MASTER WELDING SPEC - 101

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# Scope

This manual includes the welding specifications to be used for the construction, fabrication, and maintenance of all Owner piping systems. All Company and contractor personnel performing work for the Company shall follow the specifications presented herein.

This manual is intended to be used in conjunction with the Company Operating and Maintenance Plan.

Specifications for nondestructive testing including radiographic testing, magnetic particle testing, visible dye penetrant inspection, ultrasonic wall-thickness examination, and an arc burn removal procedure are also a part of this manual.

This manual will be updated as required to maintain current revisions of the referenced codes and standards.

# Construction and Fabrication of Pipelines and Related Piping Systems

## Scope

This specification establishes the welding and inspection requirements for the construction and fabrication of all pipelines and piping systems for Owner.

## Codes and Standards

In addition to complying with the requirements of this specification, the regulations, codes, and standards in Appendix C, the latest edition, approved by the U.S. Department of Transportation (DOT) Office of Pipeline Safety (OPS), shall apply.

## Material Requirements

In addition to Owner material specifications and purchase order requirements, all pipe material, steel pipe flanges, fittings, and valves used in the construction of Owner pipelines and related piping systems shall meet the requirements of Appendix C.

## Welding Procedure Qualification

In accordance with DOT regulations, detailed welding procedures must be established prior to production welding and qualified to demonstrate that welds having suitable mechanical properties and soundness can be made with a particular procedure. The quality of the procedure welds shall be determined by destructive testing in accordance with API 1104 or ASME Section IX, latest editions, as applicable.

Qualification of welding procedures shall be in accordance with API 1104 for the construction of new pipelines and API 1104 Appendix B for welding of "In-Service" pipelines. Welding procedures and welders for Plant piping systems designed in accordance with ASME B31.3 shall be qualified in accordance with ASME Section IX.

The maintenance support personnel shall be responsible for conducting all testing, evaluation and approval of test results for each welding procedure. A welding procedure shall NOT be used for pipeline construction or for repair welding prior to its approval by the Welding Manager.

Unless otherwise specified and approved, the welding procedures to be used will be those provided in this manual. The approved welding procedures shall be adhered to at all times during welding. In the event that the contractor requests a change of essential variables (as defined by API 1104), a new procedure shall be developed.

As required, additional procedures will be established and incorporated into this manual.

### Temperature

The ambient temperature at which the welding procedure qualification was conducted shall be included in the procedure. The approved procedure may be used for construction at temperatures above or below the test temperature provided preheat temperatures specified in the procedure are followed.

## Welder Qualification

Until prior to performing any work, all welders should be inspected by a qualified welder API adopts 1104 Appendix B may be used for "In-Service" welding in accordance with Section 9. All welder qualification testing shall be performed under the direct supervision of a Company-approved Inspector, except for ASME Section 9.

A welder is not allowed to weld on ANY pipelines or pipeline facilities until the welder has been tested and qualified in accordance with Section 9. Once qualified, the welder is then permitted to weld within the essential variables established by the qualification test. These essential variables are detailed in API 1104 for new construction or API 1104 Appendix B "In-Service" welding.

## Welding Process and Controls

The approved field welding process to be used for construction and fabrication is the shielded metal arc welding (SMAW) process.

Welding electrode and ground requirements include, but are not limited to the following:

1. Cellulose coated electrodes (E6010, E7010 G, E8010 G, and E7010-PI) shall not be stored in ovens, but shall be maintained in a dry area at a temperature above freezing and below 100°F
2. Low hydrogen electrodes (EXX16, EXX18) used for maintenance welding shall be stored in holding ovens at 250°F minimum to 350°F maximum temperature.
3. All electrodes that have been exposed to an atmosphere that may affect their operating characteristics or weld quality shall be discarded.
4. Electrode holders shall be of the fully insulated type when used for welding on the inside of the pipe.
5. The ground connection shall be constructed of steel, of similar chemical composition, with respect to the pipe and be of sufficient size to prevent overheating. The ground shall be located and held, if necessary, in a manner that prevents arc burns on the pipe. It shall be insulated on all points contacting the pipe except for the one point of contact that should be located in the weld joint.
6. Commercially available grounding clamps may be used for fabrication and/or field construction as applicable.
7. Ground clamps shall not be welded to the pipe or fittings.

## Pre-Alignment Inspection

Prior to alignment, all pipe and/or fittings shall be inspected for defects that would impair the service life of the pipeline.

Pipe wall and bevel discontinuities shall be repaired or removed as described herein.

### Pipe Wall Discontinuities

Pipe wall discontinuities shall be handled as specified in the sections below:

#### Laminations

Laminations found in the pipe wall require that the pipe be inspected by an approved ultrasonic thickness gage and the portion of the pipe, which contains the lamination, be cut out as a cylinder. If the lamination is determined to be mid-wall, no repair is necessary.

#### Cracks

Cracks found in the pipe wall shall require that the portion of pipe containing the crack be cut out as a cylinder.

#### Dents

All dents exceeding the requirements of API 5L shall be cut out as a cylinder. All dents with metal loss shall be repaired.

#### Gouges, Grooves, Scratches, and Notches

All gouges, grooves, scratches, and notches that exceed the requirements of API 5L shall be eliminated by grinding, providing the wall thickness is not reduced to below the minimum requirements. For API 5L wall thickness tolerances refer to Section 7.8.16. In the event grinding reduces the wall thickness below the minimum requirements, the area shall be cut out as a cylinder of pipe.

### Pipe Bevel Discontinuities

#### Laminations

Laminations or other visual defects in the pipe bevel that exceed 1/4 in. shall be removed by cutting out this portion of the pipe as a cylinder.

#### Bevel Damage

Bevel damage such as dents, gouges, or depressions shall be repaired if their depth exceeds 1/16 of an inch. Repairs shall be made by grinding or filing to smooth the defect into the existing bevel. Damage that requires grinding to the point where the bevel may be modified, from the tolerances on the welding procedure, shall be rejected and the end shall be re beveled.

#### Root Face Damage

The root face (land), if damaged, may be restored to its original dimension by filing or grinding. In the event restoration is not possible, the end shall be completely re-beveled.

#### Bevel Dents

Denting restricted to the top edge of the bevel shall be ground smooth and shall not be cause for rejection, unless, in the opinion of the welding inspector, the denting extends beyond the area where the cap pass will tie in to the bevel edge.

## Welding Requirements

### Electrodes

The specific classification and type of welding electrode used during construction and fabrication shall be as described in the approved welding procedure. Electrodes shall be ordered by their American Welding Society (AWS) classification number (example E6010 and E7010 G) based on their designation in the applicable procedure. Any change in the AWS classification number requires approval by Owner Maintenance Support.

The Owner inspector has the right to disallow the use of any electrodes brought to the job site that may be of questionable condition or moisture content. Electrodes, which are of obviously questionable condition, shall not be used for any welding including welder qualification.

Welding electrodes shall be stored and handled in accordance with the manufacturers recommended practice. Electrodes should be stored in sealed original metal containers until ready for use. Those in opened containers should be protected from deterioration and excessive moisture changes. Visual inspection of the electrodes should be done prior to welding. Electrodes that show surface oxidation, fractured coatings, or eccentricity of the coating with respect to the electrode core wire should be discarded.

### Line Up and Fit Up

Lineup clamps shall be used for butt welds in accordance with the procedure specification. When it is permissible to

remove the lineup clamp before the root bead is completed, the completed part of the bead shall be in approximately equal segments spaced approximately equally around the circumference of the joint. However, when an internal lineup clamp is used and conditions make it difficult to prevent movement of the pipe or if the weld will be unduly stressed, the root bead shall be completed before clamp tension is released. Root-bead segments used in connection with external clamps should be uniformly spaced around the circumference of the pipe and shall have an aggregate length of at least 50% of the pipe circumference before the clamp is removed.

Joint alignment shall have a uniform spacing (root opening) throughout the circumference of the joint. The spacing shall be in accordance with the approved welding procedure.

### Longitudinal Seam Offset

The longitudinal seam shall be offset at 10:00 and 2:00.

### Weld Joint Bevels

Unless otherwise specified, Owner will supply pipe with beveled ends conforming to API 5L. When re-beveling is necessary it may be accomplished using a mechanized oxy acetylene beveling machine. When a transition taper is required, it shall be made using a mechanical end preparation machine or by manual preparation and then approved by the Owner Inspector. A rust preventative such as deoxaluminate may be applied to the pipe bevels to prevent rust and corrosion during long-term storage.

### Transition Joints

The transition between pipe ends of unequal thickness (thickness differences greater than 3/32 in.) shall be by mechanical tapering, by welding in accordance with ASME B31.4, or by means of a prefabricated transition nipple not less than one half pipe diameter in length.

### Weld Joint Cleaning

The beveled weld joint and the inside and outside surfaces at the end of each pipe to be field welded shall be cleaned for a minimum distance of 1 in. immediately prior to welding.

All traces of foreign material shall be removed by hand or power tools from the weld area. The pipe ends shall be completely dry prior to and during field welding. This may be accomplished by the use of propane or oxy-acetylene torches using a "rosebud" tip regardless of the ambient temperature. There shall be no traces of water at or near the outside or inside pipe surfaces during welding.

### Welding Equipment

Welding equipment used for field welding shall be maintained in good working condition and have the same performance capabilities as that which was used to qualify the welding procedure. Any machine that is not performing satisfactorily shall be removed from service and repaired or replaced.

### Weld Ground Placement

During welding, the placement of welding ground connections shall be on the last finished or unfinished weld. In accordance with DOT 195.226C a ground may not be welded to the pipe or fitting that is being welded. Grounds used for firing line welding shall be placed on the finished or unfinished weld. Arc burns on pipe or on completed welds shall be eliminated in accordance with the Owner Arc Burn Removal Procedure in in Section 18 or cut-out as a cylinder, as directed by the Company Inspector.

### Weld Joint Clearance

When the pipe is welded above ground, a minimum clearance of 16 in. is recommended. When the pipe is welded in the ditch, the bell hole shall be of sufficient size to provide the welding personnel with ready access to the joint for all welding operations.

### Tack Welds

Tack welds, which are to be incorporated in the final weld, shall be thoroughly cleaned of scale and suitably prepared at each end by means of grinding to ensure complete stringer bead continuity. Tack welds shall be free of cracks.

