DNV·GL

Pipeline Fittings Quality Assurance Technical Paper

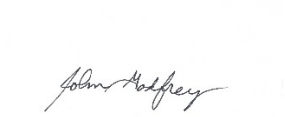
National Energy Board of Canada

Project No.: PP179886
Date: May 31, 2017

Report title:	Pipeline Materials Quality Assurance Technical Paper	Det Norske Veritas (Canada) Ltd. DNV GL Oil & Gas Compliance Solutions
Customer:	National Energy Board of Canada 517 10 Ave SW #210, Calgary, AB T2R 0A8	Suite 150, 2618 Hopewell Place NE
Date of issue:	May 31, 2017	T1Y 7J7 Calgary, AB
Project No.:	PP179886	Canada
Organization unit:	OAPCA851	Tel: 403 250 9041

Objective: This paper examines current quality assurance requirements and processes and procedures used to validate pipe and components on pipeline systems and identifies any gaps or shortcomings in the quality assurance specifications that allow pipe or fittings to be manufactured that do not meet the intended material quality requirements.

Prepared by:



John Godfrey
Principal Consultant

Approved by:

Arti Bhatia, P.Eng.
Head of Compliance Solutions

APEGA Permit to Practice: P10603

DNV GL Distribution:

☒ Unrestricted distribution (internal and external)
☐ Unrestricted distribution within DNV GL
☐ Limited distribution within DNV GL after 3 years
☐ No distribution (confidential)
☐ Secret

Keywords: quality assurance, pipe, components, fittings, materials, manufacture

Rev. No.	Date	Reason for Issue	Prepared by	Verified by	Approved by
0	2017-05-31	First issue	John Godfrey		Arti Bhatia, P.Eng.

Executive Summary

Recently, pipeline operating company quality assurance measures have identified fittings that did not meet specifications. As a result, on 5 February 2016, the Canadian National Energy Board (the NEB) issued a Safety Advisory and Miscellaneous Order (M0-001-2016) regarding substandard material. On 12 April 2017, the NEB issued a Notice of Intention to Order followed by an amended Safety Advisory SA-2016-01A2 on 12 May 2017. The amended Safety Advisory identifies additional fitting cases where material properties did not meet Company specifications, while the Miscellaneous Order will enable the NEB and Companies to identify any such fittings on existing pipelines, so that fitness for service can be assessed and appropriate mitigation measures can be implemented if required. This paper examines current quality assurance requirements and processes and procedures used to validate pipe and components on pipeline systems and identifies any gaps or shortcomings in the quality assurance specifications that allow pipe or fittings to be manufactured that do not meet the intended material quality requirements.

Microalloyed high strength steels are very sensitive to changes in manufacturing processes such as thermomechanical rolling and heat treating. This sensitivity compounds small deviations in manufacturing processes such as tempering or quenching temperature. To minimize the risk of substandard materials, the initial process qualification often referred to as First Article Inspection[1] forms the basis for all subsequent manufacturing procedures and the Manufacturing Procedure Specification (MPS) when applicable.

Variables such as heat treatment and quenching temperatures, hold times, furnace load configurations, etc. should be sufficiently detailed to allow for quality control monitoring. Initial qualification testing should be rigorous and clearly define the resultant material properties as related to the product specification. Finally, the MPS and Inspection and Test Plan (ITP) should sufficiently describe the process such that production inspection is efficiently and thoroughly conducted. Deviations from the process need to be quickly identified and supplemental testing utilized to define the impact. A robust system of traceability should allow for all materials affected by a process disruption to be identified and segregated to prevent their entry into the supply chain.

In general, standards for fittings lack the detail and rigor associated with line pipe. Enhancements to current industry standards are recommended to close the gaps identified between standards, manufacturing processes and the intended fitting performance.

The failure of components to conform to existing standards and specifications, as investigated in this report, is a direct result of failures to control the manufacturing processes. These failures in processes were not identified by the established ITP protocols, either during production monitoring or subsequent material acceptance lot testing. First Article Inspection and production monitoring is generally conducted for larger mill runs such as major construction projects. Smaller projects generally rely on manufacturers and distributors to provide fittings meeting industry standards with limited or no additional oversight.

[1] Both the supplier and purchaser perform the First Article on the ordered product. The evaluation method consists of comparing supplier and purchasers results from measuring the properties and geometry of an initial sample item against given specifications

Table of Contents

Appendices

List of Tables

1.0 SCOPE OF WORK

On 20 January 2017, the National Energy Board (NEB) issued a Request for Proposal (RFP) for provision of a Pipeline Materials Quality Assurance Technical Paper (the Paper). The request is to provide the NEB with a technical paper that examines current quality assurance requirements and processes and procedures used to validate pipe and components on pipeline systems and identifies any gaps or shortcomings in the quality assurance specifications that allow pipe or materials to be manufactured that do not meet the intended material quality requirements.

Recently, pipeline operating company quality assurance measures have identified fittings that did not meet specifications. As a result, on 5 February 2016, the NEB issued a Safety Advisory and Miscellaneous Order (M0-001-2016) regarding substandard material. The Order required companies to file with the NEB a report detailing any such fittings in use on the pipeline operating companies' systems, to identify whether these fittings have been identified as having substandard materials, and plans for mitigation should substandard materials be identified. If a company was unable to determine if the referenced fittings were purchased and installed, then it was to provide a corrective action plan.

As described in the RFP, the issue of some of the fittings not meeting the required material specifications is not considered by the NEB to represent a significant or immediate public safety or environmental risk, because all fittings in service would have passed commissioning hydrotests. Also, the NEB is not aware of reported releases of gas or liquid product as a result of fittings not meeting specifications.

The Scope of Work (SoW) is to prepare a technical paper with the following deliverables:

Section 2 – Overview of Pipeline Component Production and Quality Assurance: An overview of pipeline component production and quality assurance in relation to standards and regulations.

Section 3 – Pipeline Component Issues: An overview of pipeline system pipe and components that have been found to either: not have met specifications or to have failed during testing, commissioning or in-service; including a literature review and an analysis of specific cases (e.g. NEB Safety Advisory 2016-01 http://nebone.gc.ca/sftnvrnmnt/sft/dvsr/sftdvsr/2016/2016-01nb-eng.html).

Section 4 – Standards and Regulation Gap Analysis: Identification of gaps in the standards that would have enabled fittings that either failed or did not meet the specifications or standards to be introduced into the supply chain.

Section 5 – Quality assurance strategies: Possible strategies to provide more assurance that pipeline components are produced and installed with the required material properties.

2.0 OVERVIEW OF PIPELINE COMPONENT PRODUCTION AND QUALITY ASSURANCE

2.1 Background on production methods

Pipeline components for the purpose of this paper refers to manufactured fittings such as elbows, tees, extruded headers, reducers, and caps intended for oil and gas service. Fabricated assemblies which may contain multiple components are excluded. Components are wrought or forged from raw material

such as pipe, plate or billets. Components undergo a forming process or shaping process involving hammering, pressing, piercing, extruding, rolling, bending, welding, machining, or a combination of two or more of these operations. Following forming, components are heat treated to provide final design strength and toughness. Heat treatment may include one or more of the following methods:

- *Stress relieving* where the component is heated to a temperature below the transformation range for a specific period of time and allowed to cool in the furnace or air.
- *Normalizing* where the component is uniformly heated above the austenitic transformation range, held to achieve uniform temperature throughout the mass of the component, and cooled in air.
- *Normalizing and tempering* where the component is reheated following normalization to a temperature below the transformation range, held for a specific time, and cooled in the furnace or air.

For pipeline components with grades higher than Canadian Standards Association (CSA) Grade 359 (WPHY[2] 52), quenching and tempering is required to achieve the desired final properties. Quenching and tempering is a process that heats the steel to the fully austenitic range (normalizing) and rapidly quenches the material to achieve a microstructure with high strength and hardness. Toughness of the material is reduced during this process, but addressed by tempering. This increases toughness without having a significant impact on strength. The end result is a steel with a good balance between strength and toughness.

2.2 Quality assurance / quality control (QA / QC) overview

Component manufacturers are required to comply with the requirements of a quality management system such as ISO 9001[3]. In addition, proof tests may be required to verify the adequacy of the manufacturer's design. Depending on the standards and purchaser requirements specified, additional mandatory testing is conducted to ensure production materials or components conform to the requirements.

Typical pipeline operating company integrity management and quality assurance provisions to ensure fittings conform to the intended design include a combination of company specifications, supplemental production testing requirements, inventory control, and acceptance testing. The main provision continues to be the pre-commissioning (post construction) hydrostatic pressure test. Depending on the intended service, pipeline components are subject to pressure testing at increments of the designed operating pressure. Less common are material and dimensional tests upon receipt of the component to identify substandard materials. Additional risk factors and integrity inspection steps are discussed below.

[2] high yield strength wrought pipe

[3] ISO 9001 is the international standard that specifies requirements for a quality management system (QMS). Organizations use the standard to demonstrate the ability to consistently provide products and services that meet customer and regulatory requirements.

2.3 Relevant standards and regulations

Industry references that were reviewed for this report and are applicable to the procurement and inspection of line pipe and components include, but are not limited to:

- API Specification 5L, Specification for Line Pipe;
- ASME/ANSI B16.9, Factory-Made Wrought Buttwelding Fittings;
- ASME BPVC-2013, Boiler and Pressure Vessel Code (2015 Edition)
  - Section V-2013, Nondestructive Examination
  - Section VIII, Div. 1-2013, Rules for Construction of Pressure Vessels
  - Section IX-2013, Welding, Brazing, and Fusing Qualifications: Qualification Standard for Welding, Brazing, and Fusing Procedures; Welders; Brazers; and Welding, Brazing, and Fusing Operators.
- ASTM A370-13, Standard Test Methods and Definitions for Mechanical Testing of Steel Products
- ASTM A694, Standard Specification for Carbon and Alloy Steel Forgings for Pipe Flanges, Fittings, Valves and Parts for High-Pressure Transmission Service;
- ASTM A991/A991M-10, Standard Test Method for Conducting Temperature Uniformity Surveys of Furnaces Used to Heat Treat Steel Products
- MSS SP-75 (2014), Specification for High-Test, Wrought Butt-Welding Fittings;
- CSA Z662-15, Oil and gas pipeline systems;
- CSA Z245.1-14, Steel Pipe; and
- CSA Z245.11-13, Steel Fittings

3.0 PIPELINE COMPONENT ISSUES

3.1 Description of incidents (case studies)

3.1.1 Published events

The NEB is aware of instances of pipe and components having substandard material properties installed on pipelines under NEB or another regulatory bodies' jurisdiction[4]. In the cases examined, the documentation received from the manufacturers indicated that the materials provided met the required specifications. Subsequent testing indicated that some of the pipe and fittings did not meet all the required material specifications. In some instances, the substandard materials were determined to have been a contributing factor to pipeline failure during pressure testing.

[4] National Energy Board Safety Advisory - NEB SA 2016-01 - Potential for Substandard Properties of Pipeline Fitting Materials

Although some of the substandard materials cases described below appeared to have been isolated, the NEB subsequently identified additional cases on pipelines in Canada and the United States (US). The issue of pipe and fittings having substandard material properties entering the supply chain, and subsequently being installed on pipelines, is an industry wide concern.

Canadoil Asia Fitting Case

In December 2010, the NEB was notified of a steel fitting (elbow) that had expanded following a hydrostatic test at a pipeline facility in the US. PHMSA attributed the cause of the elbow expansion to the fitting having *a yield strength lower than the specified minimum yield strength. The pipeline operator removed a number of other fittings at the facility for mechanical testing and identified additional fittings with substandard material properties.*

The substandard fittings were traced to a manufacturer identified as Canadoil Asia[5] *with production originating from Thailand. The fittings were manufactured to the Manufacturers Standard Society (MSS) SP-75* Specification *for High-Test, Wrought, Butt-Welding Fittings and were indicated as having met the specified material requirements on the Material Test Report (MTR). However, due to inadequacies in some processes at the manufacturing plant, not all fittings met the specified material requirements.*

Ezeflow Fitting Case

In 2013, a pipeline rupture occurred on a sweet natural gas pipeline in Alberta. An estimated 16.5 million cubic meters *of natural gas was released. The Transportation Safety Board of Canada (TSB) released its Pipeline Investigation Report on the incident (P13H0107) on 3 November 2015.*

Investigations by the TSB, the NEB, as well as the pipeline operator, indicated substandard materials were present in the manufactured elbow where the failure initiated. Fitness for service testing was conducted on the pipeline fittings prior to their installation in 2008, after two fittings failed during the pressure test. Although hardness testing indicated the elbow in question had lower mechanical properties, the operator determined that the elbow was acceptable for use, as the wall thickness would compensate for the lower mechanical properties. Neither the manufacturer nor the pipeline operator physically verified the wall thickness of this specific fitting. The investigation determined that the wall thickness was less than that indicated on the MTR.

Since this incident, the pipeline operating company has increased its manufactured fitting (wall thickness) specifications beyond the manufacturing standards acceptable under the current Canadian Standards Association (CSA) Z662-15 Oil and Gas Pipeline Systems. The fitting manufacturer, Ezeflow, has made improvements to both its manufacturing procedures and its quality assurance (QA) programs. The quality issue appears to be limited to Grade 550 elbows manufactured for a single customer.

In 2008, the US Department of Transportation, Pipeline and Hazardous Materials Safety Administration (PHMSA) observed hydrostatic test failures and excessive expansions on a number of pipelines under construction in the US. Upon investigation, PHMSA attributed the cause of the incidents to the installation of pipe with substandard material properties.

[5] The Canadoil Asia facility in Thailand is no longer in operation. Canadoil Asia is no longer affiliated with Canadoil Forge and CFC Canadoil.

In 2009, PHMSA issued an advisory bulletin (ADB-09-01) warning of the potential for microalloyed high strength line pipe to exhibit inconsistent chemical and mechanical properties, with yield strengths as much as 15 percent below specified requirements. The advisory also warned that in some cases, the pipe materials may successfully pass a hydrostatic test but still present a future concern.

3.1.2 Pipeline Operating Company interviews

DNV GL conducted interviews with representatives of two pipeline operating companies to further understand the issues experienced including details of their subsequent review and analysis.

Operator A:

Operator A identified most of the issues in elbows formed from plate which were related to the material yield strength relative to the specified material grade. The pipeline operating company typically purchases fittings from distributors unless a major project allows for direct procurement from the manufacturer. Heat treatment of all substandard fittings consisted of quenching and tempering. Although the fittings were specified and documented as CSA Grade 483 (WPHY 70), subsequent transverse tensile testing revealed actual strengths with values in the 300s. No axial testing was conducted. Traceability to the plate manufacturer was not maintained, but subsequent chemical composition testing matched mill supplied Certified Mill Test Reports (CMTRs). Hardness testing also revealed large differences from end to end of the fitting. It is the pipeline operating company's assessment that loss of process control during quenching resulted in non-uniform cooling and variability in material properties from the initial entry of the fitting into the quenching tank to the final immersion.

Operator B:

Operator B identified furnace loading practices that affected normalizing of the fittings which resulted in localized areas of inadequate heat treatment. The stacking of fittings in the furnace, and use of certain steel support racks effectively increased the overall thickness and mass of the material to be heated and hence the hold time in the furnace. A sharp contrast was observed when lighter gauge racks (less mass) were used to load the furnace, and when spacing between the fittings was maintained. In both cases, the manufacturing procedure did not address the relative increase in the fitting localized mass (thickness) relative to furnace hold time. In one case, worn racks had deformed to the point that the contact area was significantly expanded and may not have conformed to the requirements of the original manufacturing procedure qualification tests. Much like welding processes, critical variables such as fitting wall thickness associated with heat treatment should be identified and included in MPS and ITP procedures.

