



PII-PMI-01

Positive Material Identification

PNDT-PMI

Revision 01

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Revision / Change Summary

Revision/Change	No.	Date	Description
Initial	0	6/19/2026	Initial issue of Prime Inspections, Inc. (PII) controlled PMI procedure under the PII Quality Management System. Issued as Rev 0 — no prior PII revision history.
Revision	01	9/6/2026	Complete rewrite to a full audit-ready procedure. Added OES (Optical Emission Spectrometry) methodology alongside XRF. Added material verification requirements per ASME BPVC Section VIII and ASME B31.3 (2024 Edition). Added calibration, quality control, and traceability sections. Updated code references to current editions (ASTM E572, E1086, API RP 578 4th Edition). Added appendices for PMI report forms, alloy reference tables, and spectral interference data. Updated personnel qualification requirements per ASNT SNT-TC-1A (2020).

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Table of Contents

1.0 SCOPE
2.0 PURPOSE
3.0 REFERENCED DOCUMENTS
4.0 DEFINITIONS AND ABBREVIATIONS
5.0 PERSONNEL QUALIFICATIONS
6.0 SAFETY REQUIREMENTS
7.0 PMI METHODOLOGY — X-RAY FLUORESCENCE (XRF)
8.0 PMI METHODOLOGY — OPTICAL EMISSION SPECTROMETRY (OES)
9.0 EQUIPMENT AND MATERIALS
10.0 CALIBRATION AND STANDARDIZATION
11.0 SURFACE PREPARATION
12.0 EXAMINATION PROCEDURE
13.0 MATERIAL VERIFICATION — ASME BPVC SECTION VIII
14.0 MATERIAL VERIFICATION — ASME B31.3 PROCESS PIPING
15.0 WELD AND CONSUMABLE TESTING
16.0 QUALITY CONTROL
17.0 DISCREPANCY RESOLUTION
18.0 REPORTING AND RECORDS
19.0 CERTIFICATION STAMPING
20.0 PROCEDURE QUALIFICATION
APPENDICES
Appendix I – PMI Examination Report Form
Appendix II – XRF Element Detection Range by Instrument Type
Appendix III – Common Alloy Grade Acceptance Ranges
Appendix IV – Spectral Interference Reference Table
Appendix V – PMI Technique Sheet Template

1.0 SCOPE

1.1 This procedure establishes the standardized methodology for Positive Material Identification (PMI) of metallic materials — including carbon steels, alloy steels, stainless steels, nickel-base alloys, copper-base alloys, and other ferrous and non-ferrous alloys — utilizing X-Ray Fluorescence (XRF) spectrometry and Optical Emission Spectrometry (OES) for the determination of elemental composition and verification of alloy grade.

1.2 This procedure covers the following:

1.2.1 Field-based and shop-based PMI using portable handheld XRF analyzers (e.g., Niton™ XL2, XL3t, XL5, or equivalent).

1.2.2 Field-based and shop-based PMI using portable OES analyzers (e.g., Spectrotest, ARUNtest, or equivalent) employing an electrical arc/spark excitation source.

1.2.3 Material verification of pressure-containing components, piping, welds, weld consumables, and plate materials per ASME BPVC Section VIII (2025 Edition) and ASME B31.3 (2024 Edition) requirements.

1.2.4 Alloy sorting and grade identification for procurement compliance, quality control, and material traceability programs per API RP 578 (4th Edition, 2024).

1.3 This procedure meets the requirements of ASTM E572 (XRF analysis of stainless and alloy steels) and ASTM E1086 (OES analysis of stainless steel by spark excitation).

1.4 Instruments such as the Thermo Fisher Scientific Niton™ GOLDD+ series may extend the detectable element range down to aluminum (Al), magnesium (Mg), silicon (Si), and phosphorus (P) when equipped with a helium purge or thin-window detector. The specific instrument's documented detection limits shall govern the elements reported.

1.5 This procedure does not cover:

1.5.1 Destructive laboratory chemical analysis (e.g., ICP-OES, combustion analysis for carbon/sulfur) except as referenced for discrepancy resolution in Section 17.0.

1.5.2 Non-metallic material identification (polymers, ceramics, composites).

1.5.3 Residual stress determination or hardness testing, which are covered under separate procedures.

2.0 PURPOSE

2.1 Prime Inspections Inc. (PII) conducts PMI testing services to provide clients with verified material identification and elemental composition data for the following purposes:

2.1.1 Material identification and alloy grade confirmation

2.1.2 Procurement compliance verification against purchase order and Mill Test Report (MTR) requirements

2.1.3 Product quality and specification compliance per applicable ASME, ASTM, API, and client material specifications

2.1.4 Manufacturing process control — verifying that correct materials are used in the correct locations

2.1.5 Assisting in the client's Material Verification Program (MVP) per API RP 578

2.2 The Client is responsible for identifying on the purchase order or contract document(s) the specific items requiring PMI. PII does not maintain the client's Material Verification Program; however, PII performs PMI testing in accordance with the client's specified requirements and this procedure. The following items typically require PMI; however, the Client shall identify the actual items on the PO or contract document(s):

2.2.1 All pressure-containing welds

2.2.2 All pressure-containing piping components, including fittings, flanges, and welds

2.2.3 Pressure-containing components and welds of heat exchangers and other pressure vessels

2.2.4 Tubular products used in the fabrication of equipment such as heat exchangers, boilers, and heaters

2.2.5 Furnace heaters and boiler internals (tube hangers, tube supports, baffles, and tube-sheets)

2.2.6 Plate material

2.2.7 Pressure-containing machinery casing, such as pumps, compressors, and process expander drivers

2.2.8 Pressure-containing instrument housings

2.2.9 Internal metallic linings, cladding, and weld overlay used for protection against corrosive environments

2.2.10 Expansion joints and bellows

2.2.11 Tubing (except as excluded in Section 2.3.7)

2.2.12 All stud bolts in the ASTM A193 and A320 classifications

2.2.13 Any other components or materials specifically designated for PMI on the PO

2.3 The following items are typically exempted from PMI testing but may be included if directed by the Client:

2.3.1 Gaskets

2.3.2 Internal machinery parts

2.3.3 Internal instrument parts

2.3.4 Internal non-pressure-containing baffles, trays, tray clips, supports, pall rings, etc.

2.3.5 Non-pressure-containing welds

2.3.6 Internal valve components

2.3.7 Type 304 SS tubing $\leq$ 19 mm (0.750 in)

2.3.8 Compression-type ferrules and fittings for use with tubing $\leq$ 19 mm (0.750 in)

3.0 REFERENCED DOCUMENTS

3.1 The following documents are referenced in this procedure. Current editions apply unless otherwise noted. Where a referenced document contains requirements that conflict with this procedure, the referencing code or contract specification shall govern.

