are not limited to:

a) generic documentation that is not product-specific;

b) material or equipment containing minimal or no documentation;

c) markings or logos that are questionable, missing, or obliterated;

d) items that have inconsistent appearance;

e) documents that have been altered;

f) items that lack material traceability or product certification;

g) ASME or ASTM stampings that may have been counterfeited;

h) source of material is from certain countries known for supplying sub-standard or counterfeit material.

10.3 Dimensional Inspections

10.3.1 The SI should be proficient in understanding and performing dimensional inspections. Equipment such as tape measures, dial indicators, calipers, protractors, and levels are all typical tools that are used for dimensional inspection. See the Welding Inspection Handbook and API RP 577 for further information on SI tools of the trade.

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

10.4 Visual Inspections

10.4.1 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 them. Portable lighting such as pen lights, high-power flashlights, etc. are common tools that the source inspector may need to perform adequate visual inspection.

10.4.2 SIs 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.

10.5 Nondestructive Examination (NDE) Techniques

10.5.1 General

10.5.1.1 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, and NDE technician qualifications, such as ASNT SNT TC-1A. The SI should be familiar with the NDE qualification/certification processes described in ASNT SNT TC-1A, especially what NDE duties/responsibilities can be performed by Level I, Level II, and Level III NDE technicians.

10.5.1.2 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.

10.5.2 Penetrant Testing (PT)

API RP 577 and ASME BPVC Section V, Article 6, T-620 cover the basic principles of PT. Discontinuities revealed during PT are normally recorded on an NDE report.

10.5.3 Magnetic Testing (MT)

API RP 577 and ASME BPVC Section V, Article 7, T-750 cover the basic principles of MT. Discontinuities revealed during MT are normally recorded on an NDE report.

10.5.4 Radiographic Testing (RT)

API RP 577 and ASME BPVC Section V, Article 2, T-220 and SE-797 cover the basic principles of RT. Discontinuities revealed during RT are normally recorded on an NDE report.

10.5.5 Ultrasonic Testing (UT)

API RP 577 and ASME BPVC Section V, Article 4, and SE 797 and Article 5, T-530 cover the basic principles of UT. Discontinuities revealed during UT are normally recorded on an NDE report.

10.5.6 Hardness Testing (HT)

API RP 577—in particular, Table 11 of the RP—cover the basic principles of hardness testing.

10.5.7 Positive Material Identification (PMI)

API RP 578 covers the basic principles of material verification and PMI. Purchasers may also have specifications regarding material verification programs and PMI, which the SI should be familiar with.

10.6 Destructive Testing

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

10.6.2 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.

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

10.6.4 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.

10.6.5 Most of the information necessary for the source inspector to know and understand about destructive testing of metals is covered in API RP 577.

10.7 Pressure/Leak Testing

10.7.1 General

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

10.7.1.1 Pressure Testing

a) Pressure testing is normally specified to check for leaks or determine whether or not there may be gross errors in design or fabrication that could cause the component to fail (fracture, crack, or deform) under pressure. Pressure tests in shops are usually conducted with water (hydro-testing) or with air (pneumatic testing), or a combination of both (hydro-pneumatic testing). 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, ASME B31.1 for power piping, or ASME B31.3 for process piping. These codes generally indicate how to witness such a test safely after the pressure has equalized and stabilized. Whether testing by hydro-test, hydro-pneumatic, or pneumatic, the pressure testing equipment should have the means to prevent overpressuring the equipment under test. The SI should check that there is an adequate method to prevent overpressure. Special attention should be given to the purchaser's hydro-test specification, monitoring/ checking of pressure gauges for calibration, and use of pressure recorders.

   Hydro-testing 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 verify that there is no air left in the system. Water is considered non-compressible while air is compressible. The compression of air left in equipment during hydro-testing can lead to catastrophic brittle fracture and severe injury if the tested commodity were to fail during the test. The ambient air condition should be closely monitored during hydro-testing that is performed outdoors. Temperature swings from increasing outside temperatures and exposure to the sun, or decreasing temperatures after dark, will cause significant increases or decreases in pressure. When the makeup and or quality of the water is specified, the SI should review the documents assuring that the water quality meets specified requirements.

b) Pneumatic testing is generally conducted with air, though sometimes it is 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 fails under pneumatic pressure being propelled with great force for long distances, thereby doing significant damage and/or inflicting severe injury.

c) Leak testing is generally the term used to describe low-pressure testing with air or gas 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 that 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 that detail the leak test procedure and generally reference an industry standard that must be followed.

10.8 Performance/Functional Testing

Performance and functional testing are generally not applicable to fixed equipment, such as vessels and piping, and is more related to machinery, instruments, analyzers, and control systems to determine that the equipment will perform as specified in service. In situations where the SI is involved in performance/functional testing, a specific procedure with acceptance criteria will be involved, and often an engineer or other SME will also witness the test. Unless otherwise specified in the contractual documents, the performance testing of vessels and piping is generally limited to assuring that they are leak-free.

10.9 Surface Preparation/Coatings Inspections

10.9.1 Performance of coating systems typically depends on how well the substrate or surface is prepared for coating applications. Typically, on fixed equipment, visual inspection of surface preparation is recommended or required. Inspections typically consist of:

a) review of coating application documentation, such as surface profile measurements and environmental conditions;

b) visual surface comparison;

c) verification of blasting medium.

10.9.2 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.

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

10.9.4 In addition to purchase order requirements and company standards, the coating manufacturer's recommendations will provide the details for correct coating application to be followed. Ensure that the manufacturer's recommended application conditions, such as temperature and humidity, were met during the coating application and that the coating batch numbers are recorded when required by the ITP.

10.9.5 Prior to releasing the fixed equipment for shipment, the source inspector should inspect the coated or lined surfaces for the following items: raised areas, pinholes, soft spots, disbondment, delaminations, blisters, holidays, bubbling, fisheyes, runs and sags, uniformity, mechanical damage, orange peel, adhesion, mud flat cracking, and proper color or shade.

10.9.6 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.

10.9.7 Inspection of internal coatings for corrosion protection are normally completed by a NACE certified coating inspector.

10.10 Final Acceptance

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

a) All work specified in the contractual agreements is completed by the S/V.

b) All NCRs have been closed out and satisfactorily resolved by the S/V QC representative and the owner's QA representative.

c) NCRs are identified and reported in the supplier's quality management system.

d) Appropriate NCR-related corrective measures are implemented and effectiveness is verified.

e) NCRs are properly followed up for containment, corrective measures, and corrective actions.

f) All punch-list items have been completed.

g) All inspection-related activities have been completed and documented.

h) 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.

10.10.1 Where applicable, the manufacturer's report book (MRB) is complete, with all documents approved and signed off, and meets all contractual requirements.