A separate issue identified involved the adequacy of quenching following normalization. In this case the temperature of the quenching medium was not monitored and maintained to assure rapid cooling of the products. Quench tanks did not provide for continual measurement of water temperature or required agitation to ensure consistent cooling rates.

Lot testing incorporating coupons was found to be inadequate to identify substandard materials. Lots, or batches of similarly produced components, were judged to be too large to differentiate between production processes, and the location and number of coupons was found not to be representative of process conditions during heat treatment.

Wall thickness variability was also identified as part of the review but was not considered detrimental. However, specific issues related to the absence of raw material (plate) traceability, material receipt inspection, and comprehensive acceptance testing were the primary drivers for these substandard fittings to enter the supply chain.

4.0 STANDARDS AND REGULATION GAP ANALYSIS

A gap analysis was performed to compare selected standards against a list of selected criteria. The criteria were selected based upon DNV GL's experience with manufacturing and quality assurance processes. The list of criteria is not meant to be all inclusive, but representative of common processes in the order typically employed during manufacturing and testing:

- Fabrication of material
  - Chemistry aim points and limits
  - Carbon equivalent
  - Heat identification
  - Slab or ingot casting requirements, slab identification, and traceability
  - Plate or skelp requirements, testing requirements, identification, and traceability
  - Plate or skelp shipping and handling requirements
  - Heat Treating
  - Forming
  - Welding
  - Hydrotesting
  - Sizing and dimensions
  - Grade requirements
  - Marking requirements
  - Shipping and Handling
- Quality control
  - Product Ordering Requirements
  - Manufacturer Procedure Specifications (MPS)
  - Inspection and Test Plan (ITP)
  - Certified Material Test Report (CMTR)
  - Material receiving and Identification

- Nondestructive examination (NDE)
- Defects
- Retests
- Final Inspection

- Traceability

The resulting comparison appears in Appendix A below. Operator qualification processes were not considered, nor were procedures related to materials required for sour service applications. Table 1 provides a summary of identified gaps by criteria, standard and associated quality strategy.

Table 1. Standards and Regulation Gap Analysis Summary

Gap	Criteria	Standard
Limit ranges not defined	Chemistry aim points and limits	CSA Z245.11-13 MSS SP-75 (2014)
Not addressed in current standards	Slab or ingot casting requirements, slab identification, and traceability	CSA Z245.11-13 MSS SP-75 (2014)
Not addressed in current standards	Plate or skelp requirements, testing requirements, identification, and traceability	CSA Z245.11-13 MSS SP-75 (2014)
Not addressed in current standards	Plate or skelp shipping and handling requirements	CSA Z245.11-13 MSS SP-75 (2014)
Not addressed in current standards	Traceability	CSA Z245.11-13
Not addressed in current standards	Manufacturer Procedure Specifications (MPS)	CSA Z245.11-13
Product specific inspection and testing plan not required	Inspection and Test Plan (ITP)	CSA Z245.11-13
Various gaps in material and lot testing	Certified Material Test Report (CMTR)	CSA Z245.11-13 MSS SP-75 (2014)
Lack of specified process controls	Heat Treating	CSA Z245.11-13 MSS SP-75 (2014)
Reliance on buyer specifications	Product Ordering Requirements	CSA Z245.11-13 MSS SP-75 (2014)

CSA Z245.1-14, Steel Pipe and CSA Z662-15, Oil and Gas Pipeline Systems were reviewed to provide a comparison to standards specific to fitting manufacture. In general, standards for fittings lack the detail and rigor associated with line pipe. Enhancements to current industry standards are recommended to close the gaps identified between standards, manufacturing processes and the intended fitting performance. Pipeline operators and/or distributors should consider enhancing product specifications to provide more rigorous traceability, process monitoring and product testing.

Of the fitting standards reviewed, MSS SP-75 was the most comprehensive relative to the selected criteria. However, gaps remain relative to traceability, raw material handling and inspection, chemical composition and lot testing. Emphasis is placed on the control of manufacturing processes by requiring production specific MPS and ITPs, the acceptance and surveillance of which is the responsibility of the purchaser. In practice, this has the potential to cause a gap between the standard and finished goods if the MPS or ITP is incomplete, or is not monitored for conformance during production.

CSA Z245.11-13 Steel Fittings has similar gaps relative to raw materials and raw material verification. The standard makes no reference to establishing manufacturing procedures similar to a MPS for monitoring the various processes involved in the manufacture of fittings. The reporting requirements are less stringent than those within MSS SP-75. The standard requires a Certificate of Compliance with limited mandatory test reporting requirements. Optional reporting requirements are left to the purchaser to include in the purchase order. As discussed below, this creates a low threshold for monitoring and reporting production process parameters of fittings produced for distributor stock or aftermarket resale.

5.0 QUALITY ASSURANCE STRATEGIES

The procurement of materials and goods has a significant impact on the overall quality of the finished pipeline. This includes the procurement of line pipe and components such as fittings, valves, flanges, closures, etc. It is essential that contractors, suppliers, and the pipeline operating company achieve alignment on quality.

The source of the pipe and fittings should be carefully considered during the materials procurement and inspection phase. Pipe and fittings purchased in millrun quantities provide the flexibility to impose project-specific specification requirements that exceed the minimum requirements of the applicable industry specification. Pipe and fittings purchased from distributor's or manufacturer's stock can often include materials that meet only the minimum requirements of the applicable industry specification. In addition, they may not have had the benefit of supplemental mill audits and inspections that are common for mill production runs of pipe and fittings. Rigorous mill pre-qualification practices and pre-purchase inspection have proven to mitigate risks associated with stock fittings. Pre-qualification can identify manufacturing facility inadequacies such as worn equipment, inadequate furnace surveying, quench tank mixing, etc. Pre-purchase inspections can also identify geometric, wall thickness, chemistry, and finishing issues prior to individual fittings entering the supply chain.

DNV GL produced a report for PHMSA providing guidance relative to new pipeline construction inclusive of the manufacturing and procurement of line pipe and components.[6] The following ten strategies adapted from Appendix B of the DNV GL report can be directly applied to the manufacture and procurement of components.

5.1 Quality Management Systems (QMS)

When required by the pipeline operating company, contractors and suppliers should have their own QMS which is aligned with the pipeline operating company's QMS. Where materials or goods are purchased on behalf of the pipeline operating company by a third party such as a distributor, the pipeline operating

[6] DNV GL – Report No. OAPUS314MJRU (PP087506), Rev. 3, "Improving Quality Management Systems (QMS) for Pipeline Construction Activities"

company's QMS should be transferable and adopted by the purchaser. In addition to the QMS, manufacturing processes require additional process documentation, review, and control to facilitate meeting the required quality, schedule, delivery, and overall project objectives including performance specifications and regulatory requirements. This section is applicable to pipe manufacturers, pipe coaters, double jointers, component manufacturers, and other parties who provide materials or products, rather than services.

It is recommended, at minimum, that the pipeline operating company require QMS alignment from suppliers of pressure-carrying pipe and components, as well as the pipeline and facilities construction contractor(s).

5.2 Development of Manufacturer Procedure Specifications (MPS)

When required by the pipeline operating company or referenced standard, the supplier shall provide a manufacturer procedure specification (MPS) detailing manufacturing processes, quality assurance methods, quality control activities inclusive of hold points, and a description of applicable geometrical checks, material testing, and NDT. The MPS should be evaluated prior to the start of production for conformance with customer specifications, industry standards, and the intended service of the product (sour, high temperature, arctic, etc.). Exceptions to the specification taken by the supplier should be carefully considered to assess the likelihood that the final product performance will meet the project criteria.

A pre-production meeting should be held to identify roles and responsibilities of the manufacturer, purchaser and/or surveillance inspectors. Meeting minutes should be retained and any agreed upon changes incorporated into the MPS prior to the start of production. When materials are to be purchased periodically from distributor's stock the expectation is that the company would have described the QMS requirements to the supplier with enough lead time that the supplier could relay the QMS requirements to the manufacturer and coordinate the preparation of the related audits, inspections, and documentation, if applicable. Distributors and suppliers should keep records of original product specifications, MPS and ITP when required during production (i.e. fittings originally manufactured to MSS SP-75), and any pre-production meeting minutes. Alternative plans for documenting data and information pertaining to material testing, properties and inspection may be necessary if some provisions of the QMS are impractical for components purchased on a less frequent basis or for those having less impact on project risk.

The MPS should clearly identify the suppliers of raw materials, consumables, and component parts, and the quality management practices utilized during the production of these materials. The MPS should also detail the requirements for any documentation provided by raw material, component part, and consumable suppliers in support of the manufacturer's QMS.

The MPS should detail each step in the manufacturing process and describe the operation in sufficient detail to verify and confirm the process meets industry standards, regulatory requirements, and purchaser specifications. Manufacturing process controls and set points should be specified for monitoring during production. Examples sections within a MPS include but are not limited to:

- Quality control measure options selected to improve the quality;

- Training and competency requirements for personnel performing the activity;
- Inspection requirements;
- Training and competency requirements for the personnel performing the inspection; and
- Applicable records.

The quality plan should reference the documented procedure or specification for the task. Additionally, the personnel performing the task or inspection should be able to understand and competently follow the procedure and quality plan and self-check their work, as applicable. However, self-checking is not a suitable substitute for inspection by other personnel who were not directly involved in the performance of the manufacturing or fabrication task. If quality issues are identified, work should be stopped or the component quarantined and the issue should be communicated to the appropriate personnel. Depending on the project, the personnel performing the activity and the inspection may be employed by the pipeline operating company, contractor, or supplier. Consideration should be given to multiple reviews of tasks or activities, as warranted.

- Material specifications and requirements;
- Raw material manufacturing requirements;
- Receiving of materials and consumables;
- Material storage and marking requirements;
- Forming, casting, or forging;
- Welding and/or assembly;
- Heat treating;
- Acceptance testing and NDT procedures and reporting;
- Geometrical measurements and reporting;
- Material testing and reporting;
- Repair and re-work procedures;
- Disposition of non-conforming materials;
- Finishing and/or coating;
- Finished material documentation and material tracking; and
- Shipping and handling.

The MPS shall give consideration to the set-up and calibration of NDT equipment and measuring instruments used during the manufacturing process. Set-up and calibration procedures shall be established for all NDT equipment utilized during production. Corresponding personnel qualification requirements shall be listed for each operation. In the event the manufacturer utilizes NDT, measuring

instruments, and/or material testing for production control, information, and/or raw material verification, the MPS shall specify the level of inspection and distribution of the results.

5.3 Development of Inspection and Test Plans (ITP)

When required by the pipeline operating company or referenced standard, required tasks for materials manufacturing shall include an ITP developed to establish activities or processes subject to monitoring, documentation review, when witnessing or verification activity is required, when testing of the product is required, or when a hold is required for production to wait for authorization to proceed.

An ITP is integral to establishing a uniform inspection and testing scheme that all parties (inspectors, manufacturers, and auditors) can follow during production. The uniform performance of activities allows for quality events to be measurable.

At a minimum, an ITP is typically developed for each pressure-carrying component of the pipeline system. The ITP should include as appropriate: testing frequency, acceptance criteria, calibration requirements, personnel qualification, reporting, and document retention. Additional information where applicable should include:

- segregation of non-conforming material;
- re-testing provisions, retention of test specimens; and
- supplemental testing of similar materials.

5.4 Manufacturing Traceability

Current industry standards do not require traceability of raw materials such as slabs, plates and welding consumables. Details and additional information concerning the specific material non-conformances listed above is lacking beyond identification of the heat numbers. Thermomechanical plate rolling practices necessary to achieve high strength base materials are not required to be traced to the mother plate. An improvement to the current standards and company specifications would be to include discrete plate tracking. Issues with wall thickness and grade may be resolved during the material receiving process if all plates from a specific mother plate can be identified. Similarly, issues of centerline segregation and variable properties within a given plate, as documented in pipe manufacturing, can be considered a risk in high strength component manufacturing[7].

Consideration should be given to recording the unique identification of each manufacturing component, raw material and/or consumable. Individual identifiers may be consolidated under a single identifier utilizing an appropriate tracking system. Quality control documentation such as heat treatment data, pressure test data, NDT results, test pieces, and mechanical and metallurgical test results should be traceable to the finished goods.

[7] PHMSA Advisory Bulletin, PHMSA-2009-0148, Potential Low and Variable Yield and Tensile Strength and Chemical Composition Properties in High Strength Line Pipe

Control of raw materials, consumables and finished goods throughout the manufacturing process is critical to identifying and segregating non-conforming materials. Additionally, traceability allows for the examination of similar items in the event that non-conformances are discovered.

Examples of items for consideration in a tracking system include but are not limited to pipe joints, fittings, castings, forgings, plate, skelp, welding consumables, heat numbers, lot numbers, and component serial numbers. Manufacturing and testing processes that employ more than one station, equipment operator or multiple discrete pieces of equipment should provide traceability to the finished goods. Examples include welding stations, furnaces, facing machines, assembly lines, tensile testers, and/or inspection stations.

In the case of distributor supplied components, the traceability is further diminished. Distributors provide a valuable service in the overall supply chain. Individual fittings are often necessary on short notice for maintenance projects or smaller projects. In many cases, it is impractical to commission a manufacturing run for small quantities of specific specification. However, obtaining additional manufacturing data for stock distributor fittings would benefit the process of determining the suitability of the material. Industry standards can be improved to include traceable raw material, heat treatment, and testing data for those products not project specific. Additionally, the pipeline operator procurement best practices including a CMTR pre-purchase review, supplemental NDE, and robust mill pre-qualification can benefit the procurement process.

The manufacturing traceability should be maintained after the piping or component is installed. Unique identifiers assigned to pipe and components and tied to geospatial locations and manufacturing traceability records facilitate the future location and assessment of any pipe or component that is related to possible performance deficiencies. The pipeline operator may employ tracking software that integrates with manufacturer systems and maintains product traceability from raw material through installed location.

5.5 Materials Inspection

Material inspection and testing requirements are specified in the MPS and ITP specific to the material being manufactured and the manufacturing process. All necessary witnessing, verification, testing, and documentation review shall be completed and accepted prior to the material or product being classified as finished goods and released to the project. Surveillance should be scheduled and implemented to provide comprehensive inspection of production. Processes that are observed are typically better controlled, and infrequent inspection may result in snap shots that are not representative of full production.

Deviations or upset conditions during the manufacturing process can lead to the introduction of defects in the finished product or the loss of traceability. Expectations for production performance such as pieces per shift, tests completed, product delivered, or repairs should be established to provide for condition monitoring. Deviations from these metrics during the manufacturing process may indicate an upset condition warranting further investigation. Hold points may be established to enable the testing and/or witnessing concurrent with the manufacturing process.

5.6 Raw materials verification

Based on the interviews conducted with the pipeline operating companies, it was identified by one pipeline operator that there is little to no traceability of distributor sourced components relative to the steel or plate mills, unlike the traceability in place for line pipe. MTR reviews and post procurement chemical analysis suggest that lean alloying chemistries may be an issue that when combined with variable heat treatment practices result in substandard material properties.

Other pipeline industry reviews have been conducted and the results documented. Chevron carried out review and testing of various flanges in response to recent incidents[8]. Their analysis identified that chemical composition limits are too permissive in MSS SP-75 and incomplete within ASTM A694. When microalloyed High Strength Low Alloy (HSLA) steel is used, traditional heat treating processes such as quenching and tempering are misapplied. Quality safeguards within industry standards are insufficient to identify all potential issues, and the use of sample coupons and/or testing of starting material may not accurately represent the properties of finished products.