3.2 Industry Codes and Standards

3.2.1 ASME BPVC Section II, Parts A, B, C (2025 Edition) — Material Specifications

3.2.2 ASME BPVC Section VIII, Division 1 (2025 Edition) — Pressure Vessels

3.2.3 ASME BPVC Section IX (2025 Edition) — Welding, Brazing, and Fusing Qualifications

3.2.4 ASME B31.3 (2024 Edition) — Process Piping

3.2.5 ASME BPVC Section V, Article 9 (2025 Edition) — Visual Examination

3.2.6 ASTM E572 — Standard Test Method for Analysis of Stainless and Alloy Steels by X-Ray Fluorescence Spectrometry

3.2.7 ASTM E1086 — Standard Test Method for Optical Emission Spectrometric Analysis of Stainless Steel by the Point-to-Plane or Unidirectional Spark Technique

3.2.8 ASTM E1085 — Standard Test Method for X-Ray Emission Spectrometric Analysis of Low-Alloy Steels (withdrawn — refer for historical guidance)

3.2.9 ASTM E999 — Standard Guide for Aerospace PMI Programs

3.2.10 API RP 578, 4th Edition (2024) — Material Verification Program for New and Existing Alloy Piping Systems

3.2.11 ASTM A240 — Standard Specification for Stainless and Heat-Resisting Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels

3.2.12 ASTM A193 — Standard Specification for Alloy-Steel and Stainless Steel Bolting Materials for High-Temperature Service

3.2.13 ASTM A320 — Standard Specification for Alloy-Steel and Stainless Steel Bolting Materials for Low-Temperature Service

3.2.14 ASNT SNT-TC-1A (2020 Edition) — Recommended Practice for Personnel Qualification and Certification in Nondestructive Testing

3.2.15 ANSI/ASNT CP-189 — Standard for Qualification and Certification of Nondestructive Testing Personnel

3.2.16 ISO 9712 — Non-destructive Testing — Qualification and Certification of NDT Personnel

3.2.17 10 CFR Part 20 — Standards for Protection Against Radiation (NRC)

3.2.18 29 CFR 1910 — Occupational Safety and Health Standards (OSHA)

3.2.19 ANSI Z87.1 — Occupational and Educational Personal Eye and Face Protection Devices

3.2.20 ASTM F2412/F2413 — Standard Specification for Performance Requirements for Protective (Safety) Toe Cap Footwear

3.3 PII Internal Documents

3.3.1 PII-WP-1, Written Practice for the Qualification and Certification of NDE Personnel (per ASNT SNT-TC-1A, 2020)

3.3.2 PII-QM-01, PII Quality Manual

3.3.3 PII Job Hazard Analysis (JHA) Master Template

3.3.4 PII-RSP-01, Radiation Safety Program

4.0 DEFINITIONS AND ABBREVIATIONS

Term	Definition
Alloy Grade	A specific designation identifying a metallic alloy by its standardized composition (e.g., 304SS, 316SS, P5, P11, P22, Inconel 625).
C of C	Certificate of Compliance or Certificate of Conformance.
Client	The purchaser/requester of PMI services from PII. This also includes the Client's authorized representative.
CRM	Certified Reference Material — sample materials for which laboratory chemical analysis data are available and are used in demonstrating test instrument accuracy and reliability (e.g., ARMI™ CRM).
Inspector	The Client's representative responsible for oversight of PMI activities.
Inspection Lot	A group of components from the same heat number from which a sample is drawn.
Material Nonconformance	A PMI test result that is not consistent with the selected or specified alloy grade or composition range.
MTR	Mill Test Report — a certified document that permits each component to be identified according to the original heat of material from which it was produced, including documentation of all test results required by the material specification.
OES	Optical Emission Spectrometry — a method of elemental analysis wherein an electrical arc or spark excites atoms in the sample, causing them to emit light at characteristic wavelengths; the light is dispersed and measured to determine elemental composition.
PMI	Positive Material Identification — a procedure used to ensure that specified metallic alloy materials for use in refineries, chemical plants, and other facilities are properly identified as to their true elemental composition and are marked according to specific industry standards and the Client's procedures.
Reference Material	Sample materials for which laboratory chemical analysis data are available and are used in demonstrating test instrument accuracy and reliability.
Representative Sample	A representative sample consists of one or more units (pieces) selected at random from the inspection lot and examined to determine the lot's acceptability.
SDD	Silicon Drift Detector — a high-resolution X-ray detector technology used in advanced handheld XRF analyzers for improved light element sensitivity and resolution.
XRF	X-Ray Fluorescence — a non-destructive analytical technique in which the characteristic X-ray spectrum emitted by a sample when irradiated with a primary X-ray source is measured to determine elemental composition.

5.0 PERSONNEL QUALIFICATIONS

5.1 Qualification and Training

5.1.1 Personnel performing PMI testing under this procedure shall be qualified and certified in accordance with P11-WP-1, which is based on ASNT SNT-TC-1A (2020 Edition). PMI personnel shall hold a minimum of NDT Level I certification in the PMI method, working under the supervision of a certified NDT Level II or Level III.

5.1.2 Personnel performing PMI testing shall have completed at least 8 hours of PMI-specific training, including hands-on training with the specific instrument model(s) to be utilized. Training records shall be maintained in accordance with P11-WP-1.

5.1.3 For XRF analyzers, training shall include radiation safety awareness as required by 10 CFR Part 20 and the P11 Radiation Safety Program (P11-RSP-01). Personnel shall have documented radiation safety training prior to independent operation of any XRF device.

5.1.4 For OES analyzers, training shall include electrical safety awareness and the specific operational hazards associated with spark excitation sources.

5.2 Vision Requirements

5.2.1 PMI personnel shall meet the minimum vision requirements of ASNT SNT-TC-1A (2020): near vision acuity of Jaeger J-1 or equivalent at minimum 12 inches (30 cm) on a standard Jaeger eye chart, and color vision sufficient to distinguish the colors used in the applicable PMI grading system and alloy color-coding scheme.

5.2.2 Vision examinations shall be administered annually and documented in the individual's personnel certification file.

5.3 Certification Levels

5.3.1 Level I personnel may perform PMI testing with written instructions and under the supervision of Level II or III personnel. Level I personnel shall not independently interpret results or authorize acceptance/rejection.

5.3.2 Level II personnel may independently perform and interpret PMI testing, document results, and authorize acceptance/rejection in accordance with this procedure and applicable codes.

5.3.3 Level III personnel are responsible for technique development, procedure approval, personnel qualification, and resolution of technical discrepancies. The designated Level III for P11 is Joshua de Monbrun, CEng, ASNT NDT Level III #242816.

5.4 Qualification Records

5.4.1 Qualifications of the technician, including training, experience, and certification records, shall be available for review when requested by Clients, auditors, or regulatory authorities.

5.4.2 Personnel certification shall be current and unexpired at the time of testing. Recertification intervals shall be per P11-WP-1 (3 years for Level I and II, 5 years for Level III).

6.0 SAFETY REQUIREMENTS

6.1 All PII personnel performing work shall wear personal protective equipment (PPE) appropriate to the site hazards, at a minimum: hard hat, ANSI Z87.1 safety eyewear, FR-rated coveralls (where required), ASTM F2412/F2413 safety footwear, cut-resistant gloves, and hearing protection in posted areas.

6.2 A Job Hazard Analysis (JHA) shall be completed and signed by all crew members prior to performing work each day and reissued whenever conditions change. The JHA shall identify site-specific hazards including, but not limited to: hot work areas, elevated work surfaces, confined spaces, chemical exposure, and radiation hazards.

6.3 XRF-Specific Safety Requirements

6.3.1 Safety glasses or goggles shall be worn while operating XRF equipment.

6.3.2 Never aim the XRF probe at any part of the body or at any person. The X-ray beam shall only be directed at the test sample or a suitable reference standard.

6.3.3 Radiation dosimetry is required for all personnel operating XRF equipment. Personal dosimeters (TLD or OSL) shall be worn at all times during XRF operation and shall be processed at intervals not exceeding 3 months.

6.3.4 The XRF instrument shall be turned off after use, and the manufacturer's storage and transport instructions shall be followed. The instrument shall be stored in its transport case when not in active use.

6.3.5 XRF instruments containing sealed radioactive sources (e.g., Cd-109, Am-241) shall be transported in accordance with US DOT regulations (49 CFR) and applicable state radiation control regulations.