10.10.2 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.

10.10.3 It is typical for the SI to perform a final review of the contractually required S/V data upon the completion of the manufacturing/fabrication and prior to shipment of the materials or equipment. This review is to determine that all documents are complete and signed off, with the as-built item and all supporting documents as identified in the contractual agreement. This is normally referred to as the manufacturer's record book (MRB). Such documentation may include but is not limited to:

a) final fabrication drawings;

b) MTRs;

c) pressure test documentation;

d) weld map;

e) NDE results;

f) heat treatment documentation;

g) product-specific QC checks;

h) NCR close-outs;

i) certification documents;

j) code compliance documentation;

k) completed/signed copy of S/V ITP.

11 Manufacturing and Fabrication Processes

11.1 General

11.1.1 The manufacturer/fabricator is responsible for the quality of all their M&F products, which includes good workmanship and compliance with all codes, standards, and specifications contained in the contractual agreements. The source inspector should verify that equipment used has been calibrated in accordance with either national standards or manufacturer's requirements so that it will perform correctly. 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 M&F processes that are commonly used include welding, heat treatment, casting, forming, forging, machining, assembly, etc. The source inspector needs to be familiar with those M&F processes to confirm compliance with codes, standards, and project document requirements. For all M&F processes, including rework and repair, the following information should be consistent and confirmed:

a) M&F process has a documented method describing how to perform the work.

b) Individuals required to perform the M&F process have proof of training and qualifications.

c) Individuals performing the work have immediate access to the relevant M&F procedures.

d) There are acceptance criteria documented to determine if the M&F processes results are acceptable.

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

11.2 Welding Processes and Welding Defects

Typical welding processes used in M&F of equipment and the variety of potential welding defects are covered in API RP 577. The SI should be familiar with these sections. Different welding processes are susceptible to different types of welding defects. Therefore, it is important for the SI to know which welding processes will be applied to the equipment during M&F and to be familiar with the typical defects that can occur during each welding process.

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 solidifying 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:

a) complex shapes, e.g. fittings, flanges, valve bodies;

b) hollow sections or internal cavities;

c) irregular curved surfaces;

d) very large size;

e) 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:

a) shrinkage voids;

b) gas porosity;

c) trapped inclusions.

11.3.3 Castings are susceptible to the creation of voids during the casting process that 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 their 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 Material grade symbols are required on valve castings (e.g. WCB, WC9, CF8M, and so forth) 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 and that the material used confirms with the stamping through a PMI process.

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 SI 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 several 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:

a) increased wear resistance without increased hardness/loss of ductility;

b) stronger/tougher than an equivalent cast or machined component;

c) less-expensive alloys can be used to produce high-strength components;

d) 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:

a) The purchaser may specify additional requirements.

b) Tension and hardness tests must be conducted to evaluate mechanical properties.

c) Repair welding is not allowed unless permitted by the product specification.

11.4.3 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 refers to any of several metal working processes in which 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, plaining, boring, broaching, and sawing.

11.5.2 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.

11.5.3 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. 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.

11.5.4 Machining requires attention to many details for a workpiece to meet the specifications set out in engineering drawings or blueprints. Besides the obvious issues 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 finished machined components. Gasket surface inspections may be an exception; it is not uncommon to witness a dial indicator sweep for flatness and to verify the gasket surface finish prior to removing the equipment/component from the machine.

11.6 Assembly

Assembly generally has more to do with machinery, instrumentation, control systems, and electrical gear looking for fit/form/function. However, for mechanical equipment such as skid units and other equipment that is to be assembled, e.g. forgings, flanges, and/or other connections, the SI should be looking for proper tolerances or tight fit-up of all connections. This can be accomplished with measurements, torque wrenches, or “pinging” bolts with a small hammer (like a slag or ball peen hammer). When pinging, caution should be exercised, as this does not guarantee the correct torque on the studs has been applied. The SI should check to make sure that bolted flanges and screwed fittings are leak-free and the correct gaskets are installed when witnessing pressure tests per 10.7.1.1.

11.7 Metallurgy Issues Associated with Manufacturing and Fabrication Processes

11.7.1 The Structure and Metals

Metallurgy is a complex science for which many schools have four-year degree 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. Most of the information necessary for the SI to know and understand about metallurgical issues is covered in API RP 577, which the SI should be familiar with.

11.7.2 Physical Properties of Metals

The physical properties of a metal or alloy are those that are relatively insensitive to structure and can be measured without the application of force. Examples of physical properties of a metal are melting temperature, thermal conductivity, electrical conductivity, coefficient of thermal expansion, and density. Most of the information necessary for the source inspector to know and understand about the physical properties of metals is covered in API RP 577.

11.7.3 Mechanical Properties of Metals

Engineers select materials of construction that provide adequate strength and toughness at operating temperatures and pressures. For source inspectors, verification that mechanical properties meet design requirements is essential. Source inspectors should understand the underlying principles of mechanical properties and the nature of tests conducted to verify the value of those properties. Most of the information necessary for the source inspector to know and understand about the mechanical properties of metals is covered in API RP 577.

11.7.4 Hardness and Hardenability of Metals

Hardenability is defined as the 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. Most of the information necessary for the source inspector to know and understand about the hardness and hardenability of metals is covered in API RP 577.

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.” Most of the information necessary for the source inspector to know and understand about the weldability of metals is covered in API RP 577.

11.7.6 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 preheat zone for welding of new process piping should extend at least one inch beyond the edge of the weld for piping. Most of the information necessary for the source inspector to know and understand about preheating is covered in API RP 577.

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 total duration of the PWHT including ramp-up, soak, and cool-down times 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 1100 °F for one hour per inch of thickness, with 15-minute minimum hold time. 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 process 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 to verify even distribution of temperature on components and to verify that no component is over-heated or under-heated during PWHT. Most of the information necessary for the SI to know and understand about PWHT is covered in API RP 577; ASME BPVC Section VIII, Division 1, UCS-56; and ASME B31.3, B31.1.

11.7.6.3 Other Heat Treatments

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

12 Pressure Vessels

12.1 General

12.1.1 A pressure vessel is a container designed to withstand internal and/or external pressure. The pressure vessels are typically constructed in accordance with ASME BPVC Section VIII or other recognized international pressure vessel codes, or as approved by the jurisdiction. These codes typically limit design basis to an external or internal operating pressure greater than 15 psig (103 kPa). However, vessels can also operate at lower pressures. External pressure on a vessel can be caused by an internal vacuum or by fluid pressure between an outer jacket and the vessel wall. Columns, towers, drums, reactors, heat exchangers, condensers, air coolers, bullets, spheres, and accumulators are common types of industry pressure vessels.