Becht Engineering and Paulin Research Group (Becht) conducted burst tests of welding tees manufactured to ASME B16.9. Their testing indicated that fabrication techniques and acceptance criteria allowed by the standard can result in thinner sections of the tees which do not meet burst test requirements.[9] Becht postulated that it was likely that the current rules are allowing manufacturers searching for an economic advantage to use lower strength material that is easier to form and to use thinner pipe which is also easier to form. This practice may result in insufficient material in the crotch areas and a reduced margin for pressure containment capacity. Becht states that some manufacturers in certain cases are using 87.5 percent of the nominal thickness as a minimum thickness criteria. This practice is generally compliant with B16.9 due to the perceived vagueness of the 'mathematical analyses' requirements of paragraph 2.2.

Recommendations were submitted to the B16 committees, however the importance of raw material dimensional properties relative to other component manufacturing processes was not addressed. Case studies referenced above identified instances where elbows exhibited lower than specified wall thickness. Current standards do not provide for traceability to specific mother plates which limits the ability to identify and quarantine substandard plates prior to manufacturing of the component.

5.7 Manufacturing Procedure Qualification

Manufacturing procedures are often developed based on qualification testing. In many cases, trial products are manufactured and tested using a variety of base materials and processes. In this way, each manufacturer develops procedures that are specific to their plants, the installed equipment, and their raw material suppliers. This method results in plant specific processes. In the case of requirements for chemical composition and heat treatment, industry standard guidance in the form of maximum or minimum values are met, but the actual targets are in the manufacturer's procedure. Deviations from any of the qualification production parameters such as furnace loading, furnace hold times, quench media temperature or agitation can result in substandard products even if the industry standard

[8] Pipeline Flanges & Fittings Substandard Properties, Kirk Baker, Chevron, Presentation to API Committee on Standardization of Oilfield Equipment and Materials (CSOEM), June 2016

[9] Burst tests of B16.9 Welded Tees, Pressure Vessels and Piping Conference (PVP) 2014 Paper 28265, March 15, 2015

requirements are met. This effect is compounded if multiple deviations in production parameters occur. Chemical composition may create steels that are sensitive to small deviations in processing such as normalizing or tempering temperatures. Similarly, wall thickness deviations, furnace loading patterns, and furnace rack condition may affect furnace hold times. The cumulative effect of deviations should be addressed in the ITP which monitors specific processes to confirm compliance with the manufacturing procedure. Multiple deviations may trigger supplemental testing or production monitoring.

5.8 Inspection and Testing Enhancements

Pipeline operating companies who have experienced material issues identified inspection and testing improvement opportunities for both manufacturing facilities and distributors. Material testing is generally conducted using coupons which undergo similar forming operations and heat treatment. Coupons often consist of the same raw material (i.e. plate) welded or attached to a production fitting. This may take the form of a welding "run on/run off" tab in the case of formed and welded material. The following items may be considered for inclusion in company specifications and/or commercial agreements to ensure testing is representative of the finished products:

- Increase lot testing frequencies to ensure test results are available for all heat treatment batches.
- Specify locations of test coupons for lot testing including the location within furnace loads.
- Conduct additional furnace uniformity testing to ensure adequate temperature settings and equipment calibration.
- Conduct destructive tests of finished components to verify the accuracy of coupon tests.
- Conduct hardness and metallographic testing to supplement lot testing.
- Restrict the use of retesting and reheat treatments without prior company approval.
- Require charts or records of all heat treatment temperature and hold times in final documentation.
- Mandate traceability to clearly track each fitting from raw material to finished goods.
- Provide for documentation of raw material, process parameters and test results of fittings intended for distributors.
- Apply furnace loading, support and stacking procedures including the use of racks or stands.
- Apply requirements and calculations for heat treatment hold times.
- Apply quench temperature limits, agitation, and process time requirements.
- Apply minimum restrictions on material chemistries for high strength products.

5.9 Procurement

The current industry procurement protocols often rely on a pipeline operating company's specifications to overcome gaps in industry standards. This creates an uneven playing field where pipeline operators

with comprehensive specifications are placed in an uncompetitive position due to higher procurement costs. The opposing risk is that non-conforming materials are not promptly identified and allowed to be placed in operations. Procurement of fabricated assembles (meter skids) or turn-key constructed facilities (pump stations) may involve an additional party purchasing fittings for inclusion in the assembly.

Based on the interviews conducted with the pipeline operating companies, it was identified by one pipeline operator that components are often procured through distributors based on a listing of pre-qualified manufacturers. The manufacturers are subject to removal should substandard or non-conforming materials be identified during the procurement acceptance and testing process.

Procurement policies and procedures including manufacturer pre-qualification and periodic review should be developed to ensure pipeline operator quality strategies are transferred to all parties in the supply chain.

5.10 Acceptance and testing

One pipeline operating company that was interviewed indicated that a pre- and post-purchase testing process has been initiated for distributor supplied components. MTRs are requested and reviewed against the pipeline operating company chemical specifications prior to issuance of the final purchase order. Prior to delivery to the job site, the pipeline operator visually inspects the component and conducts magnetic particle inspection (MPI) of the pipe ends and any suspect areas. Wall thickness is spot checked in addition to the checks initiated in areas identified by the visual inspection. The pipeline operating company does not allow substitutions of higher yield, lower wall thickness materials in part to avoid weldability issues in the field. The carbon equivalent (CE) value is reviewed at the MTR evaluation stage against pipeline operating company specifications and CSA and API standards.

6.0 CONCLUSION

Microalloyed high strength steels are very sensitive to changes in manufacturing processes such as thermomechanical rolling and heat treating. This sensitivity compounds small deviations in manufacturing process such as tempering temperature. To minimize the risk of substandard materials, the initial process qualification often referred to as First Article Inspection forms the basis for all subsequent manufacturing procedures and the Manufacturing Procedure Specification (MPS) when applicable.

Chemical composition limits are too permissive in MSS SP-75 and incomplete within ASTM A694. When microalloyed High Strength Low Alloy (HSLA) steel is used, traditional heat treating processes such as quenching and tempering, can be misapplied.

Manufacturers in certain cases are using 87.5 percent of the nominal thickness as a minimum thickness criteria. This practice is generally compliant with B16.9 due to the perceived vagueness of the ‘mathematical analyses’ requirements of paragraph 2.2.

Variables such as heat treatment and quenching temperatures, hold times, furnace load configurations, etc. should be sufficiently detailed to allow for quality control monitoring. Initial qualification testing should be rigorous and clearly define the resultant material properties as related to the product specification. Finally, the MPS and ITP should sufficiently define the process such that production

inspection is efficiently and thoroughly conducted. Deviations from the process need to be quickly identified and supplemental testing utilized to define the impact. A robust system of traceability should allow for all materials affected by a process disruption to be identified and segregated to prevent their entry into the supply chain.

The failure of components to conform to standards and specifications, as investigated in this report, is a direct result of failures to control the manufacturing processes. These failures were not identified by the established ITP protocols, either during production monitoring or subsequent material acceptance testing.

Enhancements to current industry standards are recommended to close the gaps identified between standards, manufacturing processes and the intended component performance (See Table 2). Pipeline operators and/or distributors should consider enhancing product specifications to provide more rigorous traceability, process monitoring and product testing.

Table 2. Standards and Regulation Quality Assurance Strategies

Gap	Criteria	Standard	QA Strategies
Limit ranges not defined	Chemistry aim points and limits	CSA Z245.11-13 MSS SP-75 (2014)	5.2, 5.6
Not addressed in current standards	Slab or ingot casting requirements, slab identification, and traceability	CSA Z245.11-13 MSS SP-75 (2014)	5.2, 5.4
Not addressed in current standards	Plate or skelp requirements, testing requirements, identification, and traceability	CSA Z245.11-13 MSS SP-75 (2014)	5.2, 5.6
Not addressed in current standards	Plate or skelp shipping and handling requirements	CSA Z245.11-13 MSS SP-75 (2014)	5.2, 5.6
Not addressed in current standards	Traceability	CSA Z245.11-13	5.2, 5.4
Not addressed in current standards	Manufacturer Procedure Specifications (MPS)	CSA Z245.11-13	5.2
Product specific inspection and testing plan not required	Inspection and Test Plan (ITP)	CSA Z245.11-13	5.3
Various gaps in material and lot testing	Certified Material Test Report (CMTR)	CSA Z245.11-13 MSS SP-75 (2014)	5.8, 5.9, 5.10
Lack of specified process controls	Heat Treating	CSA Z245.11-13 MSS SP-75 (2014)	5.3, 5.7, 5.8
Reliance on buyer specifications	Product Ordering Requirements	CSA Z245.11-13 MSS SP-75 (2014)	5.1, 5.5

Table 3. Acronyms

Acronym	Defined
ADB	Advisory Bulletin (per PHMSA)
ABSA	Alberta Boilers Safety Association
API	American Petroleum Institute
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
BPVC	Boiler & Pressure Vessel Code (per ASME)
CE	Carbon Equivalent
CFR	Code of Federal Regulations
CMTR	Certified Material Test Report
CSA	Canadian Standards Association
HSLA	High Strength Low Alloy
IMP	Integrity Management Program
ISO	International Organization for Standardization
ITP	Inspection and Test Plan
MO	NEB Miscellaneous Order
MPS	Manufacturer Procedure Specifications
MSS	Manufacturers Standardization Society
MTR	Material Test Report
NDE	Non-destructive examination
NDT	Non-destructive testing
NEB	National Energy Board (Canada)
PHMSA	Pipeline and Hazardous Materials Safety Administration (USA)
PQR	Procedure qualification record
PRCI	Pipeline Research Council International
QA	Quality Assurance
QC	Quality Control
QMS	Quality Management Systems
SA	Safety Advisory (per NEB)
TSB	Transportation Safety Board (Canada)
WPHY	Wrought Pipe High Yield
WPS	Welding Procedure Specification

Table 4. Definitions

Term	Definition	Source of Definition
Activity Quality Plan (AQP)	Document(s) that establishes procedures, minimum personnel qualifications, roles and responsibilities, inspection methods, and record requirements of construction activities. The intent of an AQP is to identify quality concerns and methods of control	
Analysis, heat	The chemical analysis reported by the steel producer as being representative of the heat of steel.	CSA Z245.1-14
Analysis, product	The chemical analysis made on a sample taken from the finished pipe or from material representative of the finished pipe.	CSA Z245.1-14
Assembly	The association of multiple parts/components into a finished product, including as a minimum, installation of all pressure-containing parts and pressure-controlling parts needed to ensure conformance to applicable pressure testing requirements.	API Spec 6D
Certificate of Compliance	A document that states that the product was manufactured, sampled, tested, and inspected in accordance with the requirements of this Standard (including year of publication) and of the purchase order, and was found to have met such requirements.	CSA Z245.1-14
Component	A pressure-retaining member of the piping, other than pipe	CSA Z662-15
Conformance	Satisfying the applicable documented requirements, also referred to as conformity.	
Daughter Coil	The portion of steel removed via slitting, cutting, or shearing from the mother coil which may be used to produce one or more pieces of pipe.	CSA Z245.1-14
Daughter Plate	The portion of steel removed via slitting, cutting, or shearing from the mother plate which may be used to produce one or more pieces of pipe.	CSA Z245.1-14
Defect	An imperfection of sufficient magnitude to warrant rejection based on the requirements of this Standard.	CSA Z245.1-14, CSA Z662-15
First Article Inspection	A First Article Inspection (FAI) is a design verification and design history record and a formal method of providing a reported measurement for a given manufacturing process.	
Grade	A designation of the pipe based on strength. Note: a grade is non-dimensional; however, it is numerically equivalent to the specified minimum yield strength in megapascals.	CSA Z245.1-14
Heat	The batch of steel tapped from a melting furnace.	CSA Z245.1-14
Heat Analysis	The chemical analysis reported by the steel producer as being representative of the heat of steel.	CSA Z245.11-13
Imperfection	A material discontinuity or irregularity that is detectable by inspection in accordance with the requirements of this Standard.	CSA Z245.1-14
Indication	Evidence obtained by nondestructive inspection.	CSA Z662-15

Term	Definition	Source of Definition
Inspection	Evaluate for conformity by observation and judgment accompanied, as appropriate, by testing and/or measurement.	
Inspection and Test Plan (ITP)	Written description of inspection plan which may include evaluation methods, hold points, project specific technical requirements, and resources, typically used in manufacturing.	
Inspection, non-destructive	The inspection of piping to reveal imperfections, using radiographic, ultrasonic, or other methods that do not involve disturbance, stressing, or breaking of the materials. Note: Direct visual inspection is not considered a form of non-destructive inspection.	CSA Z662-15
Management System	A framework of policies, processes, and procedures used by an organization to ensure that it can fulfill all the tasks required to achieve its objectives.	
Material Test Report (MTR)	Also known as a certificate of compliance with a note to refer to the applicable CSA Z245 Standard for definition.	CSA Z662-15, Annex P (informative) Development and qualification of welding procedure specifications
Mother coil	The entirety of a hot rolled coil of steel processed from a single reheated slab which may be used to produce one or more pieces of pipe.	CSA Z245.1-14
Mother plate	A hot rolled plate of steel processed from a single reheated slab which may be used to produce one or more pieces of pipe.	CSA Z245.1-14
Pipeline	Those items through which oil or gas industry fluids are conveyed, including pipe, components, and any appurtenances attached thereto, up to and including the isolating valves used at stations and other facilities.	CSA Z662-15
Plate	Defined as a metal sheet with a thickness of .2300" or more.	
Procedure qualification record (PQR)	The record of the data recorded during the welding of the test coupons.	CSA Z662-15, Annex P
Product analysis	The chemical analysis made on a sample taken from the finished fitting or from material representative of the finished fitting.	CSA Z245.11-13
Quality Assurance (QA)	Quality activities focused on providing confidence that quality requirements will be fulfilled. Quality assurance applies to the processes used to create the deliverables.	INGAA-May 12
Quality Control (QC)	Quality activities focused on confirming that quality requirements have been fulfilled.	INGAA-May 12
Quality Management	Coordinated activities to direct and control within an organization with regard to quality.	INGAA-May 12

Term	Definition	Source of Definition
Quality Management System (QMS)	A systematic approach designed to manage a company's objectives, policies, procedures, and processes with regards to quality. Quality is managed using four main activities: quality planning, quality assurance (QA), quality control (QC), and quality improvement.	(DNVGL) Improving Quality Management Systems (QMS) for Pipeline Construction Activities
Receiving verification	Verify that the inward goods are received at the assembler/manufacturer and are in conformance with purchase order requirements.	API Spec 6D
Safety and Loss Management System	The safety and loss management system is a systematic, comprehensive, and proactive process for the management of safety and loss control associated with activities throughout the life cycle of a pipeline system.	CSA Z662-15
Skelp	The flat-rolled product intended to be formed into pipe.	CSA Z245.1-14
Standardization	The adjustment of a nondestructive inspection instrument to an arbitrary reference value.	CSA Z245.1-14
Stock Fitting	A fitting manufactured for dealer or manufacturer stock not related to a specific purchase order. A fitting not meeting a specific purchase order, but in conformance with one or more industry standards.	
Traceable	Traceable records are those which can be clearly linked to original information about a pipeline segment or facility.	ADB 12-06
Verifiable	Verifiable records are those in which information is confirmed by other complementary, but separate, documentation.	ADB 12-06
Complete	Complete records are those in which the record is finalized as evidenced by a signature, date or other appropriate marking.	ADB 12-06