6.3.6 In the event of instrument damage, loss, or suspected radiation exposure incident, the PII Radiation Safety Officer (RSO) shall be notified immediately and the incident shall be reported to the appropriate state radiation control agency.

6.4 OES-Specific Safety Requirements

6.4.1 OES analyzers utilize an electrical spark/arc source that generates high voltage and UV radiation. Personnel shall not look directly at the arc during operation; safety glasses with appropriate UV attenuation shall be worn.

6.4.2 The OES probe shall not be activated except on a properly prepared conductive test surface. Do not arc on non-conductive materials or near flammable atmospheres.

6.4.3 OES analyzers may produce ozone during the spark process. Ensure adequate ventilation in confined spaces and follow the manufacturer's guidance for safe operation durations.

6.4.4 Ensure the unit is turned off after use and that storage instructions from the manufacturer are followed.

7.0 PMI METHODOLOGY — X-RAY FLUORESCENCE (XRF)

7.1 Principle of Operation

7.1.1 X-Ray Fluorescence (XRF) is a non-destructive analytical technique used to determine the elemental composition of materials. XRF analyzers irradiate the sample with a primary X-ray beam from a sealed radioisotope source (e.g., Cd-109, Am-241, Fe-55) or an X-ray tube. The primary radiation causes inner-shell electrons to be ejected from atoms in the sample, and as outer-shell electrons fill the vacancies, characteristic secondary X-rays (fluorescence) are emitted. The energy of each fluorescent X-ray is unique to the element from which it originates, and the intensity is proportional to the concentration of that element.

7.1.2 The detector (typically a Si-PIN diode or Silicon Drift Detector (SDD)) measures the energy and intensity of the secondary X-rays. The instrument's software converts the measured spectrum into elemental concentrations using factory calibration curves and fundamental parameters (FP) algorithms.

7.2 XRF Instrument Types

7.2.1 Portable handheld XRF analyzers shall be used for field-based PMI testing. Acceptable instruments include, but are not limited to:

- (a) Thermo Fisher Niton™ XL2 / XL3t / XL5 / XL5 Plus series
- (b) Olympus DELTA™ series (Vanta™, DELTA Classic)
- (c) Bruker S1 SORTAN / S2 COBRA / CTX series
- (d) Any equivalent handheld XRF analyzer meeting the performance requirements of this procedure and bearing a current factory calibration certificate

7.2.2 For light element detection (Al, Si, P, S, Mg), the instrument shall be equipped with a Silicon Drift Detector (SDD) and either a vacuum purge or helium purge system. Instruments without these features are limited to elements with atomic number $\geq$ Ti ($Z \geq 22$).

7.3 XRF Analytical Range and Detection Limits

7.3.1 The XRF method can detect elements with atomic numbers from approximately 16 (Sulfur) to 92 (Uranium) for standard instruments without light element capability. With SDD + helium purge, the range extends down to atomic number 11 (Sodium) or 12 (Magnesium), depending on instrument configuration.

7.3.2 Typical detection limits for portable XRF analyzers vary by element and matrix. Representative values are listed in Appendix II.

7.3.3 XRF is not suitable for measuring elements lighter than sodium ($Z < 11$), and cannot directly measure carbon (C), which is critical for distinguishing between L-grade (low carbon) and standard grades of stainless steel. Where carbon content must be verified, OES or laboratory combustion analysis shall be used.

7.4 XRF Measurement Time

7.4.1 Test times for the XRF analyzer shall be a minimum of 5 seconds for grade identification (alloy sorting) and 10 seconds for chemistry determination (quantitative analysis). Although the analyzer may display a result before the specified time has elapsed, the operator shall continue measuring until the minimum test time has been reached.

7.4.2 For low-concentration or trace element determination, measurement times of 30 to 60 seconds may be required. The operator shall refer to the instrument manufacturer's recommendations for specific element/matrix combinations.

7.4.3 When using a weld adapter (reduced 3 mm aperture) or measuring through a gap, measurement times shall be doubled or quadrupled as specified in Sections 12.0 and 15.0 of this procedure.

7.5 XRF Limitations

7.5.1 XRF analyzes only the surface layer (typically 10–100 μm depth depending on material density and element energy). Surface contamination, paint, scale, coating, or heat treatment effects may result in erroneous readings.

7.5.2 Spectral interferences exist between certain element pairs (e.g., Mo/S, P/Mo, Co/Fe, V/Ti, Cr/V, Mn/Cr). These are documented in Appendix IV and shall be considered when interpreting results per Section 17.0.

7.5.3 XRF cannot distinguish between a solid alloy and a surface coating of the same or similar composition. For weld overlay or cladding verification, the operator shall ensure the measurement is taken on the base material and not on a coating.

8.0 PMI METHODOLOGY — OPTICAL EMISSION SPECTROMETRY (OES)

8.1 Principle of Operation

8.1.1 Optical Emission Spectrometry (OES), also known as Spark OES or Arc/Spark OES, is a method of elemental analysis in which an electrical discharge (spark or arc) is generated between an electrode and the sample surface. The discharge vaporizes a small amount of material from the sample and excites the resulting atoms and ions, causing them to emit light at characteristic wavelengths. The emitted light is collected by an optical system (polychromator or spectrometer), dispersed by diffraction grating(s), and measured by photomultiplier tubes or CCD/CMOS detectors.

8.1.2 The wavelength of each emission line identifies the element, and the intensity of the line is proportional to the concentration of that element in the sample. The instrument's software uses calibration curves (established with certified reference materials) to convert emission line intensities into elemental concentrations.

8.2 OES Instrument Types

8.2.1 Portable OES analyzers shall be used for field-based PMI testing requiring OES methodology. Acceptable instruments include, but are not limited to:

- (a) SPECTRO Analytical Instruments SPECTROtest / SPECTROport series
- (b) ARUN Applied Technology ARUNtest / Metalscan series
- (c) OBLK OES-7500 / Foundry-Master series
- (d) Any equivalent portable OES analyzer meeting the performance requirements of this procedure and bearing a current factory calibration certificate

8.2.2 OES instruments shall be equipped with an argon purge system at the spark stand to enhance the measurement of carbon (C), phosphorus (P), sulfur (S), and nitrogen (N) emission lines. Without argon purge, OES is limited to metallic elements and may not reliably measure C, P, S, or N.

8.3 OES Analytical Range and Detection Limits

8.3.1 OES can detect elements from atomic number 3 (Lithium) to 92 (Uranium), including light elements not measurable by standard XRF (C, B, Be, Li). With argon purge, typical detection limits for C, P, S, and N are in the range of 5–50 ppm depending on matrix and instrument configuration.

8.3.2 OES is the preferred method for:

- (a) Distinguishing L-grade (low carbon, $\leq 0.03\%$ C) stainless steels (304L vs 304, 316L vs 316) where XRF cannot measure carbon
- (b) Verifying carbon content in P-number assignment for welding procedure qualification per ASME Section IX
- (c) Measuring phosphorus and sulfur content in steel for compliance with ASTM material specifications
- (d) Measuring nitrogen content in nitrogen-strengthened stainless steels (e.g., 316LN, 2205 duplex)

8.4 OES Measurement Time

8.4.1 OES measurement times are typically 5–10 seconds per spark location. The instrument performs multiple spark cycles within the measurement period and averages the results. The operator shall follow the instrument manufacturer's recommended measurement times for the specific alloy family being tested.

8.4.2 For low-concentration elements (trace elements), the instrument may require longer integration times. The operator shall refer to the manufacturer's operating manual for specific guidance.