12.1.2 Pressure vessels are designed in various shapes. They may be cylindrical (with flat, conical, toriconical, semispherical, semi-ellipsoidal, or hemispherical heads), spherical, or boxed (with flat rectangular or square plate heads, such as those used for the headers of air-cooled exchangers). They may be of modular construction. Cylindrical vessels, including exchangers and condensers, may be either vertical or horizontal and may be supported by steel columns, cylindrical plate skirts, or plate lugs attached to the shell. Spherical vessels are usually supported by steel columns attached to the shell or by skirts. Spheroidal vessels are partially or completely supported by resting on the ground. Jacketed vessels are those built with a casing or outer shell that forms a space between itself and the main shell. The primary difference between a tank and a vessel is that tanks generally operate at lower pressures, often at or just above atmospheric pressures.

12.2 Vessel Methods of Construction

Several different methods are used to construct pressure vessels. Most pressure vessels are constructed with welded joints. Shell rings are usually made by rolling plate at either elevated or ambient temperature. The cylinder is formed by welding the ends of the rolled plate together. This yields a cylinder with a longitudinal weld. Hot forging is another method of making cylindrical vessels. Some vessel manufacturers hot forge cylindrical shell rings for high pressure, heavy wall vessels, such as those used for hydrotreater or hydrocracker reactors. This method does not produce a longitudinal seam in the cylinder.

12.3 Vessel Materials of Construction

12.3.1 Carbon steel is the most common material used to construct pressure vessels. For special purposes, a suitable austenitic or ferritic alloy, Alloy 400, nickel, titanium, high-nickel alloys, or aluminum may be used. Copper and copper alloys (except Alloy 400) are seldom used in refinery vessels, but are common with heat exchanger tubes and may be found in petrochemical plant vessels. Materials used to construct the various parts of heat exchangers are selected to safely handle the service and the heat load required. Materials based on a life-cycle that will best resist the type of corrosion expected are selected.

Exchanger shells are usually made of carbon steel, but may be made of a corrosion-resistant alloy or clad with a corrosion-resistant material. Exchanger channels and baffles are made of carbon steel or a suitable corrosion-resistant alloy material, usually similar to the material of the tubes.

12.3.2 Tubes for exchanger bundles may be made from a variety of materials. Where water is used as a cooling or condensing medium, they are generally made of copper-based alloys or steel. In water applications, where copper alloys or steels will not provide sufficient corrosion protection, higher-alloy materials, such as duplex stainless steel, may be used, or the tube ID may be coated (baked epoxy or similar). Titanium may be used in seawater applications. Where the exchange is between two different hydrocarbons, the tubes may be made of carbon steel or a suitable corrosion-resistant alloy. Tubes consisting of an inner layer of one material and an outer layer of a different material (bimetallic) may, in some cases, be required to resist two different corrosive mediums.

12.3.3 Tube sheets for exchanger bundles are made from a variety of materials. Where water is the cooling or condensing medium, they are usually made of admiralty brass or carbon steel, but may also be constructed of high-alloy steels (clad or solid). Titanium may be used in seawater applications. Where the exchange of heat is between two hydrocarbons, the tube sheets may be composed of carbon steel or a suitable corrosion-resistant alloy. In some cases, it may be necessary to face one side of the tube sheet with a material different from that facing the other to resist two different corrosive mediums.

If carbon steel would not resist the corrosion or erosion expected, or would cause contamination of the product, vessels may be lined with other metals or nonmetals. A lined vessel is usually more economical than one built of a solid corrosion-resistant material. However, when the pressure vessel will operate at a high temperature, a high pressure, or both, solid alloy steels may be both necessary and economical.

Internal metallic layers are installed in various ways, usually to provide more corrosion resistance than would be provided by the carbon steel base layer. Those layers may be an integral part of the plate material (cladding) rolled or explosion bonded before fabrication of the vessel. They may instead be separate sheets of metal fastened to the vessel by welding (also called strip lining). Corrosion-resistant metal can also be applied to the vessel surfaces by various weld overlay processes. Metallic liners may be made of a ferritic alloy, austenitic alloy (e.g. 300 series stainless steels), Alloy 400, nickel, or any other metal resistant to the corrosive agent.

12.3.4 Austenitic stainless steels (300 series) come in a variety of Cr/Mo/Ni/Fe contents. The most widely used are the 18Cr/8Mo series (known as 18/8 stainless steels), which include type 304, 347, and 321 grades. Type 321 and 347 are stabilized grades that will avoid sensitization of the HAZ during welding, and therefore retain most of their corrosion resistance during fabrication. Type 321 is stabilized with small amounts of Ti, while Type 347 is stabilized with small amounts of Nb.

Some Type 300 stainless steels also come in “L” grades, such as 304L, 316L, and 317L. The “L” stands for low carbon. These low-carbon grades are also more resistant to sensitization of the HAZ during welding.

Some Type 300 stainless steels also come in “H” grades, such as 304H, 316H, and 317H. The “H” stands for high carbon. These high-carbon grades are stronger at high temperatures than the low-carbon grades.

12.3.5 All materials used for the construction of pressure vessels should have traceability. For example, acceptable methods of traceability for plates used in the fabrication of vessels include:

a) plate number;

b) lot number;

c) heat number;

d) country of origin.

12.3.6 Nonmetallic liners may be used to resist corrosion and erosion, reduce fouling potential (i.e. exchanger tubes), or to insulate and reduce the temperature on the walls of a pressure vessel. The most common nonmetallic lining materials are reinforced concrete, acid brick, refractory material, insulating material, carbon brick or block, rubber, phenolic/epoxy coatings, glass, and plastic.

12.3.7 Pressure vessels constructed from nonmetallic materials are usually made from fiber-reinforced plastic (FRP) and can be more resistant to some corrosive services. FRPs can be made with different resins as the matrix material and typically use glass fiber as the reinforcement. Reinforced thermoset plastics are a type of FRP that is more rigid due to the use of a thermoset resin for the matrix rather than a thermoplastic. Both of these nonmetallic materials have varying strength due to the type of fiber used, fiber weave, and the lay-up of the fiber layers.

12.4 Vessel Internal Components

Many pressure vessels have no internals. Others have internals such as baffles, distribution piping, trays, mesh or strip-type packing grids, catalyst bed supports, cyclones, pipe coils, spray nozzles, demister pads, and quench lines. Large spheroids may have internal bracing and ties, and most vacuum vessels have either external or internal stiffening rings. Some pressure vessels have heat exchangers or reboilers located in the lower shell area.