### Weld Joint Protection

Welding shall not be performed when weather conditions exist which would be detrimental to the quality of the finished weld. Rain, snow, high winds, and moisture from any source, are known to contribute to unfavorable weld quality conditions. Welding may be allowed to continue during inclement weather only after adequate shelters and precautions are implemented to insure proper weld protection. The Company Inspector shall determine if the protective measures are adequate prior to welding.

### Weld Pass Requirements

A minimum of two complete weld passes shall be made prior to leaving the weld in the unfinished condition. The purpose of this requirement is to assure weld cracking will not occur. Depending on the pipe wall thickness and/or weld stress level, the Company Inspector may require additional passes be made prior to leaving the weld in a temporarily unfinished condition.

### Preheating of Welds

When preheating is required by the procedure, temperature readings shall be taken using temperature indicating crayons or direct reading pyrometers. Measurements shall be made at four locations ninety degrees apart on each side of the weld joint. The location shall be a minimum of 2 in. from the weld joint centerline. Maximum temperature differential between any two points shall not exceed 50°F.

Preheating may be performed by propane, induction, or oxy acetylene torches with a "rosebud" tip. Preheating shall always be done when the pipe is wet or damp for purposes of drying the pipe prior to welding.

### Filler and Finish Beads

The completed weld shall have a uniform cross section around the entire circumference.

At no point shall the weld crown (cap pass) surface be below the outside surface of the pipe, nor should it be raised above the parent metal by more than 1/16 of an inch, except that the height of a weld crown may exceed 1/16 if the weld contour provides a uniform transition into the pipe material on both sides of the weld. Two beads shall not be started at the same location; and the face of the completed weld should be approximately 1/8 of an inch greater than the width of the original groove. The completed weld shall be thoroughly brushed and cleaned.

### Interpass Cleaning and Removal of Visual Defects

Each pass of the weld metal shall be cleaned of slag or remaining flux using hand or power tools with buffer wheels before a further pass is applied.

 Visible defects such as slag cavities, cold laps, and other deposition faults shall be removed by grinding.

Clusters of surface porosity, starts and stops, and high points, shall be removed by grinding prior to the deposition of the next pass.

### Arc Burns

Arc burns shall be cut out as a cylinder, or at the discretion of the Company Inspector, may be eliminated in accordance with the Owner Arc Burn Removal Procedure in Section 18. In the event the remaining wall thickness is less than the minimum specified in API 5L, Table 9, shown herein, the pipe shall be cut out as a cylinder.

| Wall Thickness Tolerances |
| --- |
| Outside Diameter (OD)–in. | Type of Pipe | Tolerance, Percent |
| Grade B or Lower | Grade X42 or Higher |
| ≤ 27/8 in. | All | +20.0, −12.5 | +15.0, −12.5 |
| > 27/8 in. and < 20 in. | All | +15.0, −12.5 | +15.0, −12.5 |
| ≥ 20 in. | Welded | +17.5, −12.5 | +19.5, −8.0 |
| ≥ 20 in. | Seamless | +15.0, −12.5 | +17.5, −10.0 |

### Weld Stripper Passes

A stripper pass may be used with the approval of a Company Inspector to eliminate unacceptable external conditions such as external undercut or incomplete fill of a cap pass. Stripper passes, when used, shall be 2 in. in length minimum, and a minimum of one electrode diameter in width. Prior to the welding of a stripper pass on a weld that has cooled to ambient temperature, the area to be welded shall be preheated to 250°F minimum to 350°F maximum for a distance of 3 in. on each side of the weld area.

### Back Welding

When pipe and/or fitting size permits access to the inside surface, back welding may be used to eliminate unacceptable internal conditions or to complete the weld on transitions or fittings to pipe. When pre-heating is required by the welding procedure, prior to back welding, the area shall be preheated from the outside to achieve a preheat temperature on the inside surface of 250°F minimum to 350°F maximum. This preheat requirement applies to all internal back welding.

### Pipe Coating Protection

Any pipe coating shall be protected from weld spatter and mechanical abrasion during welding.

### Tie-In Welds

Tie-in welds, once started, shall be completed without interruption.

### Identification of Multiple Welders

If requested by the Company Inspector, each welder shall mark the weld or section of a weld for which he has been responsible with the identification assigned to him by the Inspector using a weatherproof crayon or a permanent ink marker.

### Weld Repairs

Depending on the extent of defective weld areas found during radiographic examination, the Inspector may require the weld be cut out as a cylinder of pipe or be repaired in accordance with the following limits:

1. Repair of a crack or of any defect in a previously repaired area must be in accordance with written weld repair procedures that have been qualified under §195.214. Repair procedures must provide that the minimum mechanical properties specified for the welding procedure used to make the original weld are met upon completion of the final weld repair.
2. Defects, except cracks, found by visual examination, magnetic particle, or liquid penetrant that are externally exposed in the cover pass may be repaired.
3. Defects found by radiographic examination, such as slag inclusions, porosity or gas pockets may be repaired in compliance with API 1104 provided the defects can be removed without grinding completely through the weld. Repair of defects that require removal of the root pass require approval of the Company Inspector.

Before the above repairs are made, the defective area shall be entirely removed to clean metal by grinding in a manner acceptable to the Inspector. All slag and scale shall be removed by wire brushing.

All repair cavities shall be not less than 2 in. in length unless impractical and approved by the Company Inspector. All repairs shall be made with a minimum of two passes. The start and stop of repair passes shall not be superimposed over the start and stop of the preceding pass.

The start and stop of each repair pass shall be ground smooth.

Prior to repair welding, a minimum of 3 in. on each side of the repair area shall be preheated to a temperature of 250°F minimum to 350°F maximum and maintained during welding. Temperature shall be checked by the use of temperature indicating crayons or pyrometers.

All repairs shall meet the Acceptance Standards for Nondestructive Testing of API 1104.

### Welding Magnetized Pipe

Residual magnetic fields due to pipe handling with electromagnets, inspection of new pipe with electromagnetic fields or smart pigging of existing lines can create significant deflection of the welding arc resulting in welding problems. In the event magnetic fields are suspected or encountered in the field, the Company Inspector will measure the individual joint ends and the joint space to determine if degaussing (demagnetizing) of the weld joint is necessary to assure proper weld quality. In general, a gauss level greater than 100, as measured in the joint space, will require degaussing which will be directed by the Company Inspector.

## Inspection of Welds

### Recommended Non Destructive Testing (NDT) Methods

Owner recognizes there are several NDT methods available for field inspection of fillet and groove welds for new construction. The chart shown herein represents the present Owner NDT recommendations for each type of weld. As NDT methods change or improve, the chart will be revised to reflect the latest technology.

| Recommended NDT Methods |
| --- |
| Weld Type Joint Design | NDT Methods |
| X‑Ray | LPT | MPT |
| Groove | R |  |  |
| Fillet |  | R | A |
| **Note:** LPT = Liquid Penetrant Testing, MPT = Magnetic Particle Testing, R = Recommended, and A = Alternate Method |

### Visual Weld Inspection

Visual inspection of welds will be conducted to insure that the welding is performed in accordance with the approved welding procedure and the welding meets the requirements of this specification including API 1104.

### Radiographic Inspection

When radiographic examination of groove butt welds is conducted, it shall meet the requirements set forth in the 49 CFR 195. At the option of Owner, the extent of radiographic examination may exceed these requirements to assure quality welding is being achieved throughout the project. Refer to Section 11.4.5 for the number of girth welds to be nondestructively tested each day.

### Standard of Acceptability

Unless specified otherwise, the standard of acceptability for the radiographic film interpretation of all regulated pipeline or piping system welds shall be API 1104.

### Production Weld Qualification

At the discretion of the Company Inspector, production welds may be cut out and tested to confirm the adequacy of the welding procedure under construction conditions.

Welds meeting the requirements of API 1104 will be charged to Owner. Those welds not meeting the requirements of API 1104 will be charged to the pipeline contractor.

### Disqualification of Welders

A welder who makes a weld that fails to comply with the requirements of this section may be disqualified from further welding at the discretion of the Company Inspector. A welder can also be disqualified for arc burning pipeline.

# Inspection and Testing

## Scope

This inspection specification establishes guidelines to be followed for the inspection, destructive evaluation (DE), and nondestructive evaluation (NDE) of welds.

This specification is limited to establishing guidelines for the inspection of welds only, and not guidelines for the formation of Welding Procedure Specifications (WPS). WPSs and their corresponding Procedure Qualification Records (PQR) are outside the scope of this document and are located in the Welding Procedure Manual.

This specification is designed to assist Inspection perform the testing and examination of welds in any facility.

## Application

This specification shall be utilized for all welding processes related to the terminal whether or not the welding is actually performed within the terminal.

## Guidelines

Testing by NDE methods shall be performed by qualified individuals (as listed in Appendix A, Section 17.3, Qualification/Certification/Training of the Fixed Equipment Inspection and Testing Manual).

The following are weld inspection requirements:

1. Welds shall be examined for acceptability using visual inspection (VT).
2. The acceptability of a weld shall be determined based upon successful completion of any required NDE.
3. All methods of NDE (as listed in Section 13.0) are acceptable methods of examining a weld, provided that they clearly indicate all defects that could possibly affect the integrity of the weld.

The following are VT requirements:

1. VT of welds may be performed at any time during the welding process.
2. Prior to welding, the material shall be examined for surface conditions which may be harmful to the weld integrity.

These include (but are not limited to) the following:

* Seams
* Scale
* Paint
* Epoxy
* Dirt
* Oil
* Grease
* Foreign Material

Prior to the start of any job requiring welding, WPS, PQR and Welder Performance Qualification (WPQ) records shall be received and approved by Inspection. Only WPQs from approved third party weld testing facilities shall be utilized in the certification of all welders. Any deviation from this stipulation shall be approved in advance by Inspection.

After parts are positioned for welding, the following may be inspected to verify compliance with applicable welding procedures and specifications:

* Joint preparations (dimensions and finish)
* Alignment and fit up
* Cleanliness
* Preheat requirements
* Equipment settings
* Filler metal specifications and handling
* Additional special requirements based on the WPS

VT during welding may include, but is not limited to, the following items:

* Welding process (voltage and amperage setting, direction and speed of travel)
* Filler metal, flux or shielding as required
* Preheat and interpass temperature requirements
* Welding techniques
* Cleanliness and completeness of grinding procedures
* Distortion control

After the completion of the welding process, VT shall verify the following:

* Dimensional accuracy of weld
* Conformity to weld specifications
* Acceptability of weld based on appearance and surface conditions
* Height of reinforcement
* Post Weld Heat Treatment Documentation
* Mechanical Testing (BHN)

A weld qualifying as acceptable under a VT should not be construed as sufficient evidence of its quality. A supporting method of NDE shall be employed to fully certify the weld.