8.5 OES Limitations

8.5.1 OES is a slightly destructive technique — the spark leaves a small burn mark (typically 1–4 mm diameter) on the test surface. The burn mark shall be considered in applications where surface finish is critical (e.g., sanitary stainless steel, polished surfaces).

8.5.2 OES requires the test surface to be electrically conductive. Non-conductive materials cannot be tested by OES.

8.5.3 OES requires a clean, bare metal surface. Paint, scale, coatings, and oxidation layers must be removed prior to testing (see Section 11.0).

8.5.4 The OES instrument shall be argon-purged at the spark stand for at least 30 seconds prior to measurement to flush air from the optical path and ensure accurate light element results.

8.5.5 OES results may be affected by the sample's metallurgical condition (heat treatment, grain size, segregation). The instrument calibration shall be verified using CRM(s) of similar metallurgical condition to the test samples whenever possible.

9.0 EQUIPMENT AND MATERIALS

9.1 The following equipment and materials are required for PMI testing under this procedure. The specific equipment used shall be documented in the PMI report.

9.2 XRF Equipment

9.2.1 Portable handheld XRF analyzer with current factory calibration certificate

9.2.2 Weld test stand / probe spacer (for weld testing with reduced aperture)

9.2.3 Hot surface adapter (for surfaces > 315°C / 600°F)

9.3 OES Equipment

9.3.1 Portable OES analyzer with current factory calibration certificate

9.3.2 Argon gas supply (99.999% purity, minimum 99.998%) with pressure regulator and supply hose

9.3.3 Replacement electrode(s) as specified by the instrument manufacturer

9.3.4 Daily argon purge and burn cleaning disk for spark stand conditioning

9.4 Reference Materials

9.4.1 Certified Reference Materials (CRM) shall be used for instrument calibration verification and shall be obtained from recognized sources such as:

- Analytical Reference Materials International (ARMI™)
- Brammer Standard Company, Inc.
- NIST Standard Reference Materials (SRM)
- Certified Reference Materials from the instrument manufacturer

9.4.2 The CRM(s) used under this procedure shall be representative of the material types expected to be encountered during inspection (e.g., carbon steel, low-alloy Cr-Mo steel, 300-series stainless, 400-series stainless, nickel-base alloys). At minimum, the following CRM types shall be available:

- (a) Carbon steel CRM (e.g., for verifying Fe, C, Mn, Si)
- (b) Low-alloy Cr-Mo CRM (e.g., 1.25Cr-0.5Mo or 2.25Cr-1Mo for verifying Cr, Mo, and alloy identification)
- (c) Austenitic stainless steel CRM (e.g., 304 or 316 for verifying Cr, Ni, Mn, Mo)
- (d) Nickel-base alloy CRM (e.g., Inconel 625 or 825 for verifying Ni, Cr, Mo, Fe, Nb)

9.4.3 Reference standards shall be homogeneous and free of voids, porosity, and surface contamination. CRMs shall be stored in a clean, dry environment and handled with clean gloves to prevent surface contamination.

9.4.4 A log of CRM certifications shall be maintained. CRM certificates shall be available for review upon request by the Client or auditor.

9.5 Surface Preparation Tools

9.5.1 Hand files, rotary files, or battery-powered grinders for surface preparation

9.5.2 Abrasives: Silicon carbide (carborundum), alumina (corundum), or diamond abrasive — free of elements that could compromise measurement accuracy (Ni, Cr, Fe, Mn, Mo, etc.)

9.5.3 Aluminum masking tape (pure Al, non-alloy) for weld isolation during testing

9.6 Documentation Equipment

9.6.1 Calibration certificates for all instruments (factory calibration and daily verification records)

9.6.2 PMI report forms (see Appendix I) or electronic data collection device

9.6.3 Isometric drawings or sketches of tested piping and equipment

10.0 CALIBRATION AND STANDARDIZATION

10.1 Factory Calibration

10.1.1 All PMI instruments shall have a current factory calibration certificate on file at PII. Factory calibration shall be performed by the instrument manufacturer or an authorized service center at intervals not exceeding 12 months or as specified by the manufacturer, whichever is more frequent.

10.1.2 Rental equipment shall be supplied with a factory calibration certificate. Copies of calibration certificates shall be kept on file at PII and shall be available for review.

10.1.3 Instruments shall be returned to the manufacturer for recalibration when:

- (a) The factory calibration expires (12 months or manufacturer-specified interval)
- (b) The instrument fails daily verification and cannot be brought into tolerance by field recalibration
- (c) The instrument has been dropped, damaged, or exposed to extreme environmental conditions
- (d) The detector or source has been replaced

10.2 Daily Instrument Startup and Stabilization (XRF)

10.2.1 The XRF analyzer shall be turned on and the operator shall log in with the designated password. The instrument shall be allowed to run for at least 1 minute to stabilize the electronics before proceeding with calibration.

10.2.2 After the stabilization period, a daily detector calibration shall be performed. Access the instrument's calibration routine (e.g., on Niton instruments: Utilities → Calibrate Detector). The instrument will perform an auto-calibration and display a pass/fail result.

10.2.3 After successful detector calibration, measure an approved alloy test standard (e.g., the manufacturer-supplied 1-1/4 Cr – 1/2 Mo alloy standard). The instrument shall correctly identify the alloy grade and the major alloying elements (primarily Cr and Mo) shall fall within the calculated acceptance Limits (3-Sigma of the average of factory readings). If the standard is correctly identified and concentrations are within tolerance, testing may commence.

10.2.4 If the check standard values do not read correctly, recalibrate the instrument per 10.2.2 above. If after re-calibration the readings still do not fall within the 3-Sigma accuracy boundaries, contact the PMI Coordinator or supervisor and discontinue use of the instrument. Tag the instrument "Out of Calibration" and remove from service.

10.3 Daily Instrument Startup and Stabilization (OES)

10.3.1 The OES analyzer shall be turned on and the argon supply opened. The optical path shall be purged with argon for at least 30 seconds prior to the first measurement.

10.3.2 Perform a type standardization (standardization) per the manufacturer's procedure using a standardization sample (typically a low-alloy steel disk supplied with the instrument). The standardization must pass for all relevant channels/elements before proceeding.

10.3.3 After standardization, measure a CRM representative of the materials to be tested. Verify that all measured element concentrations fall within the CRM's certified tolerance range. If out of tolerance, re-standardize and verify. If still out of tolerance, discontinue use and contact the PMI Coordinator.

10.4 Hot Surface Testing

10.4.1 If surface temperatures of the components to be tested will exceed 315°C / 600°F but remain below 427°C / 800°F, the operator may use the instrument with a 6 mm (0.250 in) air gap between the front of the instrument's measuring plate and the sample surface (Hot Surface Adapter).

10.4.2 When testing hot surfaces with the Weld Adapter in place, double the standard measurement time to maintain precision (compensates for signal loss due to the air gap and the reduced 3 mm aperture).

Measurement accuracy compensation is handled automatically by the instrument software (up to a maximum 6 mm air gap).

10.5 Periodic Calibration Verification (During Testing)

10.5.1 The calibration/standardization shall be confirmed periodically during testing to minimize the impact of and correct for any potential instrument drift.

10.5.2 At minimum, measure the certified calibration check standard (e.g., the 1-1/4 Cr – 1/2 Mo alloy standard or applicable CRM) at least once every 2 hours of continuous operation.

10.5.3 If the periodic check is correct, continue testing. If incorrect, recalibrate the detector per 10.2.2 (XRF) or 10.3.2 (OES), verify with CRM, and re-confirm the measurements taken since the last successful verification. All measurements taken since the last successful verification shall be re-tested.

10.5.4 If the instrument cannot be brought into tolerance after recalibration, discontinue use, tag the instrument "Out of Calibration," and notify the PMI Coordinator.