Table 5. References

Category	Document	Title
Standard	ASME BPVC-2013	ASME BPVC, Boiler and Pressure Vessel Code (2013 Edition)
Standard	ASME/ANSI B16.9	ASME/ANSI B16.9, Factory-Made Wrought Buttwelding Fittings
Standard	API Spec 5L	API Spec 5L, Specification for Line Pipe, American Petroleum Institute (API), www.api.org
Standard	API Spec Q1	API Spec Q1, Quality Management System Requirements for Manufacturing Organizations for the Petroleum and Natural Gas Industries, American Petroleum Institute (API), www.api.org
Standard	API Spec Q2	API Spec Q2-11, Quality Management System Requirements for Service Supply Organizations for the Petroleum and Natural Gas Industries, First Edition (Spec Q2), American Petroleum Institute (API), www.api.org
Standard	ASTM A370-13	ASTM A370-13, Standard Test Methods and Definitions for Mechanical Testing of Steel Products, 2013
Standard	ASTM A694	ASTM A694, Standard Specification for Carbon and Alloy Steel Forgings for Pipe Flanges, Fittings, Valves and Parts for High-Pressure Transmission Service
Standard	ASTM A991/A991M-10	ASTM A991/A991M-10, Standard Test Method for Conducting Temperature Uniformity Surveys of Furnaces Used to Heat Treat Steel Products
Standard	CSA Z245.1-14	CSA Z245.1 Steel Pipe
Standard	CSA Z245.11-13	CSA Z245.1 Steel Fittings
Standard	CSA Z662-15	CSA Z662 Oil & Natural Gas Pipeline Systems
Standard	ISO 9001	ISO 9001, Quality Management Systems; International Organization for Standardization; Switzerland, 2015, www.iso.org
Standard	MSS SP-75-2014	MSS SP-75-2014 High-Strength, Wrought, Butt-Welding Fittings
Regulatory	ADB-09-01	PHMSA-2009-0148; “Pipeline Safety: Potential Low and Variable Yield and Tensile Strength”, Bulletin ADB-01, May 2009.
Regulatory	IB16-018	ABSA Informational Bulletin “Concerns about Carbon Steels with Low Toughness Properties”; IB16-018, November 25, 2016.
Regulatory	MO-001-2016	Identification of Pipe and Fittings with the Potential to Exhibit Substandard Material Properties and Order MO-001-2016, February 5, 2016.
Regulatory	NEB SA 2016-01A2 – Pipeline Fitting Materials Quality Assurance	Safety Advisory SA 2016-01A2 is an amendment (May 12, 2017) to SA 2016-01A that was issued on April 12 2016.

Category	Document	Title
Regulatory	IB16-018	ABSA Informational Bulletin "Concerns about Carbon Steels with Low Toughness Properties", November 25, 2016.
Presentation		Barry Messer and Ted Hamre on "New Low Temp Impact Toughness Issues with Carbon Steel Piping Components", September 30, 2014.
Presentation		Barry Messer on "Carbon Steel Low Toughness issues - CS Pipe forged flanges and fittings", November 2015.
Presentation	Kirk Baker- Pipeline flanges & Fittings Substandard Properties-June 2016.pdf	Baker, Kirk for Chevron "Pipeline flanges & Fittings Substandard Properties"; API CSOEM, Washington, DC, June 2016.
Paper	DNVGL/PHMSA	Gould, Melissa J. (DNV GL) "Improving QMS for Pipeline Construction Activities", Prepared for DOT and PHMSA, 2015.
Paper	INGAA White Paper	INGAA, "Identification of Pipe with Low and Variable Mechanical Properties in High Strength, Low Alloy Steels (Energy Pipeline Industry Pipe Quality Action Plan September 2009"
Paper	INGAA White Paper	INGAA, "Overview of Quality Management Systems – Principles and Practices for Pipeline Construction", May 2012.
Paper	INGAA White Paper	INGAA, "Guidelines for Practical Implementation of a Construction Quality Management System" July 2014
Paper	PVP2014-28265	Paulin Research Group et al, "Burst Test of B16-9 Welded Tees", ASME PVP2014-28265, 2014.
Paper	NCPWB technical bulletin, May 2016	Sperko, Walter, "Risk of Brittle Fracture of Carbon Steel Piping During Hydrostatic Testing", 2016, National Certified Pipe Welding Bureau
Paper	Letter to the editor: Carbon steel piping, Chemical engineering	Huitt, Bill, "Letter to the editor: Carbon steel piping", Chemical engineering, July 1, 2016.
Paper	Europipe paper	Kalwa, Dr. Ing Christoph, et al., "High Strength Steel Pipes: New Developments and Applications", June 10-11, 2002 Onshore Pipeline Conference, Texas.
Report	TSB P13H0107.pdf	TSB Pipeline Investigation Report P13H0107 Rupture TransCanada (Near Fort McMurray, Alberta), October 17, 2013.

APPENDIX A

Gap Analysis

A gap analysis was performed to compare selected standards against a list of criteria. The criteria were:

- Fabrication of material
  - Chemistry aim points and limits
  - Carbon equivalent
  - Heat identification
  - Slab casting requirements, slab identification, and traceability
  - Plate or skelp requirements, testing requirements, identification, and traceability
  - Plate or skelp shipping and handling requirements
  - Heat Treating
  - Forming
  - Welding
  - Hydrotesting
  - Sizing and dimensions
  - Grade requirements
  - Marking requirements
  - Shipping and Handling
- Quality control
  - Product Ordering Requirements
  - Manufacturer Procedure Specifications (MPS)
  - Inspection and Test Plan (ITP)
  - Certified Material Test Report (CMTR)
  - Material receiving and Identification
  - Nondestructive examination (NDE)
  - Defects
  - Retests
  - Final Inspection
- Traceability

The resulting comparison appears in the table below. Pipeline operator qualification was not considered, nor were procedures related to sour service.

The Standards reviewed were as followed:

- CSA Z662-15, Oil and gas pipeline systems
- CSA Z245.1-14, Steel Pipe
- CSA Z245.11-13, Steel Fittings
- MSS SP-75 (2014), High Strength, Wrought, Butt-Welding Fitting

Category	Quality Process Element	CSA Z662-15 - Oil and gas pipeline systems	CSA Z245.1-14 -Steel Pipe	CSA Z245.11-13 -Steel Fittings	MSS SP-75 (2014) -High-Strength, Wrought, Butt-Welding Fitting
	Chemistry aim points and limits	7.5.2.1 Filler metals shall be as specified in CSA W48 or ASME Boiler and Pressure Vessel Code, Section II Part C, or they shall have chemical and mechanical properties that are as specified in CSA C48 or ASME Boiler and Pressure Vessel Code, Section II Part C, even though they were not specifically manufactured in accordance with either.	**6.1 General** Except as allowed by Clause 6.3.5.4, the methods, practices, and definitions pertaining to chemical analysis shall be in accordance with the requirements of ASTM A751.	**7.1 General** Except as otherwise required by this Standard, the methods, practices, and definitions pertaining to chemical analysis shall be as specified in ASTM A751	7.1 The determination of the chemical composition of each heat of steel used in meeting the requirements of Table 1 shall be determined by a product analysis controlled by the fitting manufacturer.
		14.3.1.2 Detailed material specifications shall be prepared for all unlisted materials…The material specifications for each material item (e.g., type and grade) shall comply with the requirements of ASME B31.3, Paragraph 323.1.2. The requirements shall include but are not limited to the following: a) chemical properties....	**6.3.1 General** The requirements for product analysis shall be as given in Table 5.		
		Annex P Development and qualification and welding procedure specifications. P.1.1 This Annex provides guidelines for acquiring welding data, application of the welding data and the preparation of welding procedure documentation…**P.3.1 General**…Data acquisition, as a minimum, consists of the recording of all essential change information during the welding of the test coupons for the development of the PQR. The details of the materials used including grade and heat number, if applicable, shall be recorded so that carbon equivalent can be calculated and recorded on the PQR. In the absence of MTRs, it is acceptable to perform a chemical analysis of the test coupon(s).	**6.3.2 Frequency** Product analyses shall be conducted once per heat.	**7.3 Product analysis** For Grades 290 and higher, at a frequency of one test per heat, a product analysis shall be determined by the fitting manufacturer or the steel manufacturer. The requirements for product analysis shall be as specified in Table 6.	7.2 The choice and use of alloying elements for fittings made from high-strength, low-alloy steels to give the tensile properties that are prescribed in Table 2 shall be made by the manufacturer, and included and reported to identify the type of steel.
		7.1.9 For each joint of steel pipe of unknown origin to be used as permitted by Clause 5.6.4b, the carbon equivalent shall be determined using the formula in Clause 7.6.4.4 by means of chemical analysis prior to the assignment or development of an appropriate welding procedure.	**6.2 Heat Analysis** -The requirements for heat analysis shall be as specified in Table 5. [*Table 5 stipulates:...where F is a compliance factor that depends on carbon content and shall be as given in Table 6.*] *(Chemical composition limits for heat and product analyses)*		7.3 Carbon Equivalent shall be computed by one of the following equations.…
		7.2.6 For the purpose of welding steel piping materials as specified in Clause 7.2.5, …provided that the maximum carbon equivalent does not exceed that given in Table 7.1.			
		7.2.7 For welding steel piping materials having a specified minimum yield strength higher than 386 Mpa using welding procedure specifications qualified as specified in Clause 7.2.4 or 7.2.5, an increase in carbon equivalent of more than 0.05 from that of the material used for the procedure qualification shall be considered to be an essential change and shall necessitate requalification of the welding procedure specification or establishment and qualification of a new welding procedure specification.			

Category	Quality Process Element	CSA Z662-15 - Oil and gas pipeline systems	CSA Z245.1-14 -Steel Pipe	CSA Z245.11-13 -Steel Fittings	MSS SP-75 (2014) -High-Strength, Wrought, Butt-Welding Fitting
		7.6.4.4 Base materials The following shall be specified for the base materials:…d)for base materials having a specified minimum yield strength higher than 386 Mpa, maximum carbon equivalent used in procedure qualification. The following formula shall be used for determining the carbon equivalent (CE) value....			
		7.6.5 Essential changes for qualification of welding procedure specifications ……the carbon equivalent requirement shall apply to both the branch pipe and the run pipe.			
		Table 7.3 Essential changes for qualification of welding procedure specifications			
		7.9.10.2 Except where the qualified welding procedure specification provides otherwise,…Where the carbon equivalent value of the material being joined is in excess of 0.40, the second weld bead….			
		7.17.2.4 For all material grades, the maximum carbon equivalent of the base material used in procedure qualification shall be recorded in the procedure qualification records. An increase in the carbon equivalent of more than 0.02 from that of the material used for the welding procedure specification qualification shall be considered to be an essential change, and shall necessitate requalification of the welding procedure specification or establishment and qualification of a new welding procedure specification.			
	CE calculation requirements	Table 7.10 Essential changes for qualification of welding procedure specifications (WPS) intended for welding on in-service piping	**13.5.1 General**…the specimens shall be made of material that has a carbon equivalent not more than 0.05% lower than that of the pipe on which repair welds will be made…	**7.2 Heat Analysis** -*The requirements for heat analysis shall be as specified in Table 6.* *(Chemical composition limits for heat and product analyses)*	
		Table 12.3 Essential changes for qualification of welding procedure specifications			
		12.10.7 Repair procedures for steel distribution pipeline systems …Repair procedures for steel distribution pipeline systems shall be as specified …except as follows:…b) For pipe having a specified minimum yield strength of 317 Mpa or less, or pipe having a minimum yield strength greater than 317 MPa, up to and including 386 MPa, with a carbon equivalent of 0.30 or less, ...			
		16.6.1 Carbon Equivalent For all material grades, the maximum carbon equivalent of the base material used in procedure qualification shall be recorded in the procedure qualification records.			

Category	Quality Process Element	CSA Z662-15 - Oil and gas pipeline systems	CSA Z245.1-14 -Steel Pipe	CSA Z245.11-13 -Steel Fittings	MSS SP-75 (2014) -High-Strength, Wrought, Butt-Welding Fitting
Raw Material		**16.6.2 Change in carbon equivalent** When steel piping materials with a carbon equivalent greater than 0.45 are being welded, an increase in carbon equivalent of more than 0.02 from that of the material used for the procedure qualification shall be considered to be an essential changes and shall necessitate requalification of the welding procedure specification or the establishment and qualification of a new welding procedure specification. 16.6.7 , (see note) **Annex K (Standards of acceptability for circumferential pipe butt welds based upon fracture mechanics principles)** K.3.1 Welding procedures…2)consideration should be given to the effects of changes in residual elements that are not included in the carbon equivalent formula. **Annex P Development and qualification and welding procedure specifications**. P.1.1 This Annex provides guidelines for acquiring welding data, application of the welding data and the preparation of welding procedure documentation…**P.3.1 General**…Data acquisition, as a minimum, consists of the recording of all essential change information during the welding of the test coupons for the development of the PQR. The details of the materials used including grade and heat number, if applicable, shall be recorded so that carbon equivalent can be calculated and recorded on the PQR. In the absence of MTRs, it is acceptable to perform a chemical analysis of the test coupon(s).	17.4 For each heat of steel supplied, the manufacturer shall furnish a report of the deoxidation practice, heat analysis, product analysis, and carbon equivalent values….		16.3 ***Certified Material Test Report (CMTR)*** A Certified Material Test Report shall be furnished listing the actual results of the chemical product analysis, including **carbon equivalent**.
	Slab or Ingot Casting requirements; identification and traceability	*no mention*	4.4 Quality program The manufacturers of slab/billet, hot rolled coil/plate and pipe shall comply with the requirements of a nationally- or internationally recognized quality management system.	*no mention*	6. Materials -(The requirements listed do not include any steel manufacturing requirements, MTRs, ITPs, etc. for traceability)
			5.3.1 Skelp widths for helical seam pipe shall not be less than 0.8 times or more than 3.0 times the pipe's specified outside diameter. **5.3.2** For welded pipe, a coil/plate rolling practice shall be defined and documented stating all critical variables (with tolerances) required to achieve the necessary mechanical properties in the finished pipe. The rolling practice shall be designed and controlled to ensure a suitable uniformity of properties along the entire length of plate/coil intended for manufacture of pipe and among the coil/plates rolled to the same rolling practice from the same heat lot.	*no mention of plate or skelp*	