12.5 Vessel Design and Construction Standards

In the U.S. and many other countries, pressure vessels are typically constructed in accordance with ASME BPVC Section VIII, which is divided into three parts: Division 1, Division 2, and Division 3. Division 1 provides requirements applicable to the design, fabrication, inspection, testing, and certification of pressure vessels operating at either internal or external pressures exceeding 15 psig. Division 2 provides alternative and more stringent rules for the design, fabrication, and inspection of vessels than those found in Division 1. Most pressure vessels for U.S. refineries are now built to conform to the latest edition of Division 1. Some high-pressure vessels are designed and built in accordance with the specifications of Division 2. Division 3 provides alternative rules for construction of high-pressure vessels with design pressure generally above 10 ksi (70 MPa).

The ASME BPVC requires that welding procedures and welders who construct pressure vessels be compliant with Section IX of the ASME BPVC. The SI is responsible for ensuring that procedures and welders are so qualified.

In Annex A, the most common types of ASME Code Symbol Stamps are shown. These stamps are applied to vessel nameplates by ASME-certified shops upon completion of the vessel or PSV to show compliance with a particular section of the ASME BPVC. The SI should be familiar with these code stamps.

Divisions 1 and 2 of Section VIII of the ASME BPVC require the manufacturer of a vessel to have a quality assurance system. Before the manufacturer can obtain a certificate of authorization from ASME, a written quality manual must be provided and approved, and the system must be implemented. The quality assurance system requires detailed documentation of examinations, testing, and design data regarding the vessel, and provides a history of the construction of the vessel. This documentation is necessary when evaluating vessels after being placed in service.

The ASME BPVC lists materials that may be used for construction, provides formulas for calculating thickness, provides rules on methods of manufacture, and specifies the procedures for testing completed vessels. Inspection is required during construction and testing of vessels. The code also prescribes the qualifications of the persons who perform the construction inspections, i.e. code authorized inspectors (AI).

After an authorized construction inspector of the jurisdiction (AI) certifies that a vessel has been built and tested as required by the ASME BPVC, the manufacturer is empowered to stamp the vessel with the appropriate symbol of the ASME BPVC. The SI should be aware that the AI is only interested that the vessel is built to the specified construction code, e.g. ASME BPVC. Additional requirements that may be specified in the contractual documents (and often are included), but that are potentially more stringent than the construction code requirements, will not be addressed by the AI; the SI will need to be more diligent when reviewing requirements not contained in the code of construction.

The symbol stamped on a pressure vessel is an assurance by the manufacturer that the vessel has been designed, constructed, tested, and inspected as required by the ASME BPVC.

Some states and cities, as well as many countries, have laws and regulations beyond that of the ASME BPVC (and other codes) that govern the design, construction, testing, installation, inspection, and repair of pressure vessels used in their localities. These laws may supersede the ASME BPVC's (and other code's) minimum requirements.

Construction codes are periodically revised as the designs of pressure vessels improve and as new and improved construction materials become available. However, it is vital that the SI make sure that the vessels are constructed in accordance with the editions of the codes specified in the contractual agreements, which may not be the same as the current editions of codes and standards.

12.6 Dimensional Check of Pressure Vessels

The SI should conduct dimensional checks of pressure vessels to verify they are within the required tolerances of the specification. At a minimum, these checks consist of the following:

a) mill under-tolerance of plates and pipes;

b) tolerances for formed heads;

c) out-of-roundness of shell;

d) nozzles and attachments orientation;

e) nozzles and attachments projection;

f) nozzles and attachments elevation;

g) nozzles and attachments levelness;

h) weld fit-up;

i) weld reinforcement.

12.7 Heat Exchangers

12.7.1 Exchangers are used to reduce the temperature of one fluid by transferring heat to another fluid without mixing the fluids. Exchangers are called condensers when the temperature of a vapor is reduced to the point where some or all of the vapor becomes liquid by the transfer of heat to another fluid, often water. When a hot fluid is cooled to a lower desired temperature by the transfer of heat to another fluid, the exchanger is usually referred to as a cooler. When ambient air is used to reduce the temperature of a hot liquid to a lower desired temperature, the exchanger is referred to as an air cooler (or fin-fan).

12.7.2 There are several types of shell and tube-bundle exchangers. Usually, the tubes are attached to the tube sheet by expansion (rolling). The tubes may be rolled and welded or attached by packing glands. A description of some types of commonly used exchangers follows.

12.7.3 Exchangers are equipped with baffles or support plates, the type and design of which vary with the service and heat load the exchanger is meant to handle. Pass partitions are usually installed in the channels and sometimes in the floating tube-sheet covers to provide multiple flows through the tubes. The flow through the shell may be single pass, or longitudinal baffles may be installed to provide multiple passes. The baffling used in the shell will determine the location and number of shell nozzles required. Frequently, an impingement baffle plate or rod baffle is located below (if inlet is top side) the shell inlet nozzle to prevent impingement of the incoming fluid on the adjacent tubes.

12.7.4 The tubes may be arranged in the tube sheet on either a square or triangular pitch. When the fluid circulating around the outside of the tubes may coke or form other dirty deposits on the tubes, the square pitch is generally used. The square pitch arrangement permits better access for cleaning between the tubes.

12.7.5 An air-cooled unit (sometimes referred to as a fin-fan) is similar to an exposed tube bundle unit; however, ambient air is used as the cooling medium. A bank of tubes is located in a steel framework through which air is circulated by a fan placed either above or below the tube bank (a fan above the tube bank is usually referred to as an induced draft air cooler and a fan below the tube bank is usually referred to as a forced draft air cooler). These coolers may be used for the condensing or cooling of vapors and liquids, and are installed where water is scarce or for other reasons. API Standard 661 covers the minimum requirements for design, materials, fabrication, inspection, testing, and preparation for delivery of air coolers.

12.7.6 In the U.S., heat exchangers and condensers are designed and built in accordance with ASME BPVC, TEMA standards, API Standard 660, *Shell-and-Tube Heat Exchangers*, and API Standard 661, *Air-Cooled Heat Exchangers for General Refinery Services* (other countries may follow equipment design requirements other than ASME, TEMA, and API). As with all fixed equipment items, the M/F is responsible for ensuring that the fabricated heat exchanger complies with the applicable standard when it is specified in the contractual documents. Sections 2 and 3 of the TEMA mechanical standard for shell and tube exchangers are pertinent to the SI, as they cover:

a) fabrication tolerances;

b) shop inspection;

c) nameplates;

d) code data reports;

e) preparation for shipment.

13 Piping

13.1 General

For piping designed and fabricated to ASME B31.1/3, the SI is responsible for verifying that all required examinations and testing have been completed and for inspecting the piping to the extent necessary to be satisfied that it conforms to all applicable specification and examination requirements for ASME B31.1/3 and the engineering design. Process piping in the oil, gas, and chemical industries is designed and fabricated to B31.3, while power piping (associated with boilers) is designed and fabricated to B31.1.