10.6 Material-Specific Performance Verification

10.6.1 The instrument shall be verified for material-specific performance prior to commencing testing on each material type. This shall be done using a Certified Reference Material (CRM) representative of the material to be tested.

10.6.2 If CRMs are not available for a specific material type, the instrument may be verified using a material of known composition (e.g., a sample with an MTR on file). The verification result shall be documented.

11.0 SURFACE PREPARATION

11.1 Good sample surface preparation is essential for obtaining accurate PMI results. All non-representative material — including paint, scale, markings, dust, grease, oil, and corrosion products — shall be removed prior to testing. This may be accomplished using hand files, rotary files, grinders, or abrasive paper to obtain a clean, bare metal surface.

11.2 Attention shall be paid to the composition of any abrasives being used to clean sample surfaces. Abrasives shall not contain elements that could compromise measurement accuracy by embedding in the sample surface. It is best to use light-element abrasives free of interfering elements (Ni, Cr, Fe, Mn, Mo, etc.), such as:

- (a) Silicon carbide (carborundum)
- (b) Corundum (alumina / Al_2O_3)
- (c) Diamond

11.3 Care shall be taken not to transfer elements between examination specimens or compromise material integrity during the surface preparation process. For example, a grinding wheel used on carbon steel shall not be subsequently used on stainless steel, as iron particles from the carbon steel can embed in the stainless surface and cause false readings. Dedicated abrasive tools or discs shall be used for each material family.

11.4 Test areas on welds may have to be ground flat to provide a flush surface for the instrument probe. A battery-powered right-angle grinder with several extra batteries has been found to provide good service with rapid surface preparation in field conditions.

11.5 For OES testing, the surface shall be cleaned to bare metal over an area at least as large as the OES probe tip (typically 8–12 mm diameter). The surface shall be smooth enough to maintain consistent contact between the probe and the sample to ensure a stable spark.

11.6 For both XRF and OES, if the surface cannot be adequately prepared (e.g., in tight access areas, on complex geometry, or where the material is coated with permanent corrosion protection), the operator shall note the condition in the report and may qualify the result as 'indicative only' if the surface condition precludes a definitive measurement.

12.0 EXAMINATION PROCEDURE

12.1 Prior to beginning testing, the specific PMI testing and documentation requirements for the job shall be discussed with the PMI Coordinator or designate. The Client's purchase order or contract documents shall be reviewed to identify the specific materials, components, and welds requiring PMI, the applicable acceptance criteria, and the reporting format.

12.2 Sampling Plan

12.2.1 100% Testing: Unless otherwise specified by the Client or purchase order, 100% testing shall be performed on all components and materials designated for PMI testing.

12.2.2 Representative Sample: When specified by the Client or purchase order, representative samples shall be taken in the following manner as a minimum:

- (a) For lots of 5 units or fewer, testing shall be 100%
- (b) For lots greater than 5 units, the greatest of 5 units or 5% shall be analyzed, unless otherwise dictated by the Client

12.2.3 For API RP 578 programs, the sampling frequency shall be per the Client's Material Verification Plan (MVP). PII shall perform testing at the frequency specified in the MVP.

12.3 Test Point Selection

12.3.1 One test point for each piping component (pipe, tee, elbow, reducer, flange, etc.) is required as a minimum. Weld test requirements vary according to size — see Section 15.0.

12.3.2 For plate material, test at the corners and center of each plate (minimum 5 points per plate) or as specified by the Client.

12.3.3 For forged or cast components, test at the thickest section or as specified by the Client. Avoid testing at sharp edges or radius transitions where the probe cannot achieve full surface contact.

12.4 XRF Measurement Procedure

12.4.1 Ensure the instrument has passed daily calibration and CRM verification per Section 10.0.

12.4.2 Prepare the test surface per Section 11.0 — remove all non-representative material to expose clean, bare metal.

12.4.3 Position the instrument probe flush against the test surface, ensuring the measurement aperture is fully covered by the sample material.

12.4.4 Initiate the measurement. Hold the instrument steady throughout the measurement cycle. Do not move the instrument during measurement.

12.4.5 Wait for the instrument to display the final result after the minimum measurement time has elapsed (5 seconds for alloy ID, 10 seconds for chemistry). Do not accept results displayed before the minimum time has been reached.

12.4.6 Record the displayed alloy grade and elemental concentrations on the PMI report form (Appendix I).

12.5 OES Measurement Procedure

12.5.1 Ensure the instrument has passed daily standardization and CRM verification per Section 10.0.

12.5.2 Open the argon supply and purge the spark stand for at least 30 seconds.

12.5.3 Prepare the test surface per Section 11.0 — grind to bare metal over an area at least as large as the OES probe tip.

12.5.4 Position the OES probe firmly against the test surface, ensuring full contact between the probe face and the sample.

12.5.5 Initiate the spark and maintain firm pressure throughout the measurement cycle (typically 5–10 seconds).

12.5.6 After the measurement is complete, record the alloy grade and elemental concentrations from the instrument display onto the PMI report form.

12.5.7 Inspect the burn mark left by the spark. If the burn mark appears irregular (uneven, incomplete, or shows signs of arcing to adjacent material), re-prepare the surface and repeat the measurement.

12.6 Non-Contact and Undersized Samples

12.6.1 For samples that do not fully cover the measurement aperture, increase the testing time in inverse proportion to the decrease in percentage of aperture covered. For example, if a rod covers only 1/2 of the aperture area, double the measurement time (from 10 to 20 seconds for chemistry).

12.6.2 Undersized samples shall be placed in a radiation-safe test stand or similar test fixture. Do not test undersized samples by laying them on another substrate material (wood, plastic, metal) — erroneous measurements may occur due to interfering elemental signals from the substrate.

12.6.3 Non-contact sample measurements (with air gap up to 6 mm / 0.250 in from the measurement aperture) require double exposure time (5 to 10 seconds for ID, 10 to 20 seconds for chemistry).

12.6.4 Inside pipe measurements on pipes less than 2 feet in diameter will result in non-contact measurements — follow the guidance in 12.6.3 above.

13.0 MATERIAL VERIFICATION — ASME BPVC SECTION VIII

13.1 This section addresses PMI material verification requirements for pressure vessel components in accordance with ASME BPVC Section VIII, Division 1 (2025 Edition). Where the Client's specification or the applicable edition of Section VIII imposes more stringent requirements, those requirements shall govern.

13.2 Material Verification Requirements

13.2.1 All pressure vessel materials — including plate, forging, pipe, fittings, flanges, and bolting — shall be verified by PMI when specified by the Client, the vessel specification, or the applicable edition of Section VIII.

13.2.2 PMI shall verify that the material matches the designated ASME Section II material specification (e.g., SA-516 Gr 70 for carbon steel plate, SA-312 TP316 for stainless steel pipe, SA-182 F22 for alloy forging).

13.2.3 For welded construction, PMI shall verify:

- (a) Base metal composition at the location of each weld tested
- (b) Weld consumable composition per Section 15.0
- (c) Heat-affected zone (HAZ) base metal composition (adjacent to the weld)

13.3 Section VIII Material Specifications

13.3.1 Common Section VIII pressure vessel materials and their PMI-identifiable elements are listed in Appendix III. The PMI operator shall verify that the measured elemental concentrations fall within the ranges specified by the applicable ASME Section II material specification.

13.4 Verification Frequency (Section VIII)

13.4.1 Unless otherwise specified by the Client, PMI verification shall be performed on 100% of pressure-containing components unless the Client specifies a representative sampling plan per Section 12.2.