Category	Quality Process Element	CSA Z662-15 - Oil and gas pipeline systems	CSA Z245.1-14 -Steel Pipe	CSA Z245.11-13 -Steel Fittings	MSS SP-75 (2014) -High-Strength, Wrought, Butt-Welding Fitting
	Plate or skelp requirements; Plate or skelp testing requirements; Plate or skelp identification and traceability	5.2.2.4 Where Category II or III pipe at minimum design temperatures lower than -5C is required, proven notch toughness properties of longitudinal, helical, and skelp end welds shall be required of SAW welds for the deposited weld metal centerline location and the heat-affected zone (HAZ), and of electric welds for the weld zone location, in accordance with Clause 8.5 of CSA Z245.1 (notch toughness tests-weld).	5.3.3 The ability of the rolling practice to achieve the pipe mechanical properties shall be demonstrated by way of representative historic data and/or pre-production trials. For grades higher than Grade 359, if the coil/plate is purchased from an external supplier, the pipe manufacturer shall conduct an initial onsite technical audit of the coil/plate mill and periodic on-site or remote confirmation that the coil/plate rolling practice continues to achieve the planned results. Coil/plate rolling practice validation criteria shall be verified as part of the audit. 7.2.6.3.2 For pipe Grades 414 and higher, where both retests conform to the specified requirements and provided individual pipe traceability to mother coil/plate location, the manufacturer shall test additional lengths adjacent to (before, after and beside, as applicable) the initial failure within the mother coil or plate considering adjacent daughter coil(s) or plates(s) as applicable. Pipe testing shall continue u until satisfactory results...surround the non-conforming section of the mother coil/plate. The pipes from the nonconforming section of mother coil/plate shall be rejected and the remainder of the pipe from the lot shall be accepted, including the initial test length (the length from which the initial test specimen was taken), provided that the following locations, as applicable, in such a length are subsequently tested and such retests conform to the specified requirements: a) where the length does not contain a skelp end weld, both ends of the length; or b) where the length contains a skelp end weld, both ends of the initially test portion of the length. 12.2.1.2 Electric-welded pipe produced from single lengths of plate skelp shall additionally have the weld seam at the pipe ends inspected for at least 200 mm by manual ultrasonic methods or by other methods agreed on by the purchaser and the manufacturer. 17.3 Where specified in the purchase order, the manufacturer shall furnish a report of the type of skelp rolling mill used.	**6.1 Steelmaking process** Fittings shall be made from open hearth, electric furnace, or basic oxygen-process steel.	6. Materials -(The requirements listed do not include any steel manufacturing requirements, MTRs, ITPs, etc. for traceability)
	Plate or skelp shipping and handling requirements	*no mention of requirements*	17.4 For each heat of steel supplied, the manufacturer shall furnish a report of the deoxidation practice, heat analysis, product analysis, and carbon equivalent values….In addition, the report shall identify the name and location of facilities used for pipe manufacturing, plate/coil rolling and steelmaking.	*no mention of requirements*	*no mention of requirements*

Category	Quality Process Element	CSA Z662-15 - Oil and gas pipeline systems	CSA Z245.1-14 -Steel Pipe	CSA Z245.11-13 -Steel Fittings	MSS SP-75 (2014) -High-Strength, Wrought, Butt-Welding Fitting
			17.6 For each lot supplied, the manufacturer shall furnish a report of the applicable tensile properties		
	Manufacturer Procedure Specifications (MPS) requirements	*references to welding procedure specifications but not Manufacturer Procedure Specifications (MPS)*	*no references*	*references to welding procedure specifications but not Manufacturer Procedure Specifications (MPS)*	14. 1 Fittings shall be manufactured in accordance with a documented MPS. If specified by the purchaser, manufacturing shall not proceed until the MPS has been accepted by the purchaser. The MPS shall specify …
	Inspection and Test Plan (ITP) and Certified Material Test Report (CMTR) requirements	*No references to ITP*	*No references to ITP, CMTR or MTR*	*No references to ITP, CMTR or MTR*	16.2 ITP The inspection and testing to be performed during qualification and production shall be as summarized in Sect 16.2.1 below…
		(Annex) P.5.3 WPS content…In order for a WPS to be complete, it shall include PQRs and all applicable supporting documentation, including nondestructive inspection reports, lab reports and MTR.	17.1 The manufacturer shall furnish a certificate of compliance for each order item. Note: A single document containing certificate of compliance information and test report information may be used.	15.1 The manufacturer shall furnish a certificate of compliance for each order item.	16.3 **Certified Material Test Report (CMTR)** A CMTR shall be furnished listing the actual results of the chemical product analysis, including CE...; mechanical properties of each lot of steel and tensile strength of weld (if applicable)...; …heat treatment used including temperatures....; NDE....; and any special or supplemental tests required by the purchase order.....
		(Annex) **N.5 Integrity management program records** N.5.1 Operating companies shall prepare and manage records related to pipeline system design, construction, operation, and maintenance that are needed for performing the activities included in the integrity management program. Items to be considered for inclusion in such records shall include the following, as appropriate for the type of pipeline system...e)material test reports...	17.2 Where specified in the purchase order, the manufacturer shall furnish a report of the steelmaking process and casting method used.	15.2 Where specified in the purchase order, for grades lower than Grade 290, the manufacturer shall furnish a report of the heat analysis for each heat of steel supplied. For each heat analysis, the elements reported shall include carbon, manganese, phosphorous, sulphur and silicon. 15.3 ...for grades 290 and higher....	
		10.1.1 Engineering assessments of existing pipeline system shall be conducted and documented ... and the analysis shall include consideration of the following, as applicable:…b)material specifications and properties…	17.3 Where specified in the purchase order, the manufacturer shall furnish a report of the type of skelp rolling mill used.	15.3 Where specified in the purchase order, for Grades 290 and higher, the manufacturer shall furnish a report of the product analysis and the carbon equivalent value for each heat of steel supplied. For each heat analysis, the elements reported shall include each of the elements specified in Table 6.	**16.4 Rejection** Each fitting in which injurious defects are found during shop or field fabrications may be rejected, and the manufacturer shall be notified.
			17.4 For each heat of steel supplied, the manufacturer shall furnish a report of the deoxidation practice, heat analysis, product analysis, and carbon equivalent values….In addition, the report shall identify the name and location of facilities used for pipe manufacturing, plate/coil rolling and steelmaking.	15.4 Where specified in the purchase order, the manufacturer shall furnish a report of the results of any of the mechanical tests …specified by the purchaser to be reported.	*see additional notes on CMTR ….Appendix X1 for Supplementary Requirements (not applicable to product furnished to this standard Practice, except when specified on the purchase order…), including SR-19 through SR-22.*

Category	Quality Process Element	CSA Z662-15 - Oil and gas pipeline systems	CSA Z245.1-14 -Steel Pipe	CSA Z245.11-13 -Steel Fittings	MSS SP-75 (2014) -High-Strength, Wrought, Butt-Welding Fitting
	Material receiving and identification	6.5 Inspection 6.5.1 The provisions in Clause 6.5 shall apply, as appropriate, during the period of time from the receipt of materials to the completion of installation; such provisions shall also apply to prefabricated assemblies..6.5.2.1 The company shall perform inspections to ensure that the requirements of this Standard are met. 6.5.2.2 The company shall have documented procedures for conducting inspections. Note: These procedures should include a) the number and type of inspectors; b) the number and type of field and shop measurements; c) the relevant reporting and record requirements; and d) documentation outlining the roles, responsibilities, minimum qualifications, duties, and tasks of inspectors. 6.5.4 Pipe and components shall be inspected for defects. Such inspection shall include, but not limited to, inspection for flattening, ovality, straightness, pits, slivers, cracks, gouges, dents, defective weld seams, and defective field welds...	*no mention*	*no mention*	6.Materials -includes description of acceptable steel but no documentation/traceability addressed.
	Forming	*no references to forming processes*	**11.5.10 Geometric Deviations** Geometric Deviations from the normal cylindrical contour of the pipe within 200 mm of each pipe end that occur as a result of the pipe-forming process or manufacturing operations (e.g., flat spots or peaks) shall not exceed 3 mm, measured as the gap between the extreme point of the deviation and the prolongation of the normal contour of the pipe.	6.4 Forming and Heat-treating processes	14.1 Fittings shall be manufactured in accordance with a documented Manufacturing Procedure Specification (MPS). If specified by the purchaser, manufacturing shall not proceed until the MPS has been accepted by the purchaser. The MPS shall specify the following items, as applicable...b) For fitting manufacture:: 1) Forming method.....
				12.1.4.1 Tees manufactured by cold-forming methods shall be liquid penetrant or magnetic particle inspected using methods specified in ASTM E165 or ASTM E709, respectively. Such inspection shall be performed after the final heat treatment. Tees so inspected shall comply with Appendix 6 or 8, whichever is applicable, of the ASME Boiler and Pressure Vessel Code, Section VIII, Division 1.	14.2 Fittings may be made by forging, hammering, pressing, piercing, rolling, extruding, upsetting, welding, or by a combination of these operations. The forming procedure shall be so applied that it will not produce injurious defects in the fittings.
					15.3 **Magnetic Particle or Liquid Penetrant Examination** All butt-weld tees manufactured by cold-forming method(s) shall be subjected to magnetic particle or liquid penetrant examination. This examination shall be performed after final heat treatment. ….

Category	Quality Process Element	CSA Z662-15 - Oil and gas pipeline systems	CSA Z245.1-14 -Steel Pipe	CSA Z245.11-13 -Steel Fittings	MSS SP-75 (2014) -High-Strength, Wrought, Butt-Welding Fitting
	Welding	4.3.18 Pressure design for components	**4.2.1 Weldability** In general, the weldability of pipe depends on the pipe's chemical and mechanical properties, the pipe end dimensions, the welding procedure, and the welding conditions. Pipe shall be capable of being welded when the welding procedures are in accordance with the requirements of CAN/CSA Z662.	**1.1 General** This Standard covers wrought steel buttwelding fittings, including extruded headers and factory-produced bends, primarily intended for use in oil or gas pipeline systems.	1.3 The term "welding fittings" applies to butt-welding fittings such as elbows, segments, of elbows, ….Girth weld requirements are... covered by the applicable ASME B31 code….
		4.3.19 Pressure design for components — Reinforcement of single openings		**4.2 Weldability** Fittings shall be capable of being welded in accordance with CSA Z662 when using welding procedure specifications that comply with that Standard.	5.1 Unless otherwise agreed upon as per Section 2.3, welding fittings shall be capable of withstanding a hydrostatic test pressure as specified in Section 2.2; however, hydrostatic testing by the manufacturer is not required.
		6.2.4 Alignment and welding		6.3.1 Fittings shall be made (a) using welding procedure specifications qualified in accordance with the ASME Boiler and Pressure Vessel Code, Section IX and (b) by welders or welding operators qualified in accordance with the ASME Boiler and Pressure Vessel Code, Section IX.	6.1 The steel shall be fully "killed" and made using….Steel shall be suitable for field welding to other fittings, flanges, and pipe manufactured to applicable specifications listed in the ASME B31 Codes.
		7 Joining 7.1 General 7.1.1 ... Clause 7 covers the requirements for joining pipes, components, and non-pressure-retaining attachments to piping by means of arc welding, gas welding, and mechanical methods.		6.3.2 For Category II fittings, the welding procedure qualification tests shall include Charpy V-Notch impact tests of both the weld metal and the heat-affected zone. Specimen location and orientation shall be as specified in ……	6.3 The steel used shall be suitable welding-quality carbon steels or of a suitable welding-quality high-strength, low-alloy steel.
		10.10.6 Weld imperfections in field circumferential welds	**5.4 Pipe manufacture** 5.4.1 For submerged-arc-welded pipe, at least two weld passes shall be used, with at least one pass made from the inside and at least one pass made from the outside….	11.4.3 Butt welds shall have full penetration. Backing rings shall not be used. For submerged arc welds, welding shall be done with at least one pass from the inside. However, where inaccessibility makes such welding impracticable, a manual or machine root bead shall be employed, provided that a visual inspection of the root bead is performed.	12.1 One of the principles of this Standard Practice is the maintenance of a fixed position for the welding ends with reference to the center line of the fittings or the overall dimensions, as the case may be….
					13. Tolerances for Welding Fittings
					14.1 Fittings shall be manufactured in accordance with a documented Manufacturing Procedure Specification (MPS). If specified by the purchaser, manufacturing shall not proceed until the MPS has been accepted by the purchaser. The MPS shall specify the following items, as applicable...a) For starting material: ...2) Welding NDE results, if not completed by the fitting manufacturer; b) For fitting manufacture:.. 2) welding procedure specification and approval record, if applicable,...

Category	Quality Process Element	CSA Z662-15 - Oil and gas pipeline systems	CSA Z245.1-14 -Steel Pipe	CSA Z245.11-13 -Steel Fittings	MSS SP-75 (2014) -High-Strength, Wrought, Butt-Welding Fitting
		10.10.7 Weld imperfections in mill seam welds and mill circumferential welds	**8.6 Hardness tests** For electric-welded pipe, hardness testing of the weld zone and the parent metal shall be conducted at the frequency of one test per welding shift…	11.5.3 The repair of fittings by welding….	14.4.1 Seam-welded pipe that is made in accordance with an ASTM or API Specification shall comply with the welding requirements of the applicable material specification. All other welds, including those used in the manufacture of other pipe or cylinders shall be made by welders, welding operators, and welding procedures qualified in accordance with the provisions of Section IX of the ASME Boiler and Pressure Vessel Code. Qualified Welding Procedure Specification (WPS) and Procedure Qualification Records (PQR) shall be available for review or acceptance by the purchaser, if requested.
					14.4.2 The joints shall be furnished in accordance with the requirements of Paragraph UW-35 (a) of Section VIII, Division 1 of the ASME Boiler and Pressure Vessel Code.
					14.4 see additional notes on Welding Fabrication….Appendix X1 for Supplementary Requirements (not applicable to product furnished to this standard Practice, except when specified on the purchase order…), including SR-1 Longitudinal-Bead Underbead Cracking Test in accordance with Appendix X2. Tests shall be performed on each heat of material (either from the starting material or a fitting)....Appendix X2 Longitudinal-Bead Underbead Cracking Test...Appendix X3 Recommendations for Segmenting...
			5.4.4 The weld zone of electric-welded pipe shall receive a normalizing heat treatment or a continuous in-line heat treatment, with a minimum temperature of 620C that will control the structure so that the mechanical properties in the heat-affected zone approximate those of the parent metal. The macrohardness of the heat-affected zone shall not exceed 24 HRC or an equivalent value obtained by conversion from another macrohardness scale in accordance with the requirements of ASTM E140.	**6.4 Forming and Heat-treating processes**	4.2.1 Fittings that have the same basic design configuration and method of manufacture shall be selected from production for testing and shall be identified as to material, grade, and lot, including **heat treatment**. They shall be inspected for dimensional compliance to this Standard Practice.
					6.1 The steel shall be fully "killed" and made using recognized melting practices to provide intended heat-treat response ….Steel shall be suitable for field welding to other fittings, flanges, and pipe manufactured to applicable specifications listed in the ASME B31 Codes.

Category	Quality Process Element	CSA Z662-15 - Oil and gas pipeline systems	CSA Z245.1-14 -Steel Pipe	CSA Z245.11-13 -Steel Fittings	MSS SP-75 (2014) -High-Strength, Wrought, Butt-Welding Fitting
	Heat treating	4.3.19 g) Where reinforcements are used that cover the weld joining the branch and run pipes, a vent hole shall be provided in the reinforcement to reveal leakage and to provide venting during welding and heat-treating operations. Vent holes shall be plugged during service to prevent crevice corrosion between the pipe and reinforcements; such plugging materials shall not be capable of sustaining pressure within the crevice.	5.4.5 Heat-treated pipe shall be identified in accordance with the requirements of Clause 15.2	**8.1 General** Where specified by Clauses 6.4, 6.5.4, of 11.5.3(e), the fittings shall be heat treated using one or more of the procedures specified in Clauses 8.2 to 8.5.	8.2 …If the fittings will be exposed to an assembly Post-Weld Heat Treatment (PWHT) or a field PWHT and the PWHT temperature is higher than the final tempering temperature for the fitting, additional tensile testing shall be requested by the purchaser to ensure the fitting meets the requirements of Section 8 after the PWHT thermal cycle.
					9.1 All fittings shall be furnished in a heat treated condition done by a trained operator. Hot formed fittings shall be cooled below the lower critical temperature prior to heat treatment. ….
				8.2 Stress Relieving Fittings shall be heated to a suitable temperature below the transformation range, but not less than 540C; held at this temperature for a minimum of 1hr per 25 mm of maximum thickness, but not less than 0.5 h; and cooled in the furnace or in air.	9.1.1 **Stress Relieving** Stress relieving shall be limited only to guide bar welds unless otherwise agreed upon between the manufacturer and the purchaser. Fittings shall be heated to a suitable temperature below the transformation range, but not less than 1000f, holding at temperature for not less than one hour per inch of maximum thickness, but never less than one-half hour and cooling in the furnace or in air.
				8.3 Normalizing Fittings shall be uniformly heated above the transformation range, held at this temperature for a sufficient time to achieve uniform temperature throughout the mass, and cooled in air.	9.1.2 **Normalizing** Fittings shall be uniformly reheated above the transformation range (austenite range)…
				8.4 Normalizing and tempering Fittings shall be normalized as specified in Clause 8.3; tempered by reheating to a temperature below the transformation range, but not less than 540C; held at this temperature for a minimum of 1 h per 25 mm of maximum thickness, but not less than 0.5 h; and cooled in the furnace or in air.	9.1.3 **Normalizing & Tempering** Fittings shall be normalized in accordance with Section 9.1.2. They shall then be tempered by reheating to a temperature below the transformation range, but not less than 1000F, held at temperature for a minimum of one hour per inch of maximum thickness, but not less than one-half hour and cooled in the furnace or in air.
				8.5 Quenching and tempering Fittings shall be uniformly heated above the transformation range; held at this temperature for a sufficient time to achieve uniform temperature throughout the mass; immediately immersion-quenched in a suitable liquid medium; and tempered as specified in Clause 9.4. Quenching facilities shall be of sufficient size and equipped to ensure proper cooling.	9.1.4 **Quenching & Tempering Fittings** shall be uniformly reheated above the transformation range, held at temperature sufficient to achieve uniform temperature throughout the mass and immediately immersion quenched in a suitable liquid medium. They shall then be reheated and tempered per Section 9.1.3. Quenching facilities shall be of sufficient size and equipped to assure proper and uniform cooling.