13.2 Valves

13.2.1 There are various methods for manufacturing valves. The purchase order documents should be checked to determine what methods apply. The valve bodies and bonnets are typically made of cast or forged material. The body and bonnet are then machined as required by the valve specification. The seat may be integral with the body, or a seat ring would be welded or threaded into place. The seat or seat ring would normally be hard surfaced. The valve disc (closure mechanism) would be machined from bar or plate and may also be hard surfaced before machining. The valve is then assembled, stem packing added (where required), and then tested, typically to API Standard 598.

13.2.2 When performing source inspection for valves, the SI should review the purchase order for required valve characteristics (i.e. size, material, rating, trim, etc.) and verify that the valves meet the specification.

13.2.3 Valve pressure testing is normally required for the shell body, seat leakage, back seat, and packing. Hydrostatic testing is normally applied per API Standard 598; however, pneumatic testing is normally applied for seat leakage testing. The test medium, pressures, and holding times should be in accordance with the contractual documents and/or API Standard 598.

13.2.4 API Standard 598 does not apply to every valve that is manufactured. The standard is mostly applied to standard metallic valves (butterfly, gate, globe, ball, etc.) used in ASME B31.1 or B31.3 applications. Other specialty valves (such as relief valves, control valves) may have to be tested in accordance with other standards as specified in the purchase order documents. It is the responsibility of the SI to confirm the requirements in the purchase order documents.

13.2.5 NDE requirements for valves (body, bonnets, welding, weld preps) are not found in API Standard 598. NDE requirements for valves will be governed by the applicable piping code (ASME B31.3 or B31.1) and/or the purchase order documents.

13.2.6 At a minimum, marking on valves shall comply with the requirements of MSS-SP-25, *Standard Marking System for Valves, Fittings, Flanges and Unions*, unless otherwise specified in the purchase order documents. Markings shall be applied to the body of a valve or an identification plate.

13.2.7 Markings indicating conformance with recognized documents/standards (such as ASME, ANSI, AWWA, API, UL/FM, etc.) may be applied only by authorized, licensed, or approved manufacturers. Such markings shall be applied only to the products that fully comply, and may be shown on the body or an attached plate at the option of the manufacturer.

13.2.8 Flow directional indication shall be marked on unidirectional valves. Commonly used markings include arrows or the words “inlet” or “outlet” marked on the appropriate end.

13.2.9 Other product markings that can be cast, forged, or engraved on the body, or put on a permanently attached tag, include:

a) manufacturer’s name, trademark, or symbol, unless the size or shape does not permit;

b) the rating designation, which is one of the required markings. The rating can be in the form of recognized national standard pressure class (i.e. 150#, 300#, etc.). If the valve does not conform to a recognized national standard, the rating may be shown by numbers and letters representing the pressure rating at maximum/minimum temperatures;

c) ASTM/ASME material identification (not required for some copper/brass materials and gray/ductile iron);

d) melt identification (heat number);

e) valve trim identification (stem-disc-seat);

f) size designation; usually, this will be the nominal pipe size. In some instances where the closure size is smaller than the inlet/outlet size, the size will be shown as (nominal pipe size) x (closure pipe size). For example, if the inlet/outlet pipe size is 6 in. and the closure pipe size is 4 in., the size of the valve will be shown as 6X4;

g) special identification (such as UL/FM, B16.34, NACE, etc.);

When the shape or size does not permit inclusion of all the required markings, some markings may be omitted starting with the least important information such as size;

Required markings, if shown on the body, need not be duplicated on the identification plate.

13.3 Flanges

13.3.1 A flange is a method of connecting piping segments and piping to valves, pumps, and vessels. Flanges are usually welded or screwed into such systems and then joined with studs and nuts. The SI should be familiar with the different types used on the equipment in the contractual documents. Proper controls must be exercised in the application of flanges to attain a joint that has leak tightness. Special techniques, such as controlled bolt tightening (torqueing/tensioning) are described in ASME PCC-1, *Guidelines for Pressure Boundary Bolted Flange Joint Assembly*.

13.3.2 Pipe flanges that are made to standards such as ASME B16.5 [see 9.2.3.3 d) 12) IV] or ASME B16.47 are typically made from forged materials and have machined surfaces for gaskets.

13.3.3 ASME B16.5 covers NPSs from ½ in. to 24 in. and ASME B16.47 covers NPSs from 26 in. to 60 in. Each specification further delineates flanges into pressure classes: 150, 300, 400, 600, 900, 1500, and 2500 psi for ASME B16.5, and 75, 150, 300, 400, 600, and 900 for ASME B16.47.

13.3.4 ASME B16.48 covers piping line blanks (blinds).

13.3.5 The gasket type and bolt type are generally specified by ASME BPVC Section VIII, Division 1, Appendix 2.

13.3.6 Flanges are recognized by ASME pipe codes such as ASME B31.1, *Power Piping*, and ASME B31.3, *Process Piping*. Materials for flanges are usually covered in ASME designation: SA-105, *Specification for Carbon Steel Forgings for Piping Applications*, SA-266, *Specification for Carbon Steel Forgings for Pressure Vessel Components*, or SA-182, *Specification for Forged or Rolled Alloy-Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service*.

13.3.7 Typical types of flanges include:

a) Weld neck flange: This flange is circumferentially welded into the system at its neck, which means that the integrity of the butt-welded area can be easily examined by radiography. The bores of both pipe and flange match, which reduces turbulence and erosion inside the pipeline. The weld neck is therefore favored in critical applications

b) Slip-on flange: This flange is slipped over the pipe and then fillet welded to the pipe, both on the ID and OD.

c) Blind flange: This flange is used to blank off pipelines, valves and pumps; it can also be used as an inspection cover. It is sometimes referred to as a blanking flange.

d) Socket welded flange: This flange is counter bored to accept the pipe before being fillet welded.

e) Threaded flange: This flange is referred to as “threaded” or “screwed.” It is used to connect other threaded components in low-pressure, noncritical applications. The advantage of threaded flanges is that no welding is required.

f) Lap joint flange: These flanges are used with a stub end that is butt welded to the pipe, with the flange loose behind it. This means the stub end creates the sealing face for the flange gasket. The lap joint is favored in low-pressure applications because it is easily assembled and aligned.

g) Ring type joint (RTJ) flange: This is a method of providing leak-proof flange connections in high-pressure service. A metal ring is compressed into a hexagonal (or oval) groove on the face of the flange to make the seal. This jointing method can be employed on weld neck, slip-on, and blind flanges.

h) Other types of specialized or proprietary connectors may be specified on certain equipment. The SI should become familiar with these types of connectors if they are specified in the contractual documents.