A weld proving unacceptable (one or more defects exceeding acceptance criteria) based on VT shall be repaired or replaced. The new weld shall then be subjected to examination and acceptance by the same methods.

If the noted imperfections are a result of original weld fabrication, an analysis is required to assess the impact of the weld quality on component integrity.

On occasion, radiographic profile examinations may reveal what appears to be imperfections in the weld. If crack like imperfections are detected while the piping system is in operation, further inspection with weld quality radiography and/or ultrasonics may be used to assess the magnitude of the imperfection. Additionally, an effort should be made to determine whether the crack like imperfections are from original weld fabrication or may be from an environmental cracking mechanism.

Acceptance criteria for NDE shall be in accordance with the applicable code or reference standard as listed in Section 13.0 of this manual.

## Records

The following records shall be retained for 5 years after the record has been generated for the project:

* Examination procedures
* Examination personnel qualifications
* Location and disposition of welds passing/failing acceptance criteria

# In-Service and Maintenance Pipeline Welding

## Scope

### In-Service Welding

This section establishes requirements for in-service welding and inspection of pressure piping systems for Owner. "In-service welding" is defined as any welding performed on a pipeline or pressure piping system that contains petroleum gas, liquid, or ammonia under static or flowing conditions.

Prior to welding on in-service piping, all procedures within each system's Operating Manual must be followed.

### Maintenance Welding

This procedure establishes the requirements for maintenance welding under static no flow conditions while repairing regulated pipelines or piping systems operated by Owner. The reference to Owner hereafter applies to and includes all Owner pipeline subsidiaries and affiliates.

This procedure is applicable to pipeline systems that transport hazardous liquid hydrocarbons regulated by 49 CFR 195 and is also applicable to terminal and facility piping not regulated by 49 CFR 195. This procedure contains non-restricted repair methods requiring only that the specific details of the method of repair be followed.

This procedure has methods applicable to API Specification 5L Pipe Grades A, B, X42 to X65, but some methods are limited by the restrictions noted in each Appendix. The restrictions must be thoroughly understood and adhered to during the repair operation.

"Pipeline in-service maintenance welding" is defined as welding on a pipeline or pipeline system that contains a liquid such as petroleum products, crude oil, or hydrostatic test water, which may be pressurized and in a static or flowing condition.

Welders doing maintenance welds shall be OQ qualified as required under Subpart G of Part 195, where applicable.

## Referenced Codes and Standards

In addition to complying with the requirements of this specification, the latest OPS-approved editions of the codes, standards, and specifications in Appendix C shall apply.

## Material Requirements

All materials used for in-service and maintenance welding such as patches, sleeves, backing strips, and fittings shall meet the minimum design requirements for wall thickness, yield, and tensile strength as specified by the welding procedure.

## U.S. Department of Transportation Requirements

1. Assure that pipeline repairs are made in a safe manner so as to prevent injury to persons or damage to property.
2. Inspect any buried pipe that has been exposed for any reason for evidence of external corrosion, coating damage, or pipe damage. Whenever pipe is removed from the pipeline, the internal surface of the pipe must be inspected for evidence of corrosion.
3. No movement of any line pipe is permitted unless the pressure is reduced to not more than 50% of the maximum operating pressure. Special precautions should be made when moving line pipe containing highly volatile liquids. When removing and installing pipe or valve sections in ditch per DOT 195.246, it shall be done in a manner that minimizes the introduction of secondary stresses and the possibility of damage to the pipe.
4. All welding repairs must be done by a qualified welder in accordance with API 1104 and ASME B31.4. Welder shall meet OQ/AOC requirements to weld on In-Service pipelines.
5. Record and document repairs or inspections including date, location, and description. A record of repairs made to pipe should be retained for the useful life of the part of the pipeline system to which they relate. Records of repairs made to components other than pipe should be maintained for 1 year.

## Owner Requirements

### Crude and Refined Products Division

1. Pipeline maintenance personnel must coordinate closely with the pipeline operations personnel. It is seldom that operations are completely stopped while maintenance, repairs, or construction activities are taking place.
2. Repairs will be performed by personnel working under qualified personnel who are familiar with hazards to persons and property.
3. Since each job may be different, an outline of the scope of work will be prepared and verbally communicated to the Operations Department who will make sequential notifications.
4. Direct communication will be established prior to and during the entire operation, typically among the following:
	1. Maintenance Supervisor, Project Coordinator or designee – at the repair site
	2. Dispatcher – Control Center
	3. Regional Manager or designee – at the point of origin of the product being pumped into the line section being repaired
	4. Regional Manager or designee – at the receiving point of the product being received from the line section being repaired
5. Propane should not be in the section being repaired. Only under extreme circumstances will welding be allowed on the main line while propane is in the immediate line section and then only with the approval of the Maintenance Operations Supervisor.
6. If the line is operational, the flow rates should be between 1 or 3 ft. per second without exceeding 50% of the maximum operating pressure and preferably less than 400 psi maximum pressure at the repair site. This could be obtained by the following:
	1. The origin pump station should be manned continuously, preferably running one unit.
	2. Preferably no intermediate pump stations should be running.
	3. No intermediate terminals bleeding off product.
	4. No intermediate terminals adding product.
7. Once the line flow and pressure are accepted by all parties, the Manager – Maintenance Support, or designee, will advise the Manager – Scheduling and Dispatch, or designee, and the Regional Manager, or designee, at the point of origin and the Regional Manager, or designee, at the receiving terminal or breakout station. All parties will maintain constant surveillance on the operation and advise the Manager – Maintenance Support, or designee, immediately of any variations of pressure conditions.
8. The Manager – Maintenance Support, or designee, will advise all parties involved when the welding is completed, including the Manager – Scheduling and Dispatch, or designee, and the Regional Manager(s), or designee(s), to return to normal operation and place specific restrictions on operations if other repairs are still pending.
9. The Supervisor – Construction/Maintenance, or the Supervisor – Pipeline Operations, or designee, will be responsible for completion of a Main Line Activity Report. The completed Report will be forwarded to the Engineering Department. The completed Report will be archived, and copies distributed as needed.

### Ammonia Division

1. Pipeline personnel managing the repair work will coordinate closely with the pipeline operations personnel. It is seldom that operations are completely stopped while maintenance, repairs, or construction is taking place.
2. Repairs will be performed by personnel qualified or working under qualified supervisors who are familiar with the hazards to persons and property.
3. Since each job may be different, many jobs have scope-of-work plans developed and distributed by the project planner to the Integrity Manager and the Manager of Operations. For jobs that involve line stoppling, a stopple plan will be developed and distributed to the Operations or Engineering Manager for approval and then distributed to the Manager of Distribution, ammonia system Pipeline Dispatchers, and lead inspector for the maintenance work.
4. Direct communication will be established prior to and during the entire operation between the lead inspector at the work site and the pipeline dispatchers.
5. If the line is in service, then the line pressure will be kept below 700 psi (and preferably below 500 psi) at the point of the pipe being welded. To deviate from this standard pressure range described above contact the engineering department for custom pressure restrictions. Line flow is desired in most maintenance cases to be as much flow as possible at the above pressures to cool the weld area and flush away metal shavings created in the line tapping process. Welding is restricted to a minimum wall thickness of 0.188 in. without approval of the Integrity Management Team.
6. Once the line flow and pressure is accepted by all parties, the lead inspector at the job site will advise the pipeline dispatcher that work is ready to start. The pipeline dispatchers will maintain constant surveillance on the pipeline pressures and advise the lead inspector, immediately, of any variations of pressure conditions.
7. The lead inspector at the site will advise the pipeline dispatchers when the welding is completed, and the pipeline can return to normal operations or place specific restrictions on operations if other repairs are still pending.
8. The lead inspector will be responsible for completion of the necessary documents to record the modifications to the pipeline and any product loss reports.

## Temporary Repairs

1. Temporary repairs shall be made whenever possible to contain the leak and stop the loss of product.
2. Repairs of this type may be made by using clamps, sleeves, or couplings that require no welding.
3. After the leak has been contained, a thorough examination of the pipe should be made, and permanent repair plan established.
4. After temporary repairs are completed, it may be necessary to restrict access to the work site to protect the public until a permanent repair can be made, the line is backfilled, and the area cleaned up.

## Permanent Repairs

1. Permanent repairs should be made as soon as practicable to keep the line in normal operating condition.
2. Practically all gouges and grooves of any significant depth are injurious to the pipe, and should be repaired.
3. Repairs to injurious gouges, grooves and dents, are usually made by cutting out and replacing the defective section of pipe or installing butt-welded full encirclement sleeves.
4. Weld defects or defective girth welds, or a full encirclement weld reinforcement sleeve or the defective weld, should be cut out and a new section of pipe installed or a butt-welded full encirclement sleeve should be installed over the defective pipe.
5. If the size of a pit, puncture, or defect warrants, the repair should be made by replacing the defective section of pipe as per API 1104 and ASME B31.4.
6. If it is not feasible to take the line out of service, repairs to pits, punctures, or other defects should be made by installing butt-welded full encirclement sleeves, or in some applications composite sleeves.

## Acceptable Repair Methods

Owner accepts the methods discussed herein for the repair of piping systems. In addition to the requirements specified herein, all repairs on liquid piping systems shall be done per Owner O&M Manual Pipeline Repair Sections 613 and 614 and in conformance with ASME B31.4.

Owner acknowledges the DOT Pipeline and Hazardous Materials Safety Administration (PHMSA) Alert Notice dated March 13, 1987, addressing the welding of repair sleeves and fittings. Company procedures give consideration to the use of low hydrogen welding rods, cooling rate of the weld, metallurgy of the materials being welded (welding carbon equivalent), and proper support of the pipe in the ditch. Actual procedure elements are incorporated into the in-service welding procedure data.

### Pipe Replacement

If practical, replacement of the area containing the defect by cutting out a cylindrical piece of pipe and replacing the defective section with a new piece is the preferred option subject to available downtime.

When cutting out a defective section of pipe, the cuts should be made with manually-operated or air driven pipe cutters or saws for the refined Products Division, or torch cutting with a beveling machine for the Ammonia Division.

If welding is to be performed, the excavation and surrounding area should be checked for explosive vapor concentrations.

Product soaked dirt should be removed an adequate distance from the excavation so that it does not present a safety hazard.