13.4.2 For components with Mill Test Reports (MTR), PMI shall be used to confirm that the as-received material matches the MTR chemistry. Discrepancies between PMI results and the MTR shall be resolved per Section 17.0.

13.5 Records for Section VIII Vessels

13.5.1 PMI records for Section VIII vessels shall include:

- (a) Vessel identification (item number, drawing number)
- (b) Component identification (part number, heat number from MTR)
- (c) Material specification designation (e.g., SA-516 Gr 70, SA-312 TP316L)
- (d) PMI instrument make, model, and serial number
- (e) Measured elemental concentrations
- (f) Pass/fail determination per the material specification
- (g) Technician name, certification level, and date

14.0 MATERIAL VERIFICATION — ASME B31.3 PROCESS PIPING

14.1 This section addresses PMI material verification requirements for process piping systems in accordance with ASME B31.3 (2024 Edition). Where the Client's specification or the applicable edition of B31.3 imposes more stringent requirements, those requirements shall govern.

14.2 Material Verification Requirements

14.2.1 All process piping materials — including pipe, fittings, flanges, bolting, and weld consumables — shall be verified by PMI when specified by the Client, the piping specification, or the applicable edition of B31.3.

14.2.2 PMI shall verify that the material matches the designated ASME Section II / ASTM material specification (e.g., A335 P11 for 1-1/4Cr-1/2Mo seamless pipe, A312 TP316L for low-carbon stainless steel pipe, A193 B8M for stainless steel bolting).

14.3 B31.3 Fluid Service Categories

14.3.1 The extent of PMI verification may vary based on the B31.3 Fluid Service category:

- (a) Category M (Highly Toxic/Reactive Fluid Service): 100% PMI verification of all pressure-containing components and welds is recommended unless otherwise specified.
- (b) Category D (Lower Risk Fluid Service): PMI verification frequency shall be per the Client's specification.
- (c) Normal Fluid Service: PMI verification shall be performed per the Client's Material Verification Plan or at the frequency specified on the purchase order.

14.4 B31.3-Specific Considerations

14.4.1 For high-pressure, high-temperature piping systems (e.g., in refinery hydroprocessing units), PMI shall verify Cr-Mo alloy content (P5, P9, P11, P22, P91) to confirm correct alloy placement. Special attention shall be given to distinguishing between similar alloys (e.g., P11 vs P22, P22 vs P91) using the differentiating elements (Cr, Mo, V, W).

14.4.2 For stainless steel piping systems, PMI shall verify Cr and Ni content at minimum. Where the distinction between L-grade (304L/316L) and standard grade (304/316) is required, OES shall be used to measure carbon content, or the material shall be verified by MTR review.

14.4.3 For nickel-base alloy piping systems (e.g., Inconel 625, Incoloy 825, Hastelloy C-276), PMI shall verify the full element suite identifiable by the instrument (Ni, Cr, Mo, Fe, Co, W, Nb, Ti).

14.5 Traceability and Documentation

14.5.1 Each tested piping component shall be traceable via line number, component number, and/or isometric drawing reference. PMI test locations shall be documented on an isometric drawing or sketch.

14.5.2 PMI records for B31.3 piping shall include the same information as listed in Section 13.5, plus the piping line number and isometric drawing reference.

14.6 Common B31.3 Piping Materials

14.6.1 Common B31.3 piping materials and their PMI verification elements are listed in Appendix III.

15.0 WELD AND CONSUMABLE TESTING

15.1 Prior to welding, consumables shall be tested in accordance with Section 15.5 below. Weld testing shall be performed after welding is complete and the weld surface has been prepared per Section 11.0.

15.2 Required Number of Test Points per Weld

Weld Type	Size (Diameter)	Minimum Test Points
Socket Weld	0.750 – 2.000 in	One test point
Butt Weld	0.750 – 1.500 in	One test point
Butt Weld	2.000 – 4.000 in	Two test points
Butt Weld	≥ 6.000 in	At least four test points

15.2.1 For welds 6 in and larger, at least four test points evenly distributed around the circumference of the weld shall be measured. If no discrepancies are found, the average of the primary-identifier element chemistries across all points tested on that weld may be used for documentation purposes.

15.3 At the discretion of the inspector, additional locations on the weld may be tested — for example, on large diameter welds or at any time deemed necessary to ensure the correctness of the weld material.

15.4 Weld Measurement Technique

15.4.1 Care shall be taken in testing welds to position the analyzer so it reads only the weld material and not the adjacent base metal, to avoid false readings.

15.4.2 If the instrument is not equipped with a “weld inspection” feature (reduced aperture), reduce the measuring area to 3 mm by software function. The reduced aperture width shall be smaller than the width of the weld being tested.

15.4.3 Isolate the weld by masking adjacent metal with a non-readable material such as several layers of pure aluminum tape. Ensure the aluminum mask material contains no interfering elements, is not an aluminum alloy, has no surface contamination, and is thick enough to block X-rays from the underlying material.

15.4.4 Quadruple the measurement time when using the Weld Adapter: increase from 5 seconds to 20 seconds for alloy ID and from 10 seconds to 40 seconds for chemistry, to compensate for the added air gap and/or reduced analysis area.

15.5 Welding Consumable Testing

15.5.1 Each box of welding rod to be used for the job shall be prepared by first puddling a sample (at least two passes) and grinding the resulting bead smooth for testing.

15.5.2 Documentation for weld rod testing shall include:

- (a) Rod designation (e.g., E7018, E308-15)
- (b) Rod manufacturer’s name
- (c) Box lot number
- (d) Elemental composition of the tested sample

15.5.3 Rod boxes shall be marked “PMI Confirmed” with:

- (a) Name of the authorized person who performed the testing
- (b) Date of testing
- (c) Other information as specified (e.g., vendor or contractor ID)

15.5.4 GTAW (TIG) wire may be tested directly from the box, either individually with a Weld aperture or IsoWeld, or by using several bundled wire pieces to cover more of the analyzer's aperture window. If satisfactory results cannot be obtained, puddling and grinding of the wire shall be done per 15.5.1 above.

16.0 QUALITY CONTROL

16.1 Calibration/standardization shall be confirmed periodically during testing to minimize the impact of and correct for instrument drift. See Section 10.5 for the periodic verification interval (every 2 hours of operation, at minimum).

16.2 Measure the certified calibration check standard (e.g., 1-1/4 Cr – 1/2 Mo alloy standard or applicable CRM) at least once every 2 hours of operation. If correct, continue testing. If incorrect, recalibrate and re-confirm the previous 2 hours of measurements.

16.3 Duplicate Measurements

16.3.1 For critical applications (e.g., highly toxic fluid service per B31.3 Category M, or high-pressure high-temperature service), duplicate measurements shall be taken at each test point and the results compared. If duplicate results differ by more than the instrument's stated repeatability specification, a third measurement shall be taken and the cause investigated.

16.4 Instrument Inter-Comparison

16.4.1 When two or more PMI instruments are deployed on the same project, the instruments shall be cross-verified against a common CRM at the start of each shift. Inter-instrument agreement shall be within the manufacturers' stated repeatability specifications.

16.5 Environmental Controls

16.5.1 PMI instruments shall be operated within the manufacturer's specified environmental range (typically 14°C to 40°C / 57°F to 104°F, 10–90% RH non-condensing). Operation outside these conditions shall be noted in the report and may require additional verification.