13.3.8 Flanges have different types of faces, i.e. sealing surfaces for different services, such as raised-face, flat face, ring joint, and lap joint. Raised-face is the most common type.

13.3.9 There are many types of flange gaskets used for proper bolted flange joints, including spiral wound, compressed asbestos, graphite, ring joint, corrugated metal, double-jacketed, rubber, Teflon, etc. Flange gaskets allow mated flanges to be sealed under the proper bolt load.

13.3.10 Spiral wound gaskets are more common in the hydrocarbon production and process industries. They comprise a mix of metallic rings and filler material with inner and/or outer rings. Generally, the spiral wound gasket has a metal alloy wound outwards in a circular spiral with a filler material (typically a flexible graphite or PTFE) wound in the same manner but starting from the opposing side. This results in alternating layers of filler and metal. The filler material in these gaskets acts as the sealing element, with the metal providing structural support. The SI should be familiar with the gasket identification markings as required by ASME B16.20. Once installed in a bolted flange assembly, the type and material of spiral wound gaskets can be identified by color coding on the outside edge. These gaskets have proven to be reliable in most applications, and allow lower clamping forces than solid gaskets. It is important for the SI to verify that a bolted flange assembly contains the specified gasket or premature gasket failure could occur resulting in a leak or blow-out.

13.4 Fittings

13.4.1 There are several types of pipe fittings. Piping systems designed and fabricated to ASME B31.1/3 utilize forged, wrought, and cast fittings. Fitting components commonly used include elbows, couplings, unions, reducers, o-lets, tees, crosses, caps, blanks (blinds), and plugs.

13.4.2 Manufacturing processes used to make fittings consist of forgings, bars, plates, and seamless or fusion welded tubular products with filler metal added.

13.4.3 Construction materials of carbon steel and alloy steel must conform to the chemical requirements provided in the applicable industry standard specification.

13.4.4 The SI must be familiar with the specified information vital to the quality of manufactured fittings: heat treatment, chemical composition, mechanical properties (such as tensile and impact test properties), dimensions, surface quality, inspection and testing, certification, and product marking.

13.4.5 Manufacturing tolerances for widely used wrought fittings may be found in ASME B16.9 for butt welding fittings and ASME B16.11 for socket weld and threaded fittings.

14 Structural Components

14.1 The basic design code for fabrication and erection of structural steel comes from the American Institute of Steel Construction (AISC). The primary sections of the AISC generally used include (but are not limited to):

a) AISC 303, *Code of Standard Practice for Steel Buildings and Bridges*

b) AISC 325, *Steel Construction Manual*

c) AISC 348, *Specification for Structural Joints Using ASTM A325 or A490 Bolts*

d) AISC 360, *Specification for Structural Steel Buildings*

The applicability of the above referenced codes will be identified in the purchase order documentation. For purposes of the SI examination, the SI need not be familiar with the contents of these standards.

14.2 The welding of structural steel generally falls under the requirements of AWS D1.1; however, in some instances, AISC does provide specific limitations or requirements that supersede the requirements of AWS D1.1.

14.3 When NDE is required, the process, extent, and standards of acceptance will be defined in the purchase order documentation.

14.4 Dimensional tolerances are generally in accordance with AISC 303 unless specifically shown on the shop drawing.

14.5 ASTM A6 covers a group of common requirements for structural steel that, unless otherwise specified in the material specification, is applied to rolled structural steel bars, plates, shapes, and sheet piling. The specification provides dimensions and permitted variations for structural shapes.

14.6 Materials used for structural steel must be new and meet the requirements of ASTM A6 unless otherwise noted in the purchase order documents. Material substitution (grade, sizes, shapes of equivalent strength) are not allowed without engineering approval.

14.7 ASTM A325, A325M, A490, and A490M are used for high-strength structural bolts.

14.8 Marking: All structural steel must be clearly marked for field erection (member identification). All markings are to be placed on the steel in a legible fashion.

Structural member identification will generally be performed using one of the following methods:

a) stamped on the member;

b) corrosion-resistant tag wired to the member;

c) corrosion-resistant coating.

In all cases, the member marking shall be clearly visible on the member after any galvanizing process.

If required by the purchase order documents, erection marks or member weight marking may also be required to aid in field erection.

14.9 Coating/galvanizing:

a) Members and parts to be galvanized should be designed, detailed, and fabricated to provide for flow and drainage of pickling fluids and zinc, and to prevent pressure build-up in enclosed parts.

b) Galvanizing should be in accordance with ASTM A123 or A153 unless otherwise specified in the purchase order documents.

c) Shop painting is not required unless specified by the purchase order documents.

d) Except for contact surfaces, surfaces inaccessible after shop assembly shall be cleaned and painted prior to assembly.

e) Machine-finish surfaces shall be protected against corrosion by rust-inhibitive coating that can be removed prior to erection or that has characteristics that make removal prior to erection unnecessary.

Annex A
(informative)

Most Common Types of ASME and NB Code Symbol Stamps

In Figure A.1, the symbol in the far-left column was used prior to 2013. The ASME symbol with lower designator in the second column is the replacement code symbol stamp as of 2013.

Pressure Vessels—Section VIII, Division 1		
U	ASME	Pressure Vessel
UV	ASME	Pressure Vessel Safety Valves
Pressure Vessels—Section VIII, Division 2		
U2	ASME	Alternative Rules for Pressure Vessels
Pressure Vessels—Section VIII, Division 3		
U3	ASME	High-pressure Vessels
Power Boilers—Section I		
S	ASME	Power Boilers
PP	ASME	Pressure Piping
V	ASME	Power Boiler Safety Valves
National Board Inspection Code Symbol Stamps		
	R	Repair and Alteration
	VR	Repair of Safety Valves

Figure A.1—ASME and NB Code Symbol Stamps

Annex B
(informative)

Types of Tools for Use by the Source Inspector

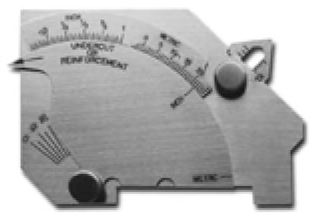
Equipment	Picture	Comment
Flashlight	 (public domain)	Supplemental light source for visual inspection
Tape measure	 (Starrett)	Dimensional inspection
Bridge cam gauge	 (public domain)	Multipurpose welding inspection gauge
Welding gauge		Measures internal alignment for components to be welded
Radiograph viewer 4" x 17"	 (public domain)	Light source for reviewing radiographic film
Radiograph film densitometer		Tool designed to measure the degree of darkness of radiographic film

Figure B.1—Source Inspection Tools (1)