Category	Quality Process Element	CSA Z662-15 - Oil and gas pipeline systems	CSA Z245.1-14 -Steel Pipe	CSA Z245.11-13 -Steel Fittings	MSS SP-75 (2014) -High-Strength, Wrought, Butt-Welding Fitting
		numerous references to post weld heat treatment	12.1.3 Pipe shall be nondestructively inspected in the same heat-treatment condition as the finished bare metal pipe. Note: Pipe that has been subjected to a quench-and-temper heat treatment will in some cases require nondestructive inspection to ensure freedom from quenching cracks.	**Annex B** - Recommended practice for the calibration and survey of heat-treating equipment	9.2. **Heat treat procedures** Heat treat procedures shall be available for review at the facility and shall include requirements for furnace temperatures and soak times at temperature. For quench treatments, cooling medium temperature before and after quench shall be controlled along with time to the quench tank. Cooling medium temperature and agitation should be considered to ensure proper cooling rate based on maximum mass being heat treated. ...
					9.3 ***Heat Treat Records*** A record of each heat treat load shall be recorded and reviewed for consistency to previous loads of the same lot. Records, at a minimum, include furnace number, date, heat codes of all pieces in the load, procedure used, order number and part descriptions.
					14.1 Fittings shall be manufactured in accordance with a documented Manufacturing Procedure Specification (MPS). If specified by the purchaser, manufacturing shall not proceed until the MPS has been accepted by the purchaser. The MPS shall specify the following items, as applicable... b) For fitting manufacture:.. 3) Heat treatment procedure including thermal cycles,...
					14.4.8 Weld metal used in the construction of fittings shall be suitable to meet the tensile-strength and notch toughness requirements of Sections 8 and 11 when heat treated in accordance with Section 9.
					16.3 Certified Material Test Report (CMTR) A CMTR shall be furnished listing …heat treatment used including temperatures....and any special or supplemental tests required by the purchase order.....
					see additional notes on PWHT….Appendix X1 for Supplementary Requirements (not applicable to product furnished to this standard Practice, except when specified on the purchase order…), including SR-16, SR-20.

Category	Quality Process Element	CSA Z662-15 - Oil and gas pipeline systems	CSA Z245.1-14 -Steel Pipe	CSA Z245.11-13 -Steel Fittings	MSS SP-75 (2014) -High-Strength, Wrought, Butt-Welding Fitting
	Hydrostatic pressure testing	*see also pressure testing*	**9.1 Mill hydrostatic testing requirements** Except as allowed by Clause 14, each length of pipe shall withstand, without leakage, a mill hydrostatic test to the minimum pressure required by Clause 9.4 or to a higher minimum test pressure specified in the purchase order.	*Term used is Pressure Test. See Section 4.3 for Pressure rating.*	2.2 All fittings produced in accordance with this Standard Practice shall be designed to withstand a field hydrostatic test pressure, after installation, at a pressure level equivalent to that required to develop a hoop stress equal to the specified minimum yield strength for pipe of equivalent grade and wall thickness based on Barlow's formula....
		4.2.2.1 The design temperature range for each segment of the pipeline system shall be specified by the designer for the conditions expected during installation, pressure testing, start-up, and operation…	**9.2 Test duration** Test pressures for all sizes of seamless pipe and for welded pipe in sizes 457 OD or smaller shall be held for not less than 5 s. Test pressures for welded pipe larger than 457 OD shall be held for not less than 10 s.	4.3.2 After installation, fittings shall be capable of withstanding the pressure test at a pressure level required to develop a hoop stress equal to the specified minimum yield strength for pipe of equivalent grade and wall thickness attached to the fitting. or at a higher pressure level specified in the purchase order, without failure, leakage, or impairment of serviceability or mechanical properties.	
		4.2.3 Sustained force and wind loading The weight of pipe, components, contents, insulation cover, wind loading, and other sustained forces shall be considered in stress analysis for the various piping support circumstances encountered during pressure testing and operation.	9.3 Verification of test		4. Design Proof-Test ….4.3 The test fluid shall be water or other liquid. Hydrostatic pressure shall be applied to the assembly. At least three (3) proof tests for each fitting, joint size, or configuration are recommended.
		6.2.8 Internal Cleaning Prior to pressure testing, the completed pipeline sections shall be cleaned of construction debris and foreign matter.	9.4 Test pressures	**5 The Design Proof Test** 5.4 The test fluid for the hydrostatic proof test shall be water or another appropriate liquid. …the hydrostatic pressure shall be applied until the fitting ruptures or until the pressure in each part of the assembly is at least 105% of the adjusted proof test pressure....	4.4 it is not necessary to conduct an individual test of fittings with all combinations of sizes,….
		8. Pressure Testing	Table 1 Minimum hydrostatic test pressure		4.4.1 One test fitting may be used to qualify similarly proportioned fittings with a size range…..
		8.7.7 Pressure-test measurements and records		5.5 It shall not be necessary to conduct an individual test of fittings with all combinations of size, wall thickness, and grade. ….	5.1 Unless otherwise agreed upon as per Section 2.3, welding fittings shall be capable of withstanding a hydrostatic test pressure as specified in Section 2.2; however, hydrostatic testing by the manufacturer is not required.
		6.2.3 Bends and elbows in steel piping. For steel piping, changes in direction may be made by the use of bends or elbows, or both, subject to the following limitations:…d) Circumferential welds that are subject to stress during bending shall be nondestructively inspected after bending.	11.1 Inspection Pipe shall be inspected visually or by a combination of visual and nondestructive methods to detect defects and determine compliance with the dimensional and work quality requirements.		14.1 Fittings shall be manufactured in accordance with a documented Manufacturing Procedure Specification (MPS). If specified by the purchaser, manufacturing shall not proceed until the MPS has been accepted by the purchaser. The MPS shall specify the following items, as applicable...a) For starting material: ...2) Welding NDE results, if not completed by the fitting manufacturer...
		6.2.11.4 Evaluation of pipe and coating integrity shall include a) prior to pull back, visual and nondestructive inspection of all girth welds….b)visual inspection of the pipe and coating for damage where it exits the drill hole upon completion of the pull back; and c)post-installation pressure test of the drag section ...Note: Consideration should be given to a) pre-test of the drag section; b) post-installation coating survey; and c) in-line inspection.		Section 12 Non-destructive inspection	15. NDE (15.1 Radiographic Examination, 15.2 Magnetic Particle or Ultrasonic Examination, 15.3 Magnetic Particle or Liquid Penetrant Examination)

Category	Quality Process Element	CSA Z662-15 - Oil and gas pipeline systems	CSA Z245.1-14 -Steel Pipe	CSA Z245.11-13 -Steel Fittings	MSS SP-75 (2014) -High-Strength, Wrought, Butt-Welding Fitting
		6.5.12 Where necessary and as appropriate, nondestructive inspection of piping shall be performed using one or more of the following: a) radiographic inspection of welds…b)ultrasonic inspection of welds...c)ultrasonic inspection of pipe…d)electrical inspection of protective coatings; e)inspection using internal inspection devices; and f)other methods capable of achieving appropriate results.		12.1.1 Radiographic inspection - Except as allowed by Clause 12.1.2, all seam welds shall be radiographically inspected throughout their entire length and shall comply with Paragraph UW 51 of the ASME Boiler and Pressure Vessel Code, Section VIII, Division 1.	
		7.2.5 For other than partial-penetration butt welds, welding procedure specifications that are established and qualified as specified in the ASME Boiler and Pressure Vessel Code, Section IX may be used, provided that …b) the methods of visual and non-destructive inspection as specified...		12.1.2 Ultrasonic inspection - Where approved by the purchaser, welds may be ultrasonically inspected. Welds so inspected shall comply with Appendix 12 of the ASME Boiler and Pressure Vessel Code, Section VIII, Division 1.	
		7.6 Arc and gas welding-Qualification of welding procedure specifications 7.6.1 …prior to the start of production welding, welding procedure specifications shall be established as specified ..and shall be qualified by the production of welds that are made as specified..and that meet the applicable destructive testing requirements..and the applicable nondestructive inspection requirements specified for production welds...		12.1.3 Liquid penetrant or magnetic particle inspection - Where specified in the purchase order, liquid penetrant or magnetic particle inspection of all accessible weld surfaces shall be performed after final heat treatment. Welds so inspected shall comply with Appendix 6 or 8, whichever is applicable, of the ASME Boiler and Pressure Vessel Code, Section VIII, Division 1.	
		7.10 Arc and gas welding-Inspection and testing of production welds 7.10.1.3 Welds that are nondestructively inspected using ultrasonic methods shall be visually inspected as specified…7.10.1.4 The company shall have the right to inspect production welds nondestructively or by removing them and conducting mechanical tests. Such inspections may be made during or after welding, or both.		12.1.4.1 - Tees manufactured by cold-forming methods shall be liquid penetrant or magnetic particle inspected using methods specified in ASTM E165 or ASTM E709, respectively. Such inspection shall be performed after the final heat treatment. Tees so inspected shall comply with Appendix 6 or 8, whichever is applicable, of the ASME Boiler and Pressure Vessel Code, Section VIII, Division 1.	
		7.10.3 Mandatory nondestructive inspection…		12.1.4.2 - The side wall on both sides of the tee shall be inspected in a circular area, as shown in Figure 5. Internal and external surfaces shall be inspected where size permits accessibility.	
	Non destructive Examination	7.10.4 Nondestructive inspection 7.10.4.1 Methods In selecting methods of nondestructive inspection, the company shall consider the a) nature of imperfections that can results from the welding processes to be used; b) capability of the nondestructive inspection methods to detect such imperfections; and c) accuracy of indication, interpretation, and evaluation possible with such nondestructive inspection methods. The nondestructive inspection procedures used shall be documented and approved by the company...		12.2.1 - Welds that have not been radiographically or ultrasonically inspected by the pipe manufacturer shall be inspected throughout their entire length after bending and shall comply with Paragraph UW 51 or Appendix 12, whichever is applicable, of the ASME Boiler and Pressure Vessel Code, Section VIII, Division 1.	

Category	Quality Process Element	CSA Z662-15 - Oil and gas pipeline systems	CSA Z245.1-14 -Steel Pipe	CSA Z245.11-13 -Steel Fittings	MSS SP-75 (2014) -High-Strength, Wrought, Butt-Welding Fitting
		7.11 Arc and gas welding-Standards of acceptability for nondestructive inspection…7.11.1.2 Right of rejection Since nondestructive inspection methods generally give only two-dimensional results, the company may reject welds that appear to meet these standards of acceptability where, in its opinion, the depth, location, or orientation of imperfections can be significantly detrimental to the structural integrity of the welds.	12 Nondestructive inspection …	12.2.2 - Where specified in the purchase order, liquid penetrant or magnetic particle inspection shall be performed on both the inside and outside bend radii. The mill scale shall be removed from the areas to be inspected. Bends so inspected shall comply with Appendix 6 or 8, whichever is applicable, of the ASME Boiler and Pressure Vessel Code, Section VIII, Division 1.	15.3 …Nondestructive examination personnel and procedures shall be qualified in accordance with ASME Boiler and Pressure Vessel Code, Section V.
		7.17.7 Nondestructive inspection of welds made on in-service piping			
		7.17.7.1 Welds (including those in branch connections) made on in-service piping shall be nondestructively inspected for defects upon completion of welding using magnetic particle inspection and, where appropriate, ultrasonic inspection. The company shall consider the risk of delayed cracking and determine whether a) the nondestructive inspection shall be repeated after a suitable delay to allow for the detection of delayed cracking; and b) special measures such as pressure reduction and support of the connection shall be taken to prevent propagation of such cracks until the second inspection is complete. Procedures for magnetic particle inspection and ultrasonic inspection should be as specified in the ASME Boiler and Pressure Vessel Code, Section V, Articles 7 and 4, respectively...			
		8.5.3 All welds in new test-head assemblies and all welds that join test-head assemblies to the pipe to be tested shall be …b)nondestructively inspected i) for 100% of their lengths…			16.3 Certified Material Test Report (CMTR) A CMTR shall be furnished listing …nondestructive examination reports as applicable, Section 15; and any special or supplemental tests required by the purchase order.....
		8.5.5 Prior to each use, the test-head assembly shall be visually inspected for conformance with the applicable requirements…Note: if the test-head assembly was previously subjected to abnormal loading, consideration should be given to pressure testing the test-head assembly or nondestructively inspecting any affected portion.			
		10.10.6 Weld imperfections in field circumferential welds.			