16.6 Quality Control Records

16.6.1 All daily calibration, CRM verification, and periodic check results shall be documented and retained as part of the project quality records. These records shall include:

- (a) Instrument make, model, and serial number
- (b) Date and time of calibration/verification
- (c) CRM identification and certified values
- (d) Measured values
- (e) Pass/fail determination
- (f) Technician name and signature

17.0 DISCREPANCY RESOLUTION

17.1 When a PMI test indicates the presence of the wrong material (weld or component), the following steps shall be followed:

17.1.1 Test several other areas on the same component or sample. For welds, check adjacent base metal components.

17.1.2 Check the instrument calibration against the certified check standard supplied with the analyzer (1-1/4 Cr – 1/2 Mo alloy standard) or other certified alloy standard.

17.1.3 If performing pre-fabrication testing and an incorrect material is identified, components having reached this point must be rejected per established quality procedures and segregated to prevent inadvertent use.

17.2 Discrepancies on field-installed or existing materials in place require notification of the Client's inspector and completion of the following:

17.2.1 Complete chemistries with a minimum 20-second measuring time shall be taken for all elements present in the suspect material to help positively identify it.

17.2.2 Review the test data for the suspect component and, if possible, confirm the results using a second analyzer.

17.2.3 If conclusive results cannot be obtained with field analyzers, the inspector may request a certified laboratory analysis of a small sample (turnings or drillings) taken from the suspect material. Laboratory analysis methods may include ICP-OES, combustion analysis for C/S, or other quantitative methods.

17.3 Spectral Interferences

17.3.1 Some XRF spectrometers will not completely resolve radiation from several element combinations. Therefore, care shall be taken when evaluating elemental percentage measurements when both elements are present. See the list of elements with potential for interferences in Appendix IV.

Element Analyzed	Potential Interference
Sulfur (S)	Molybdenum (Mo)
Phosphorus (P)	Molybdenum (Mo)
Cobalt (Co)	Iron (Fe)
Vanadium (V)	Titanium (Ti)
Chromium (Cr)	Vanadium (V)
Manganese (Mn)	Chromium (Cr)
Tungsten (W)	Nickel (Ni) (OES only)

17.4 The Client shall be notified of all discrepancy findings and shall be responsible for the final disposition of their product. All discrepancies shall be documented on a Nonconformance Report (NCR) per PII-QM-01.

18.0 REPORTING AND RECORDS

18.1 Minimum documentation required for each PMI field or shop project shall include:

18.1.1 An isometric drawing or sketch of the as-installed and tested piping or equipment. This drawing shall include equipment ID, piping line number, or other documentation reference(s) as specified.

18.1.2 Chemistry data results for the primary elements required for PMI of the material for all units tested.

18.1.3 Documentation signed and dated by the personnel performing the tests. Signed documentation shall be given to the PMI Coordinator or designate.

18.1.4 Electronic copies of secure, encrypted data files shall be maintained in addition to all paper copies of the documentation.

18.2 PMI Report Contents

18.2.1 The PMI report shall include at minimum:

- (a) Project name and Client identification
- (b) PO number and applicable specification(s)
- (c) PMI instrument make, model, and serial number
- (d) Calibration certificate reference and date
- (e) CRM(s) used for verification
- (f) Component description, ID, and heat number (from MTR, if available)
- (g) Material specification designation (e.g., A335 P11, A312 TP316L)
- (h) Measured elemental concentrations (weight %)
- (i) Alloy grade identified by the instrument
- (j) Pass/fail determination per the material specification
- (k) Technician name, certification level, and signature
- (l) Date of testing
- (m) Any discrepancies and their resolution per Section 17.0

18.3 Record Retention

18.3.1 PMI records shall be retained in accordance with PII-QM-01 and applicable Client requirements. Minimum retention period shall be 7 years from the date of testing, or as specified by the Client, whichever is longer.

18.3.2 Records may be stored in electronic format provided the storage system provides adequate backup and retrieval capability. Electronic records shall be protected against unauthorized modification.

18.4 Report Format

18.4.1 The PMI report shall be generated using the PMI Examination Report Form (Appendix I) or an equivalent electronic form approved by the PMI Coordinator. All fields shall be completed; blank fields shall be marked "N/A" with a brief explanation.

19.0 CERTIFICATION STAMPING

19.1 When required by the Client, certification stamps shall meet these requirements, or as directed by the Client:

19.1.1 All stamping shall be done with a specified/approved low-stress stamp.

19.1.2 All stamps purchased for special marking shall be marked with a control number. A list indicating the number and locations of these stamps shall be held by the PMI Coordinator.

19.1.3 Typically, a stamp is assigned to each individual analyzer, and the stamp is carried in the respective analyzer's field carry bag.

19.1.4 Any loss of a stamp shall be reported immediately to the PMI Coordinator or designate.

19.1.5 Stamps shall include the letters "PMIV" (PMI Verified).

19.1.6 Stamps shall be of the low-stress, round-face type.

19.2 When and How to Use Certification Stamps

19.2.1 Materials and components shall be tested prior to fabrication where possible.

19.2.2 Items checked prior to fabrication and before the final as-installed condition shall be marked with an approved paint pen: "PMIV".

19.2.3 Chemistry documentation may not be necessary for this phase of PMI inspection (pre-fabrication alloy sorting).

19.2.4 The number of components and type tested shall be documented for the job.

19.2.5 Discrepancies shall be noted and handled per Section 17.0.

19.2.6 Shop-made spool pieces may be stamped, providing their final field location in the piping system can be tracked and documented. Final field installation shall be confirmed by visual inspection of the stamp.

19.2.7 Usage of an approval stamp shall be in accordance with the Client's procedures for PMI of existing equipment.

19.2.8 Using an approval stamp does not negate the need for any written documentation required by this procedure or the Client.

20.0 PROCEDURE QUALIFICATION

20.1 This procedure shall be qualified by the designated NDT Level III prior to its initial use and whenever a significant change is made to the technique, equipment, or scope. Procedure qualification shall be documented on a Procedure Qualification Record (PQR) retained by PII.

20.2 Procedure qualification shall include:

20.2.1 Verification that all equipment used under this procedure meets the requirements specified in Section 9.0

20.2.2 Verification that the CRM(s) used are traceable and within their certified tolerance ranges

20.2.3 Demonstration that the instrument correctly identifies each alloy type within the scope of this procedure using the designated reference standards

20.2.4 Documentation of the measurement repeatability (standard deviation of replicate measurements) for the primary alloy families

20.2.5 Verification that the procedure personnel are qualified per Section 5.0 and PII-WP-1

20.3 Re-Qualification Triggers

20.3.1 This procedure shall be re-qualified when any of the following occur:

- (a) A change in the instrument type, manufacturer, or detector technology that affects the analytical performance
- (b) A change in the applicable code edition or specification referenced in Section 3.0
- (c) A significant change in the scope or materials covered by this procedure
- (d) At intervals not exceeding 5 years from the last qualification date

20.4 Annual Review

20.4.1 This procedure shall be reviewed annually by the designated NDT Level III and the Corporate Quality Manager to verify continued applicability and currency of code references. The annual review shall be documented by signatures on the revision summary page.

Appendix I — PMI Examination Report Form

The following form shall be used for documenting PMI results. All fields shall be completed; blank fields shall be marked N/A.

PII-PMI-01 Rev 01

Report No.:

PO Number:		Specification:	
Date of Testing:		Line/Vessel No.:	
Calibration Cert. Date:		Method (XRF/OES):	
CRM Used:		Last Verification Time:	

Examination Results

Comp. ID	Spec. Designation	Heat No. (from MTR)	Alloy Grade Identified	Cr %	Ni %	Mo %	Mn %	Pass/Fail

Date:

Reviewed By:

Appendix II — XRF Element Detection Range by Instrument Type

Representative detection limits for common portable XRF instruments with different detector configurations. Actual detection limits vary by matrix, measurement time, and instrument firmware version. Values shown are typical and provided for reference only.