Appropriate portable fans may be used to help remove vapors where movement of air is restricted. Care should be taken in the selection and/or location of portable fans to insure that arcing from the motors or from the temporary electrical source does not create a condition for possible ignition.

When welding is required, the excavation should be tested with an indicator to determine that the excavation is vapor free. If product seeps into the excavation after welding has begun, the product should be removed and the excavation again freed of vapor before welding is resumed.

Due to the possibility of arcing, adjacent rectifiers' location on either side of the work location shall be turned off, and locked out as applicable. After turning off the unit the positive lead should be disconnected from the rectifier during welding. Bonding clamps should be used on all points of separation before the line is cut or a flange joint is separated. If replacement pipe is required pipe joints should also be bonded. In areas where excessive current is on the line, additional protection should be provided, by installing ground rods on each side of the cut flange separation.

**Note:** This does not apply to the Ammonia Division.

### Full Encirclement Sleeves

Complete encirclement using split sleeves, as shown in the maintenance welding procedures in this manual, may be used for the repair of certain dents or corrosion.

Full encirclement sleeves should have a minimum length 1.5 times the nominal diameter of the pipe, but shall not be less than 4 in.

The sleeve shall be of greater wall thickness or grade than the carrier pipe and should be able to withstand the maximum operating pressure of the pipe.

Filler material may be used to fill any voids between the pipe and the sleeve.

When installing a full encirclement sleeve, care should be taken to insure proper fit of the sleeve and proper spacing for the root on the longitudinal weld of the sleeve. A backing strip of steel or suitable material shall be placed on the pipeline where the longitudinal weld will be located.

After completion of the longitudinal seams, the end welds are made. Each circumferential weld should be completely finished prior to welding the other end. For any sleeve over 8 in., it is recommended to use two welders.

### Hot Tap Fittings

Hot tap fittings including split-tees and appurtenance saddles installed on Owner piping systems must be done in accordance with the manufacturer's instructions and the requirements of this specification.

Split tee fittings shall be full encirclement with the longitudinal joint designed for the use of backing strips. A root opening of 1/16 in.–3/16 in. shall be maintained on both longitudinal seams of the split fitting. The backing strip shall be approximately 3/4 in. wide and 0.070 in.–0.090 in. thick and be of the same or comparable chemical composition to the material being welded.

Extreme caution shall be exercised when welding the longitudinal weld to prevent burning through the backing strip and welding to the carrier pipe.

The hot tap fitting shall not be located within 2 ft of a pipe anchor, girth weld, flanged connection or threaded connection unless approved by the Company Inspector.

The carrier pipe and the fitting shall be sand blasted or mechanically cleaned of all coating, scale, paint, or other foreign material. Cleaning shall be for a distance of 3 in. on either side of where the welding will be performed.

Tapping in a girth weld is not permitted. If necessary to tap through an area containing a longitudinal weld, the area shall be inspected ultrasonically including the weld for a distance of 10 in. beyond each side of the tap. The longitudinal weld shall meet the acceptance standards of API 5L.

Refer to Owner O&M Manual Section 612-3.3 for hot tap and stopple testing guidance.

### Weld+End Type Coupling

This is a temporary repair. Couplings commonly referred to as weld-plus ends should not be used for any repair or replacement unless a qualified installation and welding procedure has been established, documented and approved.

The maximum allowable gap between ends of carrier pipe is 0.250 in. inside the weld+end.

The gap should be adjusted evenly around the weld+end when tightening anchor bolts.

**Caution:** Avoid over tightening bolts.

#### Sequence of Weld+End Installation

Tighten end bolts evenly around each end of weld+end and tighten securely by making at least four complete circles around the pipe.

#### Sequence for Fillet Welding of Wrapper Sleeve

1. The wrapper sleeve material shall be the same grade and thickness, or better, as the pipe being repaired.
2. All fillet weld passes shall be made per the approved procedure.
3. The longitudinal seams shall be welded first followed by the welding of one end and then the second end with a clearance of 0.030 in. between the pipe and the wrapper sleeve.
4. Make fillet weld complete in accordance with the approved "In-Service" procedure on one end of the sleeve before welding the other end.

## Welder Qualification

All maintenance welding personnel shall be qualified in accordance with Section 9, which includes the requirements of API 1104, Appendix B

Qualification for maintenance and repair welding including full encirclement sleeve welding shall be accomplished on an actual sleeve qualification test including the fabrication, fit-up, and welding of the longitudinal groove weld and the circumferential fillet welds as defined in API 1104, Appendix B.

Welder qualification shall be conducted under the supervision of a qualified Owner Representative or third-party qualified welding inspector. An independent testing agency may be used to document the qualification testing.

## Welding Procedures

All in-service and maintenance welding on lines shall comply with the requirements of this specification of API 1104, Appendix B, where applicable.

The maintenance welding procedure(s) to be used will be the appropriate Owner qualified welding procedure(s) in Owner's WM unless specified otherwise. The maintenance welding procedures to be used will be those in this manual designated with the "M" suffix unless specified otherwise. Owner Qualified Welding Procedures are qualified for use on in-service piping with or without flow.

Contractors may submit their own maintenance and repair procedures for review and approval by Owner Engineering. The approved welding procedures shall be adhered to at all times during welding.

Welding on lines that are under internal pressure shall be done in strict conformance with the company Operating and Maintenance plan.

Welding on lines that contain liquid and/or are under internal pressure shall be done in strict conformance with Owner safety procedures and practices.

### Wall Thickness Survey

Prior to any in-service and maintenance welding on pressurized piping systems, an ultrasonic wall thickness survey shall be made of the area to be welded to disclose any possible material defects such as laminations, internal corrosion, inclusions, etc. The survey shall be made around the entire circumference of the pipe where the fillet weld(s) will be made. Any area that appears to indicate wall thickness defects shall be further evaluated by qualified Owner personnel. The minimum carrier pipe wall thickness that may be welded on is 0.188 in. without contacting Owner Engineering for approval prior to welding. The Owner Ultrasonic Wall Thickness Examination Procedure (Section 16) shall be used for this survey.

An example, shown in Figure 1, shall be made around the entire circumference of the pipe, 3 in. either side of where the circumferential fillet welds will be made. For hot taps, the survey shown in Figure 2, shall also include the area to be tapped and 3 in. around the outside area of the branch connection. The transducer should be moved slowly across the pipe in a "Z" pattern to ensure complete inspection. The transducer should not be lifted off the pipe and the thickness "spot" checked within each grid square. It is recommended that this inspection be performed with one person moving the probe and a second person reading and recording the data. Any area that appears to indicate wall thickness defects are present shall be further evaluated by Owner personnel. The minimum carrier pipe wall thickness that may be welded on is 0.188 in. unless approved by Owner Welding Inspection and Engineering personnel. Section 14 shall be used for these surveys.

Figure : UT Survey Grid for Full Encirclement Sleeve

**(Survey Conducted Completely around Pipe Circumference)**



Figure : UT Grid for Full Encirclement Sleeve and Hot Tap



**Note:** Welding of Sleeve Ends is required for Pressure Containment Only.

### Welding Electrodes

The welding procedures approved for in-service pipeline and maintenance welding on Owner piping systems are limited to the use of low hydrogen electrodes (EXX16, EXX18). Pipelines that have been depressurized and contain no liquid or gas may be welded using cellulosic electrodes (EXX10). If cellulosic electrodes are used a minimum of 24 hours, they shall be maintained prior to coding or putting the line back in-service.

The storage and handling of low hydrogen electrodes shall be as described by the manufacturer. As a minimum requirement, all low hydrogen electrodes to be used for pipeline and maintenance welding shall be stored in ovens at temperatures between 250°F minimum and 350°F maximum after they have been removed from their sealed containers.

Any electrodes which have been exposed to moisture or which are of a questionable condition shall not be used for pipeline and maintenance welding applications on Owner piping systems.

### Welding Sequence

All welding of full encirclement sleeves or fittings shall be done following the requirements of the applicable Owner welding procedure. The sequence of welding is as follows:

1. Complete the wall thickness survey at the areas to be fillet welded. If the survey indicates the pipe does not meet the minimum wall thickness tolerances of API 5L, locate another area that conforms to the thickness tolerance prior to performing the welding.
2. As stated in Section 8.10.2, 0.188 in. is the minimum wall thickness to be welded without approval from Owner Welding Inspection and Engineering personnel.
3. Place the top and bottom sleeves or fittings with the backing strips tacked to the bottom sleeve/fitting over the carrier pipe area.
4. Clamp the sleeves/fittings in place, maintaining the proper weld root space for the longitudinal welds and tack weld the sleeves and backing strips together at the ends and center in the longitudinal grooves. Tack welding of the sleeves to the carrier pipe is prohibited. It should be noted that the welding of these longitudinal groove welds results in weld shrinkage of the sleeve or fitting around the carrier pipe. Consideration should be given during fit up to allow for shrinkage of 1/16 in.–3/32 in. across the diameter of the sleeve during welding of the longitudinal groove welds. The use of feeler gages is recommended for this measurement.
5. After tacking the sleeves/fittings, the longitudinal welds are made on both sides (simultaneously if two welders are available). Care should be exercised to assure the longitudinal welds do not fuse to the pipe at the ends of the sleeve. The backing strip assures that the longitudinal welds will not penetrate into the carrier pipe wall, and thus, weaken the pipe in the hoop direction. Refer to the procedure for proper sequence of the weld passes.
6. With the longitudinal welds completed, one end of the sleeve/fitting shall be fillet welded to completion allowing the sleeve/fitting to move or shrink toward the end being welded. Refer to the procedure for proper sequence of the weld passes.
7. When one end has been completely welded, the other end shall be welded to completion. Refer to the procedure for proper sequence of the weld passes.
8. Upon completion of all welding, the longitudinal groove welds and the circumferential fillet welds shall be visually examined and inspected by the Company Inspector. The Company Inspector shall also direct an inspection in accordance with Section 13.

## Arc Burns

Arc burns shall be cut out per Section 7.8.16.

## Inspection Requirements

### Fillet Welds

Inspection of fillet welds shall be conducted using the Liquid Penetrant process in accordance with Section 13. The Magnetic Particle inspection process in Section 12 is an acceptable alternate to the Liquid Penetrant process. Any crack or defect indication that has the appearance of crack-like indications shall be cause for rejection.

### Longitudinal Groove Welds

In addition to visual inspection, the inspection of longitudinal groove welds on full encirclement sleeves/fittings shall be done using the Liquid Penetrant inspection process as referenced for fillet welds. The Magnetic Particle inspection process is an acceptable alternate to the Liquid Penetrant process in Section 13. Any crack or defect that has a crack-like appearance shall be cause for rejection.