Digital caliper		Instrument used to measure distance between opposite sides of an object; typically used for close tolerance dimensions on machined parts
OD micrometer		Instrument used to measure outside diameters/dimensions; typically used for close tolerance dimensions on machined parts
Pit gauge		Measures the depth of weld undercut or other surface discontinuities
Inspection mirror		Tool designed to support visual inspection in limited and/or obscured areas
Temperature indicator		Used for reading temperatures by changing from solid to liquid at a specific temperature
Infrared thermometer		Tool for measuring surface temperature
Clamp-on amp meter		Tool designed to measure electric current in amperage and voltage; may be used for checking welding machine settings

Figure B.2—Source Inspection Tools (2)

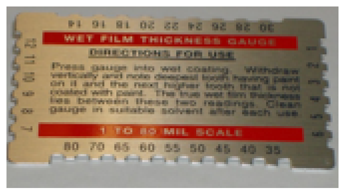
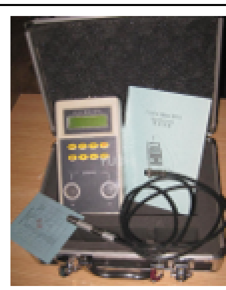
Digital surface profile gauge		Tool designed to measure the surface roughness for material that is about to be coated
Surface profile replica tape		Tool designed to replicate surface profile and measure surface roughness
Wet film thickness gauge		Tool for measuring uncured thickness of coating
Camera		Tool for photographic record-keeping
Magnifying glass		Tool for enhanced visual inspection
Positive material identification tool		Tool designed to verify or measure chemical content
Ferrite meter		Tool to measure the ferrite (iron phase) content in stainless steels

Figure B.3—Source Inspection Tools (3)

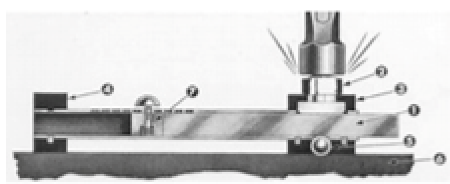
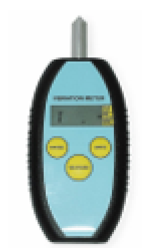
Elliott tube hole gauge (3 ball)		Useful in SI for heat exchangers, especially when tube rolling is involved
Pit gauge		Measures the size of pits in metal
Fillet gauge		Tool for measuring weld fillets
Hardness testing tools		Tool for measuring surface hardness
Vibration meter		Tool designed to measure mechanical oscillations
Borescope		Designed for remote visual inspection

Figure B.4—Source Inspection Tools (4)

Liquid penetrant kit		NDE technique for finding discontinuities open to the surface
Ultrasonic thickness meter		Tool commonly used for measuring metal thickness
Vacuum box		Tool for measuring leakage in welded components
Ultrasonic flaw detection		Volumetric NDE method for finding weld flaws
Inside micrometer set		Used for measuring inside diameters

Figure B.5—Source Inspection Tools (5)

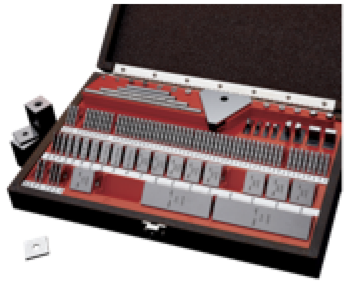
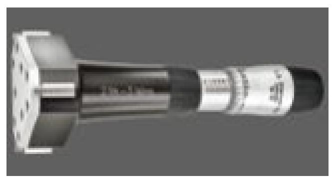
Depth micrometer		Used for measuring depth
Precision gauge blocks		Used for calibration of precision measurement equipment
Bore gauge		Measures inside diameter of components
Magnetic particle testing		Tool designed to detect surface and near-surface discontinuities in ferrous materials
Level		Device used to determine horizontally level and/or vertically plumb
Images used with the permission of Starrett (http://www.starrett.com), Olympus (http://www.olympus.ims.com/en/), Silverwing (http://www.silverwingNDE.com/) Thermo Scientific (http://www.niton.com/en/) and Tempil (http://www.tempil.com/).		

Figure B.6—Source Inspection Tools (6)

Annex C
(informative)