Category	Quality Process Element	CSA Z662-15 - Oil and gas pipeline systems	CSA Z245.1-14 -Steel Pipe	CSA Z245.11-13 -Steel Fittings	MSS SP-75 (2014) -High-Strength, Wrought, Butt-Welding Fitting
Component Manufacturing		**10.10.7 Weld imperfections in mill seam welds and mill circumferential welds**…Mill seam welds and mill circumferential welds that are found, after the piping has been placed in service, to be unacceptable on the basis of the requirements of the current applicable standard or specification shall undergo nondestructive inspection to determine the extent of the deviations from the standard of acceptability. Such an inspection shall employ an appropriate nondestructive inspection method (or a combination of methods) that is capable of detecting cracks...			
		11.26.11 Records The following records shall be maintained for an appropriate period of time: ...e) nondestructive inspection data…			
		P.5.3. WPS content …In order for a WPS to be complete, it shall include PQRs and all applicable supporting documentation, including nondestructive inspection reports, lab reports and MTR.			
		4.5.4.3 Mechanical interference fit joining methods shall be used only on electric-welded or seamless pipe. Note: When ordering plain-end pipe that will subsequently be subjected to plastic deformation in preparation for mechanical interference fit joining, designers should consider supplementing the pipe purchase specification with additional requirements, such as the following: a) tighter dimensional tolerances; b) ductility tests or increased minimum elongation requirements for tensile tests; c) limits on the inside and outside height of the weld flash of electric-welded pipe; and d) an upper limit on yield strength.	4.1.1… Notes: 1) The relationship between pipe dimensions, weight classes, and schedule numbers for pipe up to 323.9 mm OD is given in Annex A	4.1.1.2 For bends, in addition to the requirements of…, the following information shall be included in the purchase order: ...b) the dimensions and grade of any straight pipe supplied by the purchaser for bending.	4.2.1 Fittings that have the same basic design configuration and method of manufacture shall be selected from production for testing and shall be identified as to material, grade, and lot, including heat treatment. They shall be inspected for dimensional compliance to this Standard Practice.
			7.5.2.1 (Electric-welded pipe) General Root guided-bend test specimens shall be in accordance with the dimensional requirements of Figure 2 and….	4.1.3 **Additional requirements** Where applicable, the purchase order shall include information concerning the following items, which are subject to agreement between the purchaser and the manufacturer: …(c)dimensions and tolerances of non-standard fittings...	
		4.8.8 Specified dimensions of pipe and fittings shall be used in flexibility calculations.	**10.1.1** Standard values for outside diameters for pipe from 21.3 to 48.3 mm and the corresponding standard wall thickness shall be as given in Table 1. **10.2** Outside Diameter Outside diameters shall be within the tolerances specified in Clauses 11.4.1 and 11.4.2	5.2 Fittings selected for test shall be representative of production; Identified as to material, grade, lot, and heat-treatment state; and inspected for dimensional compliance with this Standard.	
		Table 5.3 ...For NPS 24 and smaller flanges, the dimensional requirements of ASME B16.5 shall be met. For NPS 26 to NPS 60 flanges, the dimensional requirements of ASME B16.47 (Series A) shall be met.		5.5 It shall not be necessary to conduct an individual test of fittings with all combinations of size, wall thickness, and grade. Provided that the untested fitting has a t/D ratio from 0.5 to 3.0 times the t/D ratio of the test fitting, a successful proof test on one fitting shall be allowed to represent other fittings, as follows: a) fittings of similar design that are not smaller than one-half or larger than twice the size of the test fitting, provided that for tees and crosses the dimensions and tolerances are as specified in Tables 2 to 5...	**12 Fitting Dimensions** 12.1 One of the principles of this Standard Practice is the maintenance of a fixed position for the welding ends with reference to the center line of the fittings or the overall dimensions, as the case may be. Dimensional standards for fittings NPS 16 and larger are shown in Tables 3 through 9. Dimensional standards and tolerances (including minimum wall thickness of 871/2%) for NPS 14 and smaller sizes are contained in ASME B16.9.
		5.2.9.2 Fittings having nonstandard dimensions may be used, provided that they are designed in accordance with the same		10.1 Standard dimensions and tolerances	
				10.2 Non-standard dimensions and tolerances	**13.1 Tolerances** The tolerance for fittings NPS 15 and larger …

Category	Quality Process Element	CSA Z662-15 - Oil and gas pipeline systems	CSA Z245.1-14 -Steel Pipe	CSA Z245.11-13 -Steel Fittings	MSS SP-75 (2014) -High-Strength, Wrought, Butt-Welding Fitting
	Sizing and dimensions	principles as standard fittings and are capable of withstanding the same tests.	10.3 Wall thickness	10.3 Wall thickness Tolerances	**13.2 Wall thickness** The minimum wall thickness may be 0.01 in. under the nominal thickness….
		10.1.1 Engineering assessments of existing pipeline systems shall be conducted and documented in accordance with the requirements of Clause 3.3 and the analysis shall include consideration of the following, as applicable: ... f) condition of the piping, including types of imperfections, dimensions, and dimensional uncertainty...	11.1 Inspection Pipe shall be inspected visually or by a combination of visual and nondestructive methods to detect defects and determine compliance with the dimensional and work quality requirements.	**11.1 Plant inspection** The finished fitting shall be free, both internally and externally, of loose mill scale, foreign matter, oil, and grease, and shall be clean and dry for final inspection. Each fitting shall be visually inspected to detect defects and to determine compliance with the dimensional and work quality requirements.	14.1 Fittings shall be manufactured in accordance with a documented Manufacturing Procedure Specification (MPS). If specified by the purchaser, manufacturing shall not proceed until the MPS has been accepted by the purchaser. The MPS shall specify the following items, as applicable...a) For starting material: ...1) Product form (seamless or welded) and dimensions... b) for fitting manufacturer:...5) Inspection, dimensions and test requirements...
			11.4 Tolerances on dimensions and mass…		Inspection Test Plan Requirements (from section 16.2.1, Dimensional Checks
		N.13.2.2 An engineering assessment ... may be performed to establish that indications of imperfections are not associated with defects and shall take the following additional items into consideration: a) knowledge and experience of the performance capabilities and limitations of the inspection method; b) the types of imperfection that might correspond to the reported indications; c) the accuracy of reported dimensions and characteristics needed for evaluating such imperfections; d) the likelihood of unreported defects (e.g., cracking) being associated with an imperfection indication; e) the piping design and material properties; and f) service conditions.	11.5.10 **Geometric Deviations** Geometric Deviations from the normal cylindrical contour of the pipe within 200 mm of each pipe end that occur as a result of the pipe-**forming** process or manufacturing operations (e.g., flat spots or peaks) shall not exceed 3 mm, measured as the gap between the extreme point of the deviation and the prolongation of the normal contour of the pipe.	Table 2-3 Dimensions of straight tees and crosses and of reducing outlet tees and reducing outlet crosses, respectively; Table 4-5 Tolerances for standard fittings Grades 290 and higher and standard fittings less than Grade 290, respectively; Table 9-13 Dimensions of caps; short radius elbows; long radius elbows; 3R Elbows; and Reducers, respectively.	Table 4-Table 9: Dimensions of Long-Radius Elbows, 3R Elbows, Straight Tees, Reducing Outlet Tees, Caps, Reducers
					Figure 1-2 Recommended Bevel for Wall Thicknesses (T) at end of fitting
			Annex A (informative) Steel pipe dimensions, weight classes, and schedule numbers	Figure 2 Guided-bend test jig dimensions; Figure 4 Design of ends for unequal grades;	*see additional notes on body sizing….Appendix X1 for Supplementary Requirements (not applicable to product furnished to this standard Practice, except when specified on the purchase order…)...Appendix X3 Recommendations for Segmenting...*
		5.7 Records of materials 5.7.1 The standards or specifications of the pipe, components, and bolting materials used in the construction of pipeline systems shall be recorded, and such records shall be retained as part of the permanent records of the pipeline system. The identity of the material shall be verified prior to its use. 5.7.2 Where materials are reused as specified in Clause 5.6, records of the identity of such materials and the results of any required inspection and testing shall be retained as part of the permanent records of the pipeline system.		*There is no mention of the phrase Traceability. Documentation Requirements include a record of the heat analysis. A report of the mechanical test is optional, dependent on the Purchase Order requirements.*	4.5 The manufacturer shall have a quality control (QC) program that verifies the manufacturing process used and ensure that the resulting geometry of the fittings or joints manufactured reasonable conforms to the geometries tested. The QC program shall control the manufacturing drawings and maintain the QC records showing conformance to these drawings....

Category	Quality Process Element	CSA Z662-15 - Oil and gas pipeline systems	CSA Z245.1-14 -Steel Pipe	CSA Z245.11-13 -Steel Fittings	MSS SP-75 (2014) -High-Strength, Wrought, Butt-Welding Fitting
	Traceability	**7.6.3 Records** Details for the welding procedure specification qualification test and the qualified welding procedure specification shall be recorded. During constructions, copies of such records shall be available for reference on site where the work is being performed. Note: Consideration should be given to the retention of these records for the life of the pipeline. These records can prove useful in performing future engineering assessments.	7.2.6.3.2 For pipe Grades 414 and higher, where both retests conform to the specified requirements and provided individual pipe **traceability** to mother coil/plate location, the manufacturer shall test additional lengths adjacent to (before, after and beside, as applicable).....		
		(Annex)A Safety and loss management systems A.7.3 Control of records The operating company shall establish procedures for the control of records, including procedures for the proper capture, classification, indexing, storage, search, retrieval, backup, retention, and disposition of records that are required for the effective implementation of the safety and loss management system. Records shall be retained as objective evidence that demonstrates conformance to and effective implementation of the safety and loss management system. Record retention periods shall be established in accordance with operational, legal, and regulatory requirements. Applicable records shall include a) management review; b) contract review; c) design review; d) design verification; e) design validation; f) design changes; g) approved suppliers and contractors; h) traceability records; i) qualified processes, equipment, and personnel; j) operation and maintenance records; k) test records; l) inspection records; m)nonconformance reports; n) internal and external audit reports; o)training records; and p)records for monitoring and measurement activities.		15.1 The manufacturer shall furnish a certificate of compliance for each order item.	4.6 A report of the testing for each test assembly shall be prepared and shall include: (a) Description of the test, including the number of tests and f factor used to establish the target proof test; (b) Instrumentation and methods of calibrations used; (c) Material test reports for the assembly's materials; (d) Actual final pressures for each test; (e) length of time from test initiation to the time of burst, or the hold time at or above the computed target pressure; (f) Calculations performed; (g) Location of rupture, if any, including a sketch. The test report shall be made available at the manufacturer's facility for inspection by the purchaser or regulatory authority.
		A.8.6.3 Identification and traceability Where traceability is a requirement, the operating company shall control and record the unique identification of the product or the system components.			14.1 Fittings shall be manufactured in accordance with a documented Manufacturing Procedure Specification (MPS). If specified by the purchaser, manufacturing shall not proceed until the MPS has been accepted by the purchaser. The MPS shall specify the following items, as applicable... b) for fitting manufacturer:...7) Traceability;...
		5.2.6.1 Flanges shall be suitable for service with the grade of pipe to which they are to be joined.	1.2.2 grade (scope of standard covers specific grades). 1.2.3 Category This Standard covers pipe in the following categories: a) Category I…b) Category II…c) Category III…	1.2.2 grade (scope of standard covers specific grades)	Table 2 Tensile Requirements

Category	Quality Process Element	CSA Z662-15 - Oil and gas pipeline systems	CSA Z245.1-14 -Steel Pipe	CSA Z245.11-13 -Steel Fittings	MSS SP-75 (2014) -High-Strength, Wrought, Butt-Welding Fitting
	Grade Requirements	5.2.9.1 Fittings shall be suitable for service with the grade of pipe to which they are to be joined.	4.1.1 Standard Requirements: The following information shall be included in purchase orders for pipe:…c) grade…	4.1.1.1 The following information shall be included in the purchase order for fittings:…c) grade…e) matching pipe grade, if different from the fitting grade...	4.2.1 Fittings that have the same basic design configuration and method of manufacture shall be selected from production for testing and shall be identified as to material, grade, and lot, including heat treatment. They shall be inspected for dimensional compliance to this Standard Practice.
		7.6.4.4 Base materials The following shall be specified for the base materials: a) standard or specification; b) grade; c) specified minimum yield strength; d) for base materials having a specified minimum yield strength higher than 386 Mpa, maximum carbon equivalent used in procedure qualification...; e) intended range of thicknesses; and f)intended range of outside diameters.	7.2.2 Yield strength For Grade 241 to Grade 620, the yield strength shall be the tensile stress required to produce a total extension under load of 0.5% of the gauge length. For grades higher than Grade 620, the yield strength shall be determined by the 0.2% offset method.		
		7.17.7 Nondestructive inspection of welds made on in-service piping 7.17.7.1 Welds…made on in-service piping shall be nondestructively inspected for defects upon completion of welding….Notes:..3) A time delay of 48 h is generally considered suitable for carbon and low-alloy steel materials. Shorter delays might be suitable based upon experience or research. Longer delays might be necessary for high-grade and thick materials, over-matched weld metal, and very low material temperatures after welding. The rationale for the delay selected should be documented.	15.2 Required markings The required markings shall be as follows:…e) the pipe grade designation…	4.1.1.2 For bends, in addition to the requirements of Clause 4.1.1.1, the following information shall be included in the purchase order: (a) bend angle, centerline radius, and tangent lengths; and (b) the dimensions and **grade** of any straight pipe supplied by the purchaser for bending.	8.6 Of the tension test specimen from any lot fails to conform to the requirements for the particular grade ordered, the manufacturer may elect to make retests…
		8.7.4.2 For liquid-medium testing, the strength test pressure shall not exceed the lesser of a) the calculated pressure corresponding to i) 110% of the specified minimum yield strength of the pipe for Grades 555 and lower; ii) 107% of the specified minimum yield strength of the pipe for grades greater than Grade 555; and iii) 66% of the specified minimum yield strength of the pipe for continuous welded pipe; b) for pipe grades up to and including Grade 555, the pressure that produces a deviation of 0.2% from straight-line proportionality on a pressure-volume plot for the test section...; or c) for pipe grades greater than Grade 555, the pressure that produces a deviation of 0.1% from straight-line proportionality on a pressure-volume plot for the test section...	16.8 The tensile strength shall not exceed 625 Mpa for Grades 386 and lower, 650 Mpa for grades higher than Grade 386 but lower than Grade 483, and 665 Mpa for grade 483…	**7.3 Product analysis** For Grades 290 and higher, at a frequency of one test per heat, a product analysis shall be determined by the fitting manufacturer or the steel manufacturer. The requirements for product analysis shall be as specified in Table 6.	13.3 Notch-toughness testing of NPS 14 and smaller is not required unless grades WPHY 65 or higher are supplied or the purchaser specifies testing.