During fit up of the sleeves/fittings to the carrier pipe, visual inspection shall be conducted to assure the proper placement of the backing strip behind the groove weld. Welding into the carrier pipe in the longitudinal direction is prohibited.

### NDT Test Time Period

After completion of a maintenance weld it is recommended that a period of time elapse to allow the weld to cool to ambient and/or line temperature prior to conducting any nondestructive test. The longer the time period after completion of welding, the greater the chance of detecting a crack in the weld if one exists. Provided that a Low Hydrogen procedure is used, the pipe can be coated and the excavation can be backfilled immediately following completion of NDT.

## Procedure and Engineering Controls

Owner maintenance personnel shall contact the Owner Control Center and Operations Personnel prior to performing any maintenance work on in-service pipelines. It is recommended a Line Time Request be submitted to Owner's scheduling department in advance of scheduling any maintenance and/or repair work on in-service pipelines that involve no-flow static conditions during maintenance welding. A detailed Work Plan should also be circulated for approval to Owner's Product Scheduling Group, Operations (to include TM and AM), Maintenance Supervisor, IMP Group, Regional Engineering, Corrosion Department, and Control Center. It is critical that all proposed work that is to take place on in-service pipelines be thoroughly communicated to all stakeholders prior to performing such work.

After performing and documenting the Wall Thickness Survey and prior to performing any maintenance welding on an in-service pipeline, ensure the pipeline is packed full with product and the pipeline is not slack. Before beginning maintenance welding, satisfy the requirements set forth in this section. A fire-watch will be required while hot-work is taking place. When all hot-work is completed, and after performing and documenting the appropriate NDT testing requirements, notify appropriate Owner personnel so that pipeline can be returned to service.

# Welder Performance Qualification

This section establishes the requirements for the qualification and certification of welders for construction, fabrication, and pipeline maintenance welding, In-Service welding for pressure piping systems for Owner.

## Standards and Codes

In addition to the requirements of this specification, the codes and standards in Appendix C, latest OPS approved edition shall apply to the qualification of welders.

## Test Location

Welder qualification shall be conducted at locations approved by the Company Inspector.

## Inspector

Welder qualification shall be conducted under the supervision of a Owner approved Inspector. An independent testing agency may be used to provide destructive testing and document the qualification testing of welders.

The Inspector shall assure that all welding is conducted in accordance with the approved welding procedures, standards and codes. This individual shall have been trained in the use of this manual and the applicable codes and standards and shall have previous experience in welder testing programs.

The inspector shall be responsible for assuring all welder qualification records are processed and distributed in accordance with the Company Operating and Maintenance Procedures.

## Qualification Categories

All Company and contract welders working on Owner pressure piping systems shall be qualified in one or more of the categories defined below. Qualification in one of these categories qualifies a welder to weld only in that specific category with the welding process used.

|  |  |
| --- | --- |
| Category | Definition |
| 1 | **Pipeline – Single:** Pipelines governed by and inspected to DOT 195 and API 1104. |
| 2 | **Pipeline – Multiple:** Pipelines and related fabrication governed by and inspected to DOT 195 and API 1104. |
| 3 | **In-Service:** Welding on in-service pipelines in accordance with API 1104 Appendix B  |
| 4 | **ASME Piping:** Piping systems constructed and inspected in accordance with ASME B31.3. |

### Pipeline – Single Qualification

Welders qualifying for a specific pipe diameter may qualify in accordance with Single Qualification, API 1104 and the requirements of this specification.

Welders qualifying under these requirements shall make a complete groove weld on pipe with the axis of the pipe in the horizontal fixed position in accordance with the applicable Owner procedure. The pipe diameter and wall thickness shall be in accordance with the project requirements.

Successful completion of this test in accordance with API 1104 qualifies the welder for the group diameter and wall thickness range which was used for qualification, subject to the essential variables listed in API 1104.

### Pipeline/Fabrication – Multiple Qualification

Welders qualifying under pipeline/fabrication requirements shall make two welds described herein in accordance with API 1104. For welder qualification, the test pipe may be API Grade B, X42 or other available pipe grades. Welders are not qualified to specific material grades.

The first weld shall be a groove weld on pipe with an outside diameter of 123/4 in. and a wall thickness of at least 0.250 in. The test pipe will be placed and welded in the horizontal-fixed position. The weld will be destructively tested in accordance with API 1104.

The second test will be a fillet weld on the same pipe size used for the groove weld test. The welder shall lay out, cut, fit, and weld a full-sized branch-on-pipe connection. A full-sized hole shall be cut in the run pipe. The weld shall be made with the run pipe axis in the horizontal-fixed position and the branch pipe axis shall be extending vertical downward.

Successful completion of both tests in accordance with API 1104 qualifies the welder for all positions, all diameters, all wall thicknesses, joint designs and fittings, subject to the essential variables listed in API 1104.

### In-Service Qualification

All welders working on pressurized piping systems (flowing or static conditions) shall be qualified in accordance with API 1104, Appendix B using an approved Owner welding procedure. Qualification will be done on pipe/sleeve diameters compatible with the needs of each district. The qualification grouping for pipe diameters and wall thicknesses shall be in accordance with API 1104, Appendix B.

To qualify welder for all positions, the test pipe and full encirclement sleeve shall be placed in the 45-degree position as shown in Figure 1, API 1104, Appendix B. The test pipe shall be 123/4 in. outside diameter with a wall thickness of 0.375 in. minimum. Two welders may be used to complete the longitudinal and fillet welds each welding their respective side. The weld test specimens shall be cut as shown in Figure 12, and the type and number shall be in accordance with Table 3 of API 1104, Appendix B. Only low hydrogen welding electrodes will be used for welding on Owner pressurized piping systems in accordance with approved Owner "In-Service" welding procedures.

### ASME Piping

All welders working on ASME B31.3 piping systems shall be qualified in accordance with the requirements of ASME Section IX.

The qualification test will be made using the pipe wall thickness/diameter the welder will be expected to weld in production. The pipe will be in the 6G position using an approved Owner or Contractor welding procedure qualified in accordance with ASME Section IX.

Qualification on pipe diameters of 27/8 in. or over allows the welder to make groove and fillet welds in all positions and on pipe diameters from 27/8 in. and over. The maximum thicknesses qualified will be 2 times the actual wall thickness of the test pipe. There is no minimum wall thickness limit for welder qualification in ASME Section IX. For pipe diameters less than 27/8 in. OD, the welder shall qualify on 2 in. (23/8 in.) OD pipe in accordance with the Owner or Contractor procedure which qualifies the welder for pipe 1 in. OD and over.

## Workmanship

All welder qualification test welds shall demonstrate good workmanship and uniform weld profiles around the entire pipe circumference. Arc burns on the pipe surface are not permitted and are sufficient grounds for terminating the qualification test.

The Company shall have the right to terminate the test at any time if the welder candidate does not possess the skills required to make the quality of weld required by this specification.

Any welder who makes a weld that fails to comply with the requirements of this specification may be disqualified from further work at the discretion of the Owner Inspector.

## Requalification

Company or contract welder requalification for Owner will be required as follows:

For API 1104 Welder Qualification, complete the following:

1. At least once every six months the welder has had a production weld or test weld radiographed and meet Section 6 of API 1104.
2. If the welder has not welded on Owner piping or been qualified/re-qualified within the last 6 months.
3. At the request of the Company Inspector.

For API 1104, Appendix B Welder Qualification, complete the following:

1. Non-destructive testing on a 123/4 in. sleeve (welded using the low hydrogen electrodes) at least every 6 months.
2. If the welder has not welded using a low hydrogen electrode with any Owner In-Service procedures on an in-service pipe within the past 6 months.

Welder Qualification may be maintained by a radiographic examination of a production or test weld every six months.

Requalification for the API 1104 Pipeline – Single Qualification category may be by radiographic examination of a production or test weld or by destructive testing of an actual test weld.

Requalification for the API 1104 Pipeline – Multiple Qualification category shall be by radiographic examination of a production or test weld or by destructive testing of an actual test weld. The requalification weld shall be a groove weld and the branch weld is not required to maintain qualification.

Requalification for the API 1104 Appendix B In-Service Qualification category shall be when the welder has not welded with low hydrogen electrodes (EXX18) using any of the Owner approved In-Service procedures on an in-service piping system for a period of 12 months or more.

Requalification for the ASME Piping category shall be by radiographic examination of a production weld or by destructive testing of an actual test weld.

The acceptance criteria for the test welds will be in accordance the respective standard. Failure to meet those requirements will result in disqualification of the welder for that portion his current qualifications. Retesting may be conducted after evidence of training in the procedure and/or a 30-day period.

# Radiographic Examination of Piping Welds

## Scope

This specification establishes the requirements for performing radiographic inspection of circumferential groove welds on all pipelines and piping systems for Owner. This specification applies to groove welds made during construction and fabrication. This specification does not apply to groove and fillet welds made during "In-Service" welding of full encirclement sleeves or patches.

## Codes and Standards

In addition to complying with the requirements of this specification, the regulations and standards in Appendix C, latest edition, shall apply.

## Radiographic Inspection Personnel

This section prescribes the qualification requirements for individuals who will be engaged in the production and evaluation of radiographs for Owner.

### Personnel Qualification

All regularly assigned radiographic personnel shall meet the requirements as defined in ASNT TC 1A and Nuclear Regulatory Commission (NRC) and/or state regulations applicable to radiation safety.

At least one member of each crew designated as being in charge shall meet the requirements for Level II. Only Level II or Level III personnel will be allowed to interpret radiographs. Records of certification for radiographers and interpreters shall be furnished to Owner prior to production radiography and shall include the following:

* Background and Experience
* Training Course Record
* Technical Examination Record
* Doctor's Report of Radiographer's Jaeger J 1 Acuity Eye Test
* Date of Qualification and Re qualification

The Owner Inspector shall request the above information when the radiographic contractor is contacted for a work assignment. Each radiographer should carry a copy of his qualification with him to the job site.

In addition, film interpreters may be required to pass a Owner qualification program and demonstrate their knowledge and understanding of this specification prior to production film interpretation.

Radiographers may be required to demonstrate their ability to produce acceptable radiographs with each radiographic procedure they use prior to performing production radiographs.

### Training Requirements

Radiographic trainees, Level I, shall be trained by the contractor, prior to assignment, in the use of radiation monitoring equipment. A radiographic trainee shall not actuate radiation-producing equipment in production radiography.