Element	Symbo l	Atomic No. (Z)	Standard XRF (Si-PIN)	SDD + He Purge
Titanium	Ti	22	≤ 0.01%	≤ 0.01%
Vanadium	V	23	≤ 0.01%	≤ 0.01%
Chromium	Cr	24	≤ 0.01%	≤ 0.01%
Manganese	Mn	25	≤ 0.01%	≤ 0.01%
Iron	Fe	26	Matrix	Matrix
Cobalt	Co	27	≤ 0.01%	≤ 0.01%
Nickel	Ni	28	≤ 0.01%	≤ 0.01%
Copper	Cu	29	≤ 0.01%	≤ 0.01%
Zinc	Zn	30	≤ 0.01%	≤ 0.01%
Molybdenum	Mo	42	≤ 0.01%	≤ 0.01%
Niobium	Nb	41	≤ 0.01%	≤ 0.01%
Tungsten	W	74	≤ 0.05%	≤ 0.05%
Tantalum	Ta	73	≤ 0.05%	≤ 0.05%
Aluminum	Al	13	Not detected	≤ 0.1%
Silicon	Si	14	Not detected	≤ 0.1%
Phosphorus	P	15	Not detected	≤ 0.05%
Sulfur	S	16	Not detected	≤ 0.05%
Carbon	C	6	Not detected	Not detected
Nitrogen	N	7	Not detected	Not detected

Note: Carbon and nitrogen cannot be measured by XRF under any configuration. For C and N determination, use OES or laboratory combustion analysis.

Appendix III — Common Alloy Grade Acceptance Ranges

Typical elemental composition ranges for common alloys encountered in PMI programs. These values are provided as a quick reference for field sorting. For acceptance, refer to the full composition limits in the applicable ASME Section II / ASTM material specification.

Alloy Grade	Material Spec.	Cr %	Ni %	Mo %	Mn %	Other Key Elements
304 SS	A312 TP304	18.0–20.0	8.0–11.0	≤ 0.0 max	≤ 2.0	C ≤ 0.08
304L SS	A312 TP304L	18.0–20.0	8.0–12.0	≤ 0.0 max	≤ 2.0	C ≤ 0.03
316 SS	A312 TP316	16.0–18.0	10.0–14.0	2.0–3.0	≤ 2.0	C ≤ 0.08
316L SS	A312 TP316L	16.0–18.0	10.0–14.0	2.0–3.0	≤ 2.0	C ≤ 0.03
317L SS	A312 TP317L	18.0–20.0	11.0–15.0	3.0–4.0	≤ 2.0	C ≤ 0.03
321 SS	A312 TP321	17.0–19.0	9.0–12.0	—	≤ 2.0	Ti ≥ 5×C
347 SS	A312 TP347	17.0–19.0	9.0–13.0	—	≤ 2.0	Nb ≥ 10×C
410 SS	A268 TP410	11.5–13.5	≤ 0.75	—	≤ 1.0	Martensitic
2205 DSS	A790 S31803	21.0–23.0	4.5–6.5	2.5–3.5	≤ 2.0	N 0.08–0.20
2507 DSS	A790 S32750	24.0–26.0	6.0–8.0	3.0–5.0	≤ 1.2	N 0.24–0.32
P5	A335 P5	4.0–6.0	—	0.45–0.65	≤ 0.5	C–Mo steel
P11	A335 P11	1.0–1.5	—	0.45–0.65	≤ 0.5	1.25Cr–0.5Mo
P22	A335 P22	2.0–2.5	—	0.87–1.13	≤ 0.5	2.25Cr–1Mo
P91	A335 P91	8.0–9.5	≤ 0.40	0.85–1.05	≤ 0.45	V 0.18–0.25
Inconel 625	B443	20.0–23.0	Rem.	8.0–10.0	≤ 0.5	Nb 3.15–4.15
Incoloy 825	B423	19.5–23.5	38.0–46.0	2.5–3.5	≤ 1.0	Cu 1.5–3.0, Ti 0.6–1.2
Hastelloy C-276	B575	14.5–16.5	Rem.	15.0–17.0	≤ 1.0	W 3.0–4.5, Co ≤ 2.5
CS (A106-B)	A106 Gr B	—	—	—	0.29–1.0 6	Carbon steel
CS (A516-70)	A516 Gr 70	≤ 0.30	—	—	0.79–1.3 0	C ≤ 0.27
B7 Bolt	A193 B7	≤ 0.15	—	≤ 0.25	≤ 1.0	Cr 0.80–1.10
B8M Bolt	A193 B8M	18.0–20.0	8.0–12.0	2.0–3.0	≤ 2.0	SS bolt

Note: “Rem.” indicates remainder (balance). Values shown are typical ranges for PMI field sorting purposes. For acceptance, the exact composition limits in the governing material specification (ASME Section II / ASTM) shall be used.

Appendix IV — Spectral Interference Reference Table

The following table lists element pairs that may exhibit spectral interference on portable XRF and/or OES instruments. When both elements in a pair are present in the same sample, the reported concentration of the analyzed element may be affected by the interfering element. The operator shall be aware of these interferences when interpreting PMI results.

Element Analyzed	Potential Interference	Typical Effect	Mitigation
Sulfur (S)	Molybdenum (Mo)	Over-reporting of S when Mo is high	Use OES for S; verify Mo separately
Phosphorus (P)	Molybdenum (Mo)	Over-reporting of P when Mo is high	Use OES for P; verify with CRM
Cobalt (Co)	Iron (Fe)	Fe K β overlaps Co K α in high-Fe matrices	Verify Co with CRM in same matrix
Vanadium (V)	Titanium (Ti)	Ti K β overlaps V K α	Verify V on CRM with known V content
Chromium (Cr)	Vanadium (V)	V K β overlaps Cr K α	Verify Cr on CRM; use longer counting time
Manganese (Mn)	Chromium (Cr)	Cr K β overlaps Mn K α	Verify Mn with CRM; use Mn K β line
Tungsten (W)	Nickel (Ni)	W L-series overlaps Ni K-series (OES)	Use W M-series or verify with CRM
Copper (Cu)	Nickel (Ni)	Ni K β overlaps Cu K α in high-Ni	Verify Cu on CRM; use Cu K β line
Niobium (Nb)	Molybdenum (Mo)	Overlapping L-series lines	Verify Nb on CRM with known Nb

General Mitigation Strategy: When a potential interference is identified, the operator shall (1) re-measure using the instrument's interference correction (if available), (2) verify the result using a CRM with known concentrations of both the analyzed and interfering elements, or (3) confirm the result using a second instrument or method.

Appendix V — PMI Technique Sheet Template

The following technique sheet shall be completed for each PMI project and retained with the project records.

Project Name:	
Client:	
PO Number:	
Applicable Specification(s):	
Instrument Make / Model:	
Instrument Serial Number:	
Method (XRF / OES):	
Factory Calibration Date:	
Daily Calibration Time / Result:	
CRM Used (ID and Grade):	
CRM Verification Result:	
Measurement Time – Alloy ID (sec):	
Measurement Time – Chemistry (sec):	
Hot Surface Adapter Used? (Y/N):	
Weld Adapter / Reduced Aperture? (Y/N):	
Surface Prep Method:	
Sampling Plan (% or representative):	
Acceptance Criteria (Code / Spec):	
Total Components Tested:	
Discrepancies Found? (Y/N) — NCR No.:	
Technician Name / Cert. Level:	
Date of Examination:	
Reviewed By (PMI Coordinator):	

END OF DOCUMENT