Category	Quality Process Element	CSA Z662-15 - Oil and gas pipeline systems	CSA Z245.1-14 -Steel Pipe	CSA Z245.11-13 -Steel Fittings	MSS SP-75 (2014) -High-Strength, Wrought, Butt-Welding Fitting
		10.4.2 Pipeline systems Records that provide the following information, as applicable, shall be maintained for the life of the pipeline system: b)technical data related to the following: i) pipes - locations and lengths for each pipe diameter installed, noting wall thicknesses, grades and standards or specifications, field test pressure, and where practical, burial depth; ...	Table 8 Tensile requirements; Table 9 Body Elongation Requirements; Table 16 Strain values for guided-bend test *(listed by Grade)*		
	Final inspection	6.5 Inspection 6.5.1 The provisions in Clause 6.5 shall apply, as appropriate, during the period of time from the receipt of materials to the completion of installation; such provisions shall also apply to prefabricated assemblies..6.5.2.1 The company shall perform inspections to ensure that the requirements of this Standard are met. 6.5.2.2 The company shall have documented procedures for conducting inspections. Note: These procedures should include a) the number and type of inspectors; b) the number and type of field and shop measurements; c) the relevant reporting and record requirements; and d) documentation outlining the roles, responsibilities, minimum qualifications, duties, and tasks of inspectors. 6.5.4 Pipe and components shall be inspected for defects. Such inspection shall include, but not limited to, inspection for flattening, ovality, straightness, pits, slivers, cracks, gouges, dents, defective weld seams, and defective field welds...	**11 Inspection, tolerances, and work quality**	**11.1 Plant inspection** The finished fitting shall be free, both internally and externally, of loose mill scale, foreign matter, oil, and grease, and shall be clean and dry for final inspection. Each fitting shall be visually inspected to detect defects and to determine compliance with the dimensional and work quality requirements.	N/A
	Marking requirements	9.3.2.3 When applying coatings not covered by CSA Z245.20 Series or CSA Z245.30, coatings shall be applied in accordance with documented procedures and an appropriate quality management system. Such procedures, as applicable, shall address...i) product marking requirements;	**15 Markings and coating**	14.2.1 Except as allowed.., the following markings shall be marked on the fittings in the following sequence and separated by dashes or adequate spaces: a) manufacturer's name or mark; b)CSA designation: Z245.11-13; c) grade...; d) test temperature...; e) "SS" for sour service, if applicable; f) identification designation: a manufacturer's ID....; g) matching pipe grade, where different from the fitting grade; h) size....; i) matching pipe wall thickness; and j) "W" for fittings that contain weld repairs to the parent metal. 14.2 Examples of the markings....14.3 Omission of markings Where the size or shape of the fitting.....	**17.1** All fittings furnished under this Standard Practice shall be clearly defined on the outside diameter with the following information marked using low-stress die stamps or interrupted-dot stamps, except as noted: a) Manufacturer's name or trademark (b) Nominal wall thickness of fittings at bevel ends c) Respective grade as given in Table 2...example WPHY60/X70.....d) Heat code identity e)size f)SEGM when appropriate, see Section 13.5 g)CE if greater than 0.42% h) "Part" for partial compliance fitting if applicable.. i)Preheat conditions if applicable...j)PT or MT as applicable....**17.2** In addition to the above, extruded headers shall also include the following information: a) Design Pressure B)Temperature c) Per ASME B31.8

Category	Quality Process Element	CSA Z662-15 - Oil and gas pipeline systems	CSA Z245.1-14 -Steel Pipe	CSA Z245.11-13 -Steel Fittings	MSS SP-75 (2014) -High-Strength, Wrought, Butt-Welding Fitting
	Shipping and handling	6.2.2 Pipe and components handling Care shall be taken in the selection of equipment and methods used in handling, transporting, stockpiling, and placing of pipe and components to prevent damage to the pipe, coating, and any lining…	4.1.1 Standard Requirements: The following information shall be included in purchase orders for pipe:…k) delivery date and shipping instructions….	4.1.1.1 The following information shall be included in the purchase order for fittings: ... i) packaging and shipping instructions; and j) required delivery date.	N/A
	Product Ordering Requirements	4.5.4.3 Mechanical interference fit joining methods shall be used only on electric-welded or seamless pipe. Note: When ordering plain-end pipe that will subsequently be subjected to plastic deformation in preparation for mechanical interference fit joining, designers should consider supplementing the pipe purchase specification with additional requirements...		4.1.1.1 The following information shall be included in the purchase order for fittings: a) CSA Standard designation and year of publication; b) quantity, size, and description; grade: d) matching pipe specified wall thickness; e) matching pipe grade, if different from the fitting grade; f) pipeline design pressure, design temperatures, and design factor (if pertinent); g) category; h) test temperature for Category II; i) packaging and shipping instructions; and j) required delivery date.	
				4.1.1.2 For bends, in addition to the requirements of Clause 4.1.1.1, the following information shall be included in the purchase order: (a) bend angle, centerline radius, and tangent lengths; and (b) the dimensions and grade of any straight pipe supplied by the purchaser for bending.	14.1 Fittings shall be manufactured in accordance with a documented Manufacturing Procedure Specification (MPS). If specified by the purchaser, manufacturing shall not proceed until the MPS has been accepted by the purchaser. The MPS shall specify the following items, as applicable...a) For starting material: ...b) for fitting manufacture:..
		(Annex)A.8.5. Procurement The operating company shall develop and implement procedures for the evaluation of suppliers and contractors and the verification of purchased product. The procedure shall identify the necessary purchasing documents and records.	**4.1.1 Standard Requirements**: The following information shall be included in purchase orders for pipe: a) the designation and year of publication of this Standard; b) quantity; c) grade; d) category…; e) specified pipe test temperature for Category II or III pipe; f) process of pipe manufacture; g)specified outside diameter; h) specified wall thickness; i) nominal length; j) end finish; and k) delivery date and shipping instructions. See also **4.1.2 Optional Requirements**.	4.1.2 **Optional requirements** Where applicable, the purchase order shall include information concerning the following items, which are optional for the purchaser: (e) plant inspection by the purchaser…(i) report of heat analysis (j) report of product analysis and carbon equivalent (k) report of specific mechanical tests ...	16.3 Certified Material Test Report (CMTR) A CMTR shall be furnished listing …any special or supplemental tests required by the purchase order.....
				4.1.3 **Additional requirements** Where applicable, the purchase order shall include information concerning the following items, which are subject to agreement between the purchaser and the manufacturer: …(c)dimensions and tolerances of non-standard fittings...	
		6.3.1 Pipe and component manufacturing defects detected	10.7.2.1 Mechanical interference fit pipe…Belled ends of welded pipe shall be nondestructively inspected in the weld area …to indicate defects, i.e., open welds, cracks, seams, and slivers….		**10 Bend tests**..;

Category	Quality Process Element	CSA Z662-15 - Oil and gas pipeline systems	CSA Z245.1-14 -Steel Pipe	CSA Z245.11-13 -Steel Fittings	MSS SP-75 (2014) -High-Strength, Wrought, Butt-Welding Fitting
	Defects	**during installation inspection** Where any pipe or component manufacturing defects (as described by the requirements specified in the applicable manufacturing standard or specification) are detected during installation inspection, the defective portion of the pipe or component shall be a) repaired as allowed by the applicable manufacturing standard or specification; b) in the case of pipe cut out as a cylinder and, where necessary, replaced with another cylinder of pipe; or c) in the case of a component, replaced with another component.	11.1 Inspection Pipe shall be inspected visually or by a combination of visual and nondestructive methods to detect defects and determine compliance with the dimensional and work quality requirements. 11.5.7 Hard spots… 11.6 Defects 13 Repair of pipe containing defects	11.5.1 Fittings containing defects shall be given one or more of the following dispositions: a) the defect shall be removed by grinding, provided that the remaining wall thickness is within the limits specified in Clause 10.; b) the defect shall be removed by grinding and the fitting repaired by welding; or c) the fitting shall be rejected.	14.5.1 Fittings shall be free of injurious defects and shall have workmanlike finish. 14.5.2 Injurious defects are defined as those having a depth in excess of 6 1/2% of specified nominal wall. **16.4 Rejection** Each fitting in which injurious defects are found during shop or field fabrications may be rejected, and the manufacturer shall be notified.
	Retesting	*There are no references to part retesting.*	6.3.5.1 Where the product analysis representing a lot fails to conform to the specified requirements, at the manufacturer's option the lot shall be rejected or retested using samples taken from two additional lengths of pipe from the affected lot. 6.3.5.2 Samples for retests shall be taken and prepared in the applicable manner specified in Clause 6.3.3 and 6.3.4 *(Sampling methods and Preparation, respectively)* . 6.3.5.3 Where both retests conform to the specified requirements, the lot shall be accepted, except for the length represented by the initial analysis that failed. 6.3.5.4 Where one or both of the retests fail to conform to the specified requirements, the nonconforming lengths shall be rejected and, at the manufacturer's option, the lot shall be rejected or the remaining lengths in the lot shall be tested individually, with any nonconforming lengths being rejected. For such individual length testing, the determinations may include only those elements that failed to conform to the specified requirements in the preceding tests of the affected lot. 7.2.6.1 Where the tension retest representing a lot fails to conform to the specified requirements, at the manufacturer's option the lot shall be rejected or retested using test specimens taken from two additional lengths of pipe from the affected lot.	9.1.1.3 Fittings stress relieved at or below a previous stress-relieving or tempering temperature need not be retested.	**4 Design Proof Test** 4.5The manufacturer shall have a quality control (QC) program that verifies the manufacturing process used....Whenever a significant change is made in the geometry or method of manufacture, the manufacturer shall either retest the new production or show by analysis that the change would not affect the results of prior tests. **8 Tensile Properties** 8.6 If the tension test specimen from any lot fails to conform to the requirements for the particular grade ordered, the manufacturer may elect to make retests on two additional pieces from the same lot, each of which shall conform to the requirements specified in Table 2. If one or both of the retests fail to conform to the requirements, the manufacturer may elect to test each of the remaining pieces in the lot. Retests are required

Category	Quality Process Element	CSA Z662-15 - Oil and gas pipeline systems	CSA Z245.1-14 -Steel Pipe	CSA Z245.11-13 -Steel Fittings	MSS SP-75 (2014) -High-Strength, Wrought, Butt-Welding Fitting
			7.2.6.3.1 For pipe grades less than Grade 414, where both retests conform to the specified requirements, the lot shall be accepted, including the initial test length (the length from which the initial test specimen was taken), provided that the following locations, as applicable, in such a length are subsequently tested and such retests conform to the specified requirements: a) where the length does not contain a skelp end weld, both ends of the length; or b) where the length contains a skelp end weld, both ends of the initially tested portion of the length.		remaining pieces in the lot. Retests are required only for the particular test with which the specimen did not comply originally.
			7.2.6.3.2 For pipe Grades 414 and higher, where both retests conform to the specified requirements and provided individual pipe traceability to mother coil/plate location, the manufacturer shall test additional lengths adjacent to (before, after and beside, as applicable) the initial failure within the mother coil or plate considering adjacent daughter coil(s) or plate(s) as applicable. Pipe testing shall continue until satisfactory results surround the non-conforming section of the mother coil/plate. The pipes from the nonconforming section of mother coil/plate shall be rejected and the remainder of the pipe from the lot shall be accepted, including the initial test length (the length from which the initial test specimen was taken), provided that the following locations, as applicable, in such a length are subsequently tested and such retests conform to the specified requirements: a) where the length does not contain a skelp end, both ends of the length; or b) where the length contains a skelp end weld, both ends of the initially tested portion of the length.		**10 Transverse Guided-Weld Bend-Tests** 10.5 If either test fails to conform to specified requirements, the manufacturer may elect to make retests on two additional specimens from the same lot, each of which shall conform to the requirements specified in Section 10.3. If any of these specimens fail to conform to the requirements, the manufacturer may elect to test prolongations from each of the remaining fittings in the lot.
			7.2.6.4 Where one or both of the retests fail to conform to the specified requirements, the nonconforming lengths shall be rejected and, at the manufacturer's option, the remaining lengths in the lot shall be rejected or tested individually, with any nonconforming lengths being rejected.		
			7.3.2.2 Retests Where one or more of the flattening tests representing a pipe fail to conform to the specified requirements, the affected pipe shall be rejected or retested using additional test rings taken from the nonconforming ends until the requirements are met, provided that such retesting does not reduce the pipe's length by more than 20%.		

Category	Quality Process Element	CSA Z662-15 - Oil and gas pipeline systems	CSA Z245.1-14 -Steel Pipe	CSA Z245.11-13 -Steel Fittings	MSS SP-75 (2014) -High-Strength, Wrought, Butt-Welding Fitting
			7.3.3.3 Retests Where one or more of the flattening tests representing a multiple length fail to conform to the specified requirements, the affected multiple length shall be given one of the following dispositions: a) The pipes produced from the affected multiple length shall be rejected. b) The satisfactory portion of the affected multiple length shall be accepted. All test results representing locations adjacent to and within such satisfactory portions shall conform to the specified requirements. The defective portion at nonconforming ends of the affected multiple length shall be removed, as confirmed by retesting and obtaining conforming flattening test results (0degree, 90degree, or both, depending on which test results were originally nonconforming) for i) both ends of the first satisfactory pipe adjacent to the defective portion; or ii) the extreme end (that end corresponding to the adjacent nonconforming end location) of the first two consecutive satisfactory pipes adjacent to the defective portion.		**11 Notch-Toughness Properties** 11.4 If the acceptance requirements of Section 11.2 are not met, one retest of three additional specimens from the same test location may be performed. Each individual test value of the retested specimens shall be equal to or greater than the specified minimum average value.
			see also retests under 7.3.4 Hot reduced electric-welded pipe, 7.4 Bend tests- Electric-welded pipe, 7.5 Guided-bend tests, 7.6 Charpy V-notch impact tests, 7.7 Drop-weight test tests		**Appendix X1 Supplementary Requirements** q)SR-17 Notch-toughness tests on the weld heat affected zone shall be performed on each lot in accordance with requirements of Sections 11.1 and 11.2. Impact retest as per Section 11.4.
			13.6.1 The performance of the repair welder shall be tested by film radiographic methods or nonfilm radiographic imaging techniques and transverse guided-bend testing of two test specimens from a test weld…Where any test result fails to conform to the specified requirements, four test specimens shall be required if the retest is made immediately or two test specimens shall be required if the repair welder takes further instructions in the practice before making the retest. To be acceptable, all retests shall conform to the specified requirements.		

Category	Quality Process Element	CSA Z662-15 - Oil and gas pipeline systems	CSA Z245.1-14 -Steel Pipe	CSA Z245.11-13 -Steel Fittings	MSS SP-75 (2014) -High-Strength, Wrought, Butt-Welding Fitting
	Quality Control	Table 5.3 Notes: ...3)The manufacturer shall have a documented quality program. API Q1 and CAN/CSA-ISO 9001 can be used for quality management programs	**4.4 Quality program** The manufacturers of slab/billet, hot rolled coil/plate and pipe shall comply with the requirements of a nationally- or internationally-recognized quality management system.	4.5 Quality Program The manufacturer shall comply with the requirements of a quality management system.	4.5 The manufacturer shall have a quality control (QC) program that verifies the manufacturing process used and ensure that the resulting geometry of the fittings or joints manufactured reasonable conforms to the geometries tested. The QC program shall control the manufacturing drawings and maintain the QC records showing conformance to these drawings...
		7.6.4 Welding Procedure Specifications 7.6.4.11 Technique The following shall be specified:...g) cleaning methods and quality to be achieved	**11 Inspection, tolerances, and work quality** 11.1 Inspection Pipe shall be inspected visually or by a combination of visual and nondestructive methods to detect defects and determine compliance with the dimensional and work quality requirements.		
		7.13.2 Radiographic procedure A written procedure shall be developed for each radiographic inspection technique used…including..the type of image quality indicators..7.13.4.1 For film radiography, radiographic films shall be classified in accordance with ISO 11699-1 and be of high contrast and relatively fine grain...7.13.6.1 Image quality indicators (IQIs) shall be used to measure the sensitivity of the radiographic image...	11.5 Work quality	**11.4 Work quality** 11.4.1 Fittings shall be free of defects and shall have a competently produced finish.	4.6 A report of the testing for each test assembly shall be prepared and shall include: (a) Description of the test, including the number of tests and f factor used to establish the target proof test; (b) Instrumentation and methods of calibrations used; (c) Material test reports for the assembly's materials; (d) Actual final pressures for each test; (e) length of time from test initiation to the time of burst, or the hold time at or above the computed target pressure; (f) Calculations performed; (g) Location of rupture, if any, including a sketch. The test report shall be made available at the manufacturer's facility for inspection by the purchaser or regulatory authority.
		A.8.6.1 Control of construction	**12.4 Radiological inspection 12.4.3 Sensitivity** Radiological inspection shall be performed using a technique of sufficient sensitivity to display the image of the image quality indicator and the essential hole or wire. Fluoroscopic inspection shall not be performed at speeds greater than those at which the image quality indicator can be read definitively. **12.4.4 Image quality indicators..12.4.5 Acceptance limits...**		
		(Annex D Guidelines for in-line inspection of pipelines) D. 4 Inspection execution			
		(Annex N Guidelines for pipeline system integrity management programs) N.10.3 Imperfections The options that may be used to reduce the frequency of failure and damage incidents associated with imperfections..include the following…j) improved quality measures for manufacturing, design, construction, and operation...			

ABOUT DNV GL

Driven by our purpose of safeguarding life, property, and the environment, DNV GL enables organizations to advance the safety and sustainability of their business. We provide classification and technical assurance along with software and independent expert advisory services to the maritime, oil and gas, and energy industries. We also provide certification services to customers across a wide range of industries. Operating in more than 100 countries, our 16,000 professionals are dedicated to helping our customers make the world safer, smarter and greener.