### Certification

Upon successful completion of the requirements of Section 10.3.2, Owner may issue, depending on the project duration, a certification card bearing the following:

* Name
* Signature of Owner Examiner/Reviewer
* Expiration Date
* Identification of Level
* Social Security Number

### Performance Review

The Level II or III radiographer and film interpreter's work will be subject to review by the Owner representative and any pattern of inconsistency will be cause for additional training, testing, or dismissal.

### Radiographic Procedures

This section prescribes the minimum requirements for establishing and qualifying the radiographic procedures to be used for the examination of welds covered by this specification.

All procedures shall be qualified prior to the performance of any radiographic inspection and approval by Owner.

### Level of Quality

The IQI shall consist of either a series of six (6) wires for ASTM E747 wire type or a series of seven (7) wires for ISO wire type IQI, arranged in order of increasing diameter. The essential wire diameter to be used, based on the thickness of the weld is shown in Table 5 for ASTM E 747 wire type IQI and Table 6 for ISO wire type IQI. At the radiographic contractor’s option, smaller wire diameter IQI than those speci-*D* = *St*/*k* fied above may be used, provided the required radiographic sensitivity is obtained. Note: For purposes of IQI selection, the thickness of the weld shall mean nominal wall thickness plus the weld reinforcement (internal plus external combined) The radiographic images of the IQI identifying style number and ASTM set letter or ISO designation shall appear clearly. The image of the essential wire diameter shall appear clearly across the entire area of interest.

##### Gamma Ray

Gamma radiography, when approved, may be performed using an approved Iridium 192 source contained in an exposure device fully approved and in accordance with all applicable federal and state regulations.

#### Film

Only Class I film shall be used for x ray unless approved by the Owner Inspector. Acceptable examples include Kodak DR 50 and M100, Dupont NDT35 and NDT45, Fuji IX25 and IX50 just to name a few,. Class I film shall be used for gamma ray.

#### Intensifying Screens

Lead foil screens shall be used. The minimum thickness front and back shall be 0.005 in. respectively.

#### Film Density

Film shall be exposed so that the H & D density shall not be less than 1.8 or more than 3.0 through the thickest portion of the weld. The recommended average film density is 2.5.

#### Film Quality

Radiographs shall be free of fog, blemishes or artifacts that interfere with their interpretation.

#### Penetrameter

API penetrameter made of radiographically similar material to the weld being inspected shall be used. The thickness and location of the penetrameter shall be in accordance with API 1104. The penetrameter selection shall be based on the thickness of the weld.

#### Shims

The shim thickness shall be based on the average reinforcement (build up) in accordance with API 1104.

#### Geometric Un-sharpness

Radiographic procedures shall be such that geometric un-sharpness as calculated from the formulas in ASTM E94 shall not exceed 0.025 in.

### Qualification Procedures

The radiographic contractor shall qualify each proposed procedure prior to its use for weld examination. A Owner representative shall be allowed to witness the test and determine the acceptance of the procedure. Advance notice must be given to Owner to schedule personnel for witnessing the procedure qualification.

A procedure may be requested to be qualified by making two complete and acceptable radiographs of a weld following the radiographic procedure details of this section. All procedure details, the test results and the approval by the Owner representative shall be recorded on the Radiographic Procedure Qualification Form provided by the Radiographic Contractor and approved by Owner. The radiographer performing the test will be simultaneously qualified with the procedure. One of the two test radiographs and one copy of the record shall be given to the Owner Inspector. The radiographer performing the test shall retain the second radiograph and a copy of the record.

Qualified procedures may be used by other radiographers from the same contractor provided they have a copy of the procedure record and they qualify their ability to produce an acceptable radiograph using the procedure details.

### Essential Variables

A procedure shall be re qualified as a new procedure when any of the following changes are made:

* An increase in radiation source size
* A change in type of radiation source
* A change in intensifying screens
* A change in film class, film manufacturer and film type when the "Relative Film Speed" is increased
* A change in technique
* A change in film processing methods such as manual to automatic

## Production Radiography

This section prescribes the minimum requirements for radiographic inspection of welding during construction.

### Radiographic Inspection Personnel

At least one Level II radiographer shall be assigned to each radiographic unit. The duties and responsibilities of the radiographer shall include, but are not limited to, the following:

* Directing the performance of the radiographic work
* Radiographic quality
* Interpretation of the radiographs
* Determining whether the welds meet the requirements of the "Standard of Acceptability" of this section
* Protection against radiation and exposure monitoring of all persons at or near radiation areas

### Production Radiographs

#### Quality

Radiographs that do not meet the requirements of this section shall be re taken and a separate report shall be made as to the reason(s) for the re take. The radiographic contractor will not be reimbursed for this additional work.

#### Weld Identification

The weld identification numbering system will be established by the radiographic contractor and approved by Owner prior to production radiography.

#### Film Identification Procedure

All film shall be clearly identified using lead numbers and letters and light printers as follows:

Lead numbers and letters (1/4 in. – 3/8 in.) shall be used for weld identification on each film.

Contractor's name, date, unit number, location, etc., shall be flashed on the overlap end of each film using a light printer.

#### Film Number Belt

Unless otherwise approved, a film clock belt shall be a part of production radiography and shall be of sufficient length to cover the entire circumference of the weld. The lead inch numbers shall be in "inch" increments approved by Owner and shall appear on the radiograph adjacent to the weld. The number "0" shall be in line with the "top button" of the weld and an arrow showing the direction of numbering shall be marked on the pipe. The direction of numbering shall be the same throughout the project and will be specified by the radiographic contractor and approved by Owner prior to production radiography.

#### Weld Marking

The radiographic contractor is required to mark the welds for repair or cut out. The specific marking material and designation system will be given to the radiographic contractor by Owner's representative prior to production radiography.

The marking medium shall be such that the marking on the pipe will be identifiable until the location of the welds and final disposition has been recorded.

#### Film Marking

The location(s) of unacceptable defects shall be marked on the film, outside of the weld area, using a black felt tip pen.

#### Film Processing

Film processing may be done by manual or automatic processes. Finished radiographs shall be free of all artifacts that will interfere with film interpretation.

#### Film Packaging

All film of accepted welds and/or repairs shall be carefully prepared and filed in numerical order. Radiographs of unacceptable welds shall be stored with the repair radiographs. Cut out weld film shall be stored separately.

Compartmentalized boxes or envelopes shall be used for filing the film. When boxes are used, each box shall contain a grid sheet identifying the film in each compartment and a copy of the applicable reports. The following information shall be placed on the front edge of the film boxes or on the front of the storage envelope.

|  |
| --- |
| **Owner** |
| Film Container Number |  |
| Date |  |
| X ray Numbers |  | to |  |
| Radiographic Contractor's Name |  |
| Project Description |  |
| Work Order No |  |

### Equipment for Interpretation

The following equipment shall be used for film interpretation on Owner projects:

#### Film Viewers

All film viewers shall be the high intensity type with a variable intensity control. The viewer shall produce a sufficient illumination to view a maximum film density of 3.5. A dimmer control switch shall be a part of the viewer to provide the proper illumination for the range of densities being viewed. The viewer screen shall be free of scratches that could lead to misinterpretation, and masking aids shall be used as necessary to prevent light leakage from interfering with film interpretation.

Radiographic film shall only be viewed in a room with subdued background lighting.

#### Film Densitometers

To assure the specification densities are met, each darkroom shall have a densitometer for checking film density. The densitometer shall be kept in good working condition and a density calibration strip shall be used to calibrate the unit prior to daily use. The densitometer calibration shall be checked periodically when it is being used.

#### Tools for Defect Measurement

The accuracy of measurements of discontinuities is extremely important. The following tools shall be used as necessary for measuring the size of weld discontinuities:

1. Rulers – A clear, thin plastic ruler graduated in 1/16 in. increments shall be used for measuring weld discontinuities.
2. Optical Comparators – If it is necessary to use a comparator, it is recommended that the maximum of 5X be used, and it should have a positive focusing adjustment.
3. Film Markers – When a discontinuity is outside of the acceptance limits, a felt tip pen that does not smudge, smear, or melt, should be used to mark the defective area of the film, along with stating the type of defect being rejected.

### Standard of Acceptability

#### Film Interpretation

The acceptability of a weld is determined according to the standards in Section 9 of API 1104. The radiographic contractor's interpreter is responsible for assuring all radiographs are interpreted in accordance with API 1104 and this section. Discontinuities shall be measured, using the tools discussed herein. In the case of broken or elongated slag lines that appear in the same plane or line, each indication shall be measured, and the total length of all indications shall be used to determine the acceptance of this discontinuity.

If a girth weld is unacceptable under these standards for a reason other than a crack, and if Appendix A of API 1104 applies to the weld, the acceptability of the weld may be determined under that appendix.

### Daily Radiographic Reports

The radiographic contractor shall be responsible for furnishing the Owner representative and construction contractor's representative with a detailed report of each of the previous day's radiography. If no radiographs were made, but were scheduled to be performed, a report shall be made by the radiographic contractor explaining the reason for the absence of radiographic support.

The number of girth welds radiographed per day shall be in accordance with DOT Part 195.234 and Owner inspection. The following guidance shall apply:

1. During construction, at least 10% of the girth welds made by each welder during each welding day must be nondestructively tested over the entire circumference of the weld.
2. All girth welds installed each day in the following locations must be nondestructively tested over their entire circumference (excepting that when nondestructive testing is impracticable for a girth weld, it need not be tested if the number of girth welds for which testing is impracticable does not exceed 10% of the girth welds installed that day):
	1. At any onshore location where a loss of hazardous liquid could reasonably be expected to pollute any stream, river, lake, reservoir, or other body of water, and any offshore area;
	2. Within railroad or public road rights-of-way;
	3. At overhead road crossings and within tunnels;
	4. Within the limits of any incorporated subdivision of a State government;
	5. Within populated areas, including, but not limited to, residential subdivisions, shopping centers, schools, designated commercial areas, industrial facilities, public institutions, and places of public assembly; and
	6. Tie-in welds.
3. Per ASME B31.4, piping operated at less than 20% of SMYS, NDT will be done at the discretion of the welding inspector.
4. When installing used pipe, 100% of the old girth welds must be nondestructively tested.