Different Types of Bolted Flange Connections

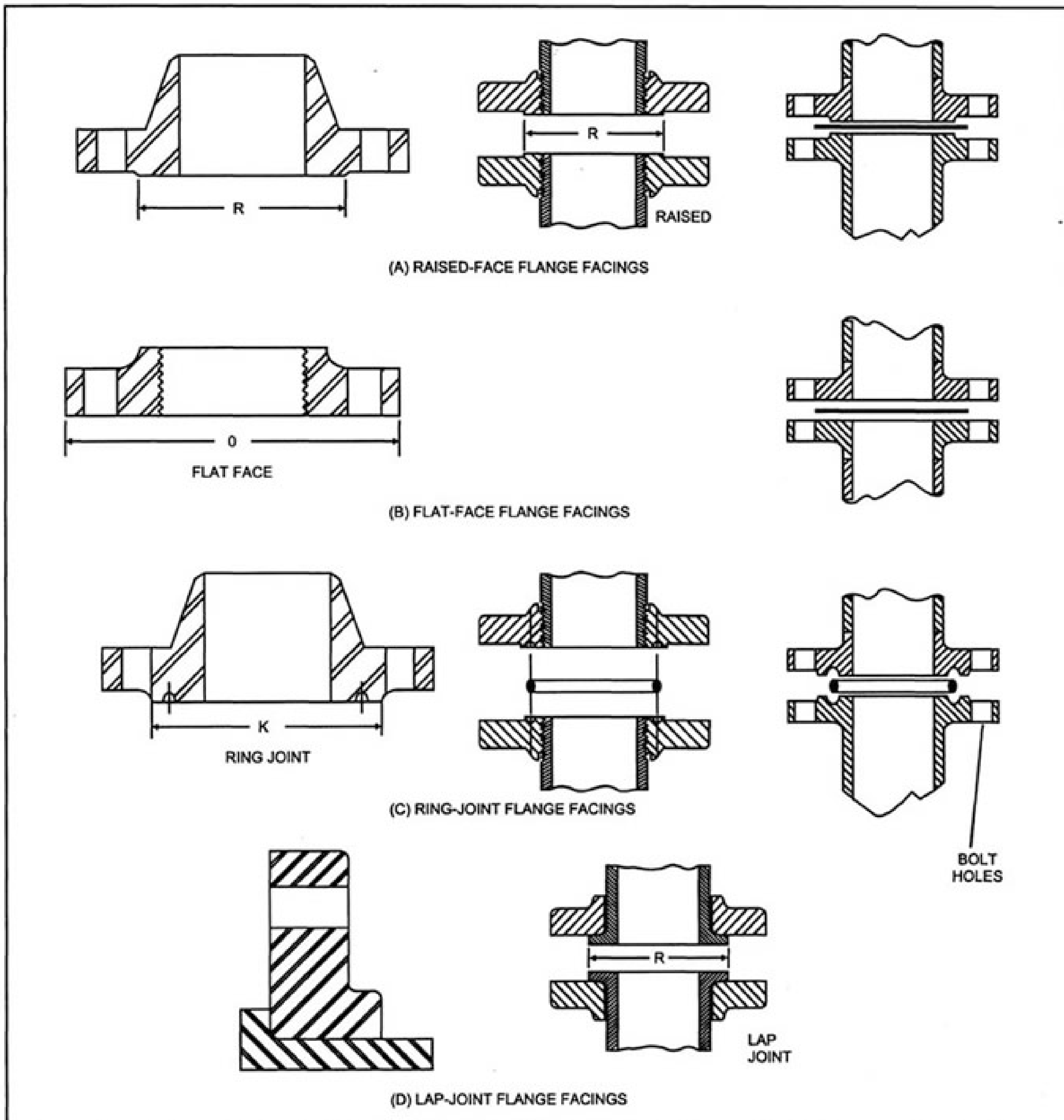


Figure 10-2. Typical Flange Facings. *(Courtesy of EPRI)*

Figure C.1—Different Types of Flange Faces (Sealing Surfaces)

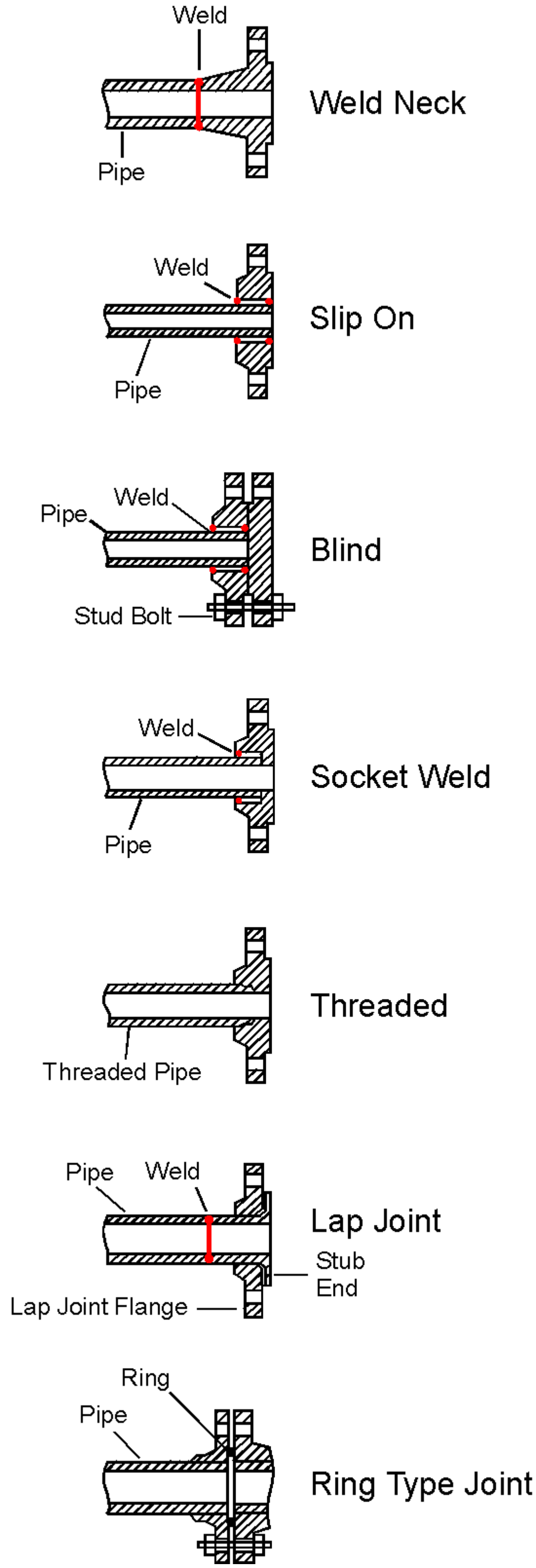


Figure C.2—Different Flange Types

Annex D
(informative)

Chemical Symbols

Table D.1—Chemical Symbols

C	The chemical symbol for carbon that may appear on an MTR.
Co	The chemical symbol for cobalt that may appear on an MTR.
Cr	The chemical symbol for chromium that may appear on an MTR.
Cu	The chemical symbol for copper that may appear on an MTR.
Fe	The chemical symbol for iron that may appear on an MTR.
Mg	The chemical symbol for magnesium that may appear on an MTR.
Mn	The chemical symbol for manganese that may appear on an MTR.
Mo	The chemical symbol for molybdenum that may appear on an MTR.
Nb	The chemical symbol for niobium that may appear on an MTR.
Ni	The chemical symbol for nickel that may appear on an MTR.
P	The chemical symbol for phosphorus that may appear on an MTR.
S	The chemical symbol for sulfur that may appear on an MTR.
Ti	The chemical symbol for titanium that may appear on an MTR.
W	The chemical symbol for tungsten that may appear on an MTR.
V	The chemical symbol for vanadium that may appear on an MTR.

Annex E
(informative)

Websites Useful to the Source Inspector

Table E.1—Useful Websites

API	American Petroleum Institute	www.api.org
ASM	ASM International	www.asminternational.org/portal/site/www/
ASME International	Formerly known as American Society for Mechanical Engineers	www.asme.org
ASNT	American Society for Nondestructive Testing	www.asnt.org
ASTM International	Formerly known as American Society for Testing and Materials	www.astm.org
AWS	American Welding Society	www.aws.org
ISA	Instrument Society of America	www.isa.org
ISO	International Organization for Standardization	www.iso.org/iso/home.html
MSS	Manufacturers Standardization Society	mss-hq.org/Store/index.cfm
NDE Resource Center	Nondestructive Testing Resource Center	www.NDE-ed.org
NEC	*National Electric Code*	www.nfpa.org
SSPC	The Society for Protective Coatings	www.sspc.org/
STI	Steel Tank Institute	www.steeltank.com
Worldsteel	Worldsteel Association	www.steeluniversity.org

AMERICAN PETROLEUM INSTITUTE

200 Massachusetts Avenue, NW
Suite 1100
Washington, DC 20001-5571
USA

202-682-8000

Additional copies are available online at www.api.org/pubs

Phone Orders: 1-800-854-7179 (Toll-free in the U.S. and Canada)
303-397-7956 (Local and International)
Fax Orders: 303-397-2740

Information about API publications, programs and services is available on the web at www.api.org.

Product No. C58801