The daily radiographic report supplied to Owner shall include, but is not limited to, the following:

* Weld ID Number
* Status of Weld (in code/out of code)
* Defect Type
* Location of Defect on Pipe Circumference
* Location of Defect in Reference to cross-section (based on judgment)
* Date of Radiography
* Pipe Diameter/Wall Thickness
* Weld Location
* Number of Welds Radiographed
* Crew Size and Unit No.
* Radiographer's Signature
* Defect Code
* Owner Representative's Signature

The radiographic contractor shall keep a copy of all daily reports for the duration of their assignment to the project.

### Welding Contractor Film Review

The welding contractor shall have the right to review radiographs when accompanied by Owner's representative. Radiographs may be reviewed on the right of way provided it does not interfere with radiographic inspection operations.

### NDT Records

Upon completion of the review of the weld radiographs, and at the discretion of the Owner Representative, the radiographs may be properly discarded. DOT, Part 195, no longer requires the retention of the radiographs.

However, a copy of the daily radiographic report showing the disposition and location of each weld shall be maintained for the life of the pipeline. These radiographic reports shall be delivered to the Owner representative and will ultimately be maintained in the "Project" file.

### Radiographic Contractor Progress Requirements

The radiographic contractor shall perform all work under this section in an orderly and expeditious manner while maintaining the required quality at all times. Reasonable time will be provided for the performance of the girth weld radiography and documentation, but at no time shall unnecessary delays due to equipment, supply, or personnel problems be allowed.

## Radiographic Inspection Equipment

Radiographic inspection units shall be equipped with all equipment and supplies necessary to produce, process, and interpret radiographs at the job site. All equipment shall be maintained in a state of good repair at all times. Sufficient spare equipment shall be readily available to eliminate downtime of radiographic operations. Only equipment approved by Owner shall be used for production radiography.

### Darkroom Facilities

Darkrooms shall, in general, be equipped for use as film processing and film viewing facilities. The radiographic contractor may elect to use separate facilities for each function providing the requirements of this section are met.

In addition to having all film processing capabilities, the darkroom shall meet the minimum following conditions:

1. Darkrooms or viewing facilities shall be large enough to comfortably accommodate at least two people viewing radiographs.
2. Each darkroom or viewing facility shall have at least one film viewer meeting the requirements of Section 10.4.4.1.
3. Each darkroom shall be equipped with a film densitometer (Macbeth Quantalog, X Rite Model 301 or equal) for checking the film density.
4. Each darkroom shall have electric power plants of sufficient size to operate all equipment. Heating and air conditioning is recommended.

# Radiographic Interpretation

The Radiographic Interpretation Guidelines are to be used as a reference guide and for the training of personnel whose duties include the review of radiographic test results. The interpretations discussed in these guidelines are not intended to suggest that all discontinuities and conditions encountered will resemble those that are depicted but are intended to be typical to those which are most often encountered when reviewing radiographs of weldments. The reference radiographs used for illustrations in this guide are from the DuPont NDT Systems Radiographer's Weld Interpretation Reference Booklet.

Only personnel qualified in accordance with the American Society for Nondestructive Testing recommended practice SNT-TC-1A to a level II or level III shall interpret radiographic results for final acceptance.

All radiographs shall be evaluated for acceptance in accordance with the applicable code. Radiographic film quality shall meet that specified in ASME Section V as a minimum.

Revisions shall be added to these guidelines as they are developed and after review and approval by the NDT Level III.

Additional information regarding the procedures in this guide may be found by referencing the publications listed in the reference section of the applicable section.

# Post weld Heat Treatment of Piping Welds

## Scope

This section establishes the post weld heat treatment (stress relieving) requirements for all piping systems for Owner.

## Codes and Standards

In addition to complying with the requirements of this section, the regulations, codes, and standards in Appendix C, latest edition, shall apply.

## Material Requirements

All piping welds on carbon steels which have a carbon content in excess of 0.32% or a carbon equivalent in excess of 0.65% shall be stress relieved as presented herein. In addition, all welds having a throat dimension that exceeds 3/4 in. shall be stress relieved.

At the option of Owner, stress relieving may also be requested for any piping welds which are considered subject to exceptional fabrication or operational stress loads.

## Post weld Heat Treatment

Stress relieving shall be conducted in accordance with the requirements of the ASME Sec VIII as presented herein.

### Methods

It is preferable to stress relieve the entire structure as a unit. When this is not feasible, the piping weld shall be locally stress relieved by heating a circumferential band containing the weld at the center. The width of the band to be stress relieved shall be at least 2 in. greater than the width of the weld.

In the event that a welded branch or attachment requires stress relieving, a circumferential band on the run pipe or header which contains the branch or attachment shall be brought up to the required temperature and held for the specified time. The width of the band shall be at least 2 in. greater than the diameter of the branch or attachment to the run pipe or header.

### Equipment

Stress relieving in the field may be accomplished by electric induction or electric resistance heaters.

All stress relieving shall be monitored by thermocouples suitably fastened to the pipe and connected to a strip chart recorder for providing a permanent record of the entire stress relieving cycle.

The number of thermocouples and the specific recorder type shall be approved by Owner prior to each stress relieving application.

## Inspection

Piping welds subjected to stress relieving shall be inspected by the same original method after the stress relieving operation has been completed. The inspection shall be conducted in accordance with the Owner specifications for radiography, magnetic particle, or liquid penetrant inspection as referenced in Sections 11, 14, and 15 and as requested by Owner.

If possible, the inspection should be done 24 hours after the stress relieving has been completed to determine the presence of delayed weld cracking.

Any additional welding on a stress relieved piping weld requires the approval of the Owner Inspector.

## Reports and Records

All reports and records of each post weld heat treatment shall be completed as directed by Owner.

The temperature chart and copy of the procedure should be attached to the radiographer's daily report. Stress relieved welds shall be noted on as built drawings.

# Magnetic Particle Inspection of Welds

## Scope

This section defines the requirements for performing magnetic particle testing (MPT) of pipe groove and fillet welds for detection of cracks and other discontinuities open to the surface using the dry powder method.

Magnetic particle examination may be used for the inspection of welds on new construction, as well as during maintenance activity. Magnetic particle inspection locates weld discontinuities that extend through the weld surface only.

## Codes and Standards

In addition to complying with the requirements of this section, the latest editions of the standard and recommended practices in Appendix C shall apply.

## Inspection Personnel

All personnel performing and interpreting the results of the magnetic particle examination shall be qualified in accordance with the ASNT TC-1A, Level II (MPT).

## Equipment

### Yoke Method

A portable DC magnetic yoke capable of a lifting force of 40 lbs at a 6 in. spacing shall be used.

### Prod Method

A calibrated direct or rectified magnetizing current machine with open circuit voltage of 25 volts or less shall be used. The machine shall be equipped with an amp meter and a remote control current switch.

The prods shall have braided copper tips and shall be kept clean and dressed to minimize electrical arcing.

### General

Commercial grade, dry magnetic particle powder shall be used, red or gray in color, whichever provides the maximum contrast with the surface being examined.

A bulb type dry powder dispenser shall be used which permits the magnetic powder to be lightly dusted on the weld and adjacent areas.

A squeeze air bulb shall be used which permits removal of excess magnetic particles without affecting the relevant magnetic particle indications (approximately 1.5 psi).

## Inspection Procedure

The area to be examined shall be clean and free of slag, scale, rust, water, and other materials that could affect the results of the examination. The inspection of groove and fillet welds shall be conducted in the following manner:

### Yoke Method

1. The poles of the magnetic yoke shall be adjusted such that good contact is made with the surface to be examined and the distance between poles does not exceed 6 in.
2. When the area to be examined is 4 in. or less, the yoke shall be placed on the part being examined as shown in Figure 3.

Figure : Example of Yoke Being Placed on Part Being Examined

Pole

Maximum

 6"

1"

1"

1. Apply the magnetic powder by lightly dusting the area between the poles.
2. The squeeze air bulb shall be used to lightly remove the excess powder. Particular attention must be given to not remove any magnetic particle indications that have been formed.
3. Remove the yoke and evaluate the magnetic particle indications.
4. Clean the surface with a paper towel or dry rag and repeat the examination with the yoke pole positions as shown in Figure 4. Repeat Steps 3, 4, and 5.

Figure : Example of Examination with the Yoke Pole Positions

Pole

Pole

MAXIMUM

 6"

1. When the area to be examined is greater than 4 in., Figure 3 and Figure 4 and Steps 3, 4, and 5 shall be repeated with the overlapping of pole positions as shown in Figure 5 for each 4 in. of the area examined.

Figure : Example of Overlapping of Pole Positions

Area #1

Area #2

1

2

3

4

2

1

4

3

Position

Position

**Note:** Dashed lines depict overlapping position of probes to assure complete weld coverage.

### Prod Method

1. The prod spacing shall be a maximum of 8 in. and a minimum of 3 in. They shall be placed on and removed from the part being examined with the current turned off. The examination shall be conducted with sufficient overlap to assure 100% coverage.
2. A minimum of 100 and a maximum of 125 amps/in. of prod spacing shall be used for thicknesses 3/4 in. or greater. For thicknesses less than 3/4 in., 90 to 110 amps/in. of prod spacing shall be used.
3. With the current turned on, the magnetic powder shall be lightly applied over the surface to be examined. The excess powder shall be removed by the use of an air bulb.

## Standard of Acceptability

All relevant indications shall be evaluated in accordance with API 1104, API 1104, Appendix B, whichever is applicable, except that cracks of any length are unacceptable.

The acceptability of a weld is determined according to the standards in Section 9 of API 1104. However, if a girth weld is unacceptable under those standards for a reason other than a crack, and if Appendix A to API 1104 applies to the weld, the acceptability of the weld may be determined under that appendix.

## Reports

A report shall be completed for each weld examined showing any indications detected. When appropriate for documentation purposes, photographs of the defect indication may be attached to the report by any suitable means.

# Liquid Penetrant Inspection of Welds

## Scope

This section covers the recommended practices for the Visible, Solvent Removable, Penetrant Testing method, hereafter referred to as Liquid Penetrant Testing (LPT). This nondestructive testing method may be used on pipeline groove and fillet welds during new construction, as well as on welds made on in-service pipelines. This method of inspection is used to detect discontinuities that extend through the weld surface only.

## Codes and Standards

The latest editions of the standards and recommended practice in Appendix C shall apply.

## Inspection Personnel

All personnel conducting liquid penetrant testing shall be qualified in accordance with the requirements of ASNT TC 1A, Level II for Penetrant Testing.

## Method Description

This section pertains to the use and application of LPT by aerosol spray cans.

The visual penetrant (bright red in color) is applied to the surface to be inspected from the aerosol can. This very fluid penetrant is pulled, by capillary attraction, into any openings in the surface being inspected.

After the proper dwell time or soak time, the penetrant is removed by wiping with a clean rag or paper towels sprayed with penetrant cleaner. Next, the developer (white in color) is applied from an aerosol spray can. The developer functions as a blotter to absorb the penetrant and provides a contrasting background to enhance the visibility of any indications.

## Inspection Procedures

The following requirements shall apply to visible penetrant inspection:

### Temperature

The penetrant materials and the surface to be inspected shall be between 60 and 125°F. In the event this is not feasible, the inspection procedure should be qualified at the temperature of intended use.

### Surface Preparation

In general, satisfactory results may be obtained when the surface to be inspected is in the as-welded condition. If necessary, grinding is permitted to eliminate surface irregularities that could mask indications of unacceptable discontinuities.

### Surface Condition

The weld surface and surrounding area up to 1 in. from the edges of the weld shall be completely free of any contaminant (oil, dirt, rust, scale, slag, etc.) that might interfere with the penetrant process. The weld and adjacent surfaces shall be completely dry prior to the application of the penetrant.

### Penetrant Application

With the pipe and penetrant temperature between 60 and 125°F and the surface cleaned, the penetrant shall be applied to the area to be inspected using aerosol spray cans. When complete coverage of the area has been completed, allow a penetrant dwell (soak) time of 7 minutes minimum to 15 minutes maximum. The penetrant shall not be allowed to dry. If necessary to prevent drying of the penetrant, re-spray the area to keep the penetrant wet during the dwell time.

### Penetrant Removal

After the desired dwell (soak) time has elapsed, the penetrant shall be removed using a clean rag sprayed with penetrant solvent. It is important to remove all excess penetrant from the surface by wiping with a clean rag or paper towels. Do not spray the solvent directly onto the area to be inspected as it may wash the penetrant from the defect or discontinuity.

### Developer Application

Once all visible penetrant has been removed, and the weld surface is dry (by normal evaporation), the developer shall be sprayed directly on the weld and adjacent area. The area shall be completely sprayed with a uniform coating of developer. The developer shall remain on the area for a minimum time of 7 minutes prior to inspection.

### Inspection

With proper illumination, inspect the developer for bleed out of penetrant from discontinuities. Constant inspection during the application of the developer will provide some assistance in evaluating relevant and non-relevant indications.

In the event of uncertainty regarding a particular indication, the entire procedure may be repeated after the area has been thoroughly cleaned with solvent.

Relevant indications are those that result from an opening to the surface such as cracks, lack of fusion, porosity, etc.

### Acceptance Criteria

Unless otherwise stated, the standard of acceptability shall be in accordance with the latest edition of API 1104, API 1104, Appendix B, or whichever is applicable, except that cracks of any length are not allowed.

The acceptability of a weld is determined according to the standards in Section 9 of API 1104. However, if a girth weld is unacceptable under those standards for a reason other than a crack, and if Appendix A to API 1104 applies to the weld, the acceptability of the weld may be determined under that appendix.

## Inspection Equipment

Liquid penetrant testing (LPT) may be conducted using commercially available testing kits marketed under various trade names. These kits include solvent cleaner, visible penetrant and developer spray cans.

## Reports

A report shall be completed for each weld examined showing any indications detected. When appropriate for documentation purposes, photographs of the defect indication may be attached to the report by any suitable means.

# Ultrasonic Wall Thickness Examination

## Scope

This section defines the minimum requirements for determining pipe or plate thickness using an ultrasonic thickness gauge for Owner.

## Equipment and Materials

A digital thickness gauge shall be used when performing material thickness measurements.

## Personnel

Personnel operating the thickness gauge shall be thoroughly familiar with its operation, application, and calibration.

Personnel assigned to use the instrument shall demonstrate their proficiency in its use to the authorized Owner representative.

## Calibration

Calibration of the digital instrument shall be performed according to the manufacturer's instructions.

Calibration of the instrument shall be confirmed on the same material and product form as the material to be measured. For calibration confirmation, each instrument shall be supplied with a calibration step block machined with steps as follows:

* 0.125 in.
* 0.188 in.
* 0.250 in.
* 0.500 in.

The instrument calibration shall be re checked approximately midway through the inspection. If the instrument is not in calibration, the previous thickness check shall be retaken.

The operator shall be alert to the need of using consistent transducer pressure, couplant type, and amount of couplant.

## Equipment Certification

All equipment shall be certified at the specified frequency according to the manufacture's recommendation.

## Technique

Excess dirt, loose scale, or other foreign material that could prevent accurate thickness measurement shall be removed from the surface to be examined.

The area to be examined shall be prepared to such an extent that a good contact between the transducer and the surface is obtained. The transducer contact face must be held parallel to the inside diameter surface.

The complete area shall be scanned and the minimum and maximum thickness readings shall be recorded.

## Final Cleaning

After the readings have been recorded and calibration of the instrument has been re checked, the couplant shall be removed from the examination surface.

## Records

When documentation of the examination results is required by Owner, the following information shall be recorded on a Company form similar to the form included in this section.

* Instrument Model and Serial Number
* Transducer Frequency
* Calibration Standard
* Couplant
* Date of Examination
* Name of Individual Performing the Examination
* Result of the Examination (minimum and maximum thickness obtained)

|  |
| --- |
| Wall Thickness Tolerances |
| Outside Diameter (OD) in. | Type of Pipe | Tolerance, Percent |
| Grade B or Lower | Grade X42 or Higher |
| ≤ 27/8 in. | All | +20.0, −12.5 | +15.0, −12.5 |
| > 27/8 in. and < 20 in. | All | +15.0, −12.5 | +15.0, −12.5 |
| ≥ 20 in. | Welded | +17.5, −12.5 | +19.5, −8.0 |
| ≥ 20 in. | Seamless | +15.0, −12.5 | +17.5, −10.0 |

# Visual Inspection of Pipeline Welding and Welded Systems

## Scope

This section establishes the visual inspection requirements for pipeline welding and welded systems for Owner.

## Codes and Standards

In addition to complying with the requirements of this section, the regulations, codes, and standards in Appendix C, latest OPS approved edition, shall apply as applicable.

## Inspection Requirements

Prior to conducting welding inspection on pipelines or piping systems, the Inspector must have the knowledge of, and be familiar with, the codes, standards and Owner specifications that govern the construction activity to be inspected.

The Inspector must have the applicable codes and Owner specifications in his possession for immediate reference on the job site. In addition, the Inspector must have the appropriate inspection equipment on hand for determining compliance to the welding procedures and construction specifications. A suggested listing of inspection equipment is presented in Section 15.5.

When the Inspector is familiar with the applicable construction specifications and is properly equipped, the following paragraphs represent primary areas that must be inspected and documented in accordance with Owner standard construction practices.

### Welder and Procedure Qualification

The Inspector is required to check the certification records for each welder working on Owner construction projects to assure that proper and current qualification data is on file for the pipe diameters and wall thicknesses being welded.

The Inspector must examine welding procedure qualification records. The Inspector is required to assure that the records of the procedure test results are complete and accurate. Any questions about the validity of Owner or contractor procedures for a particular application should be brought to the immediate attention of the Manager of Maintenance Support.

### Pipe/Component Surface Condition

The Inspector shall examine the surface of all pipe and components for defects that could affect their serviceability. Any gouge, groove, dent or other defect that exceeds the allowable depth in accordance with the applicable material standard must be either removed by grinding or the entire section replaced as a cylinder. Grinding to eliminate gouges or grooves must be followed by wall thickness measurements to assure adequate wall thickness of the pipe or component remains.

### Alignment and Fit Up

In regards to pipe and component fit up, the Inspector should periodically assure that the alignment and root space are in accordance with the Owner approved welding procedure.

The Inspector must assure the weld joint is clean and free of all foreign material such as dirt, oil, coating material, etc. The end bevels should be inspected for manufacturing defects such as laminations, improper bevel angle and an improperly machined root face. Handling defects such as dents and root face damage are also a part of the Inspector's responsibility.

The process and method of aligning the pipe and components must be done in a manner that does not result in abnormal residual stress on the completed weld.

For fillet welds, the Inspector should consider the weld shrinkage that occurs and require that the components to be joined are properly spaced prior to welding.

### Pipe Groove Welds

#### Root Pass

When preheating is required by the welding procedure, the preheat temperatures shall be measured by "tempil stiks" or other approved methods. Preheating temperatures shall be maintained during the completion of the root pass.

The Inspector shall check the general condition of the root pass electrodes and determine that the proper AWS classification and diameter are being used. The Inspector should examine the welding cable connections at the machine to determine that the correct polarity is being used.

During root pass welding, the amperage, voltage and travel speed should be measured periodically to determine compliance with the approved welding procedure.

The Inspector should recognize that root pass travel speed and amperage are closely related. Finding an excessive root pass travel speed usually indicates excessive amperage is being used and vice versa. The results of either of these being outside of the limits of the welding procedure parameters increases the potential for a thinner than desired root bead possibly leading to root bead cracking.

#### Hot Pass

The Inspector should review the condition of the hot pass electrodes and determine that the proper AWS classification and diameter are being used.

Of major importance to the Inspector is to assure that the time period between the root pass and the hot pass (specified in the approved welding procedure) is not exceeded.

Periodic amperage and voltage measurements are appropriate during the deposition of the hot pass.

The Inspector should require that the completed hot pass is cleaned of all slag by power brushing.

#### Fill Passes

An inspection of the fill pass electrodes by the Inspector should be made to determine their condition, AWS classification and diameter.

The Inspector should confirm that the welding procedure is being followed in terms of the number of fill passes for the respective wall thickness.

Amperage and voltage should be periodically measured to determine compliance with the Owner approved welding procedure. When checking voltage at the terminals of the welding machine, the Inspector should allow for a 2–3 Volt drop at the arc depending on the length of the welding cable.

During fill pass welding, the Inspector should periodically assure that interpass cleaning is sufficient to eliminate slag entrapment between passes.

#### Cap Pass

The Inspector should inspect the cap pass electrodes to determine their condition and AWS classification and diameter.

Measurement of amperage, voltage and travel speed on a periodic basis is appropriate to determine compliance to the Owner approved welding procedure.

The Inspector should assure that the cap pass is properly cleaned including the edges of the cap pass so that a complete and thorough inspection can be performed.

The visual acceptance criteria for the finished weld, unless otherwise stated, shall be as follows:

1. Cap pass must not be below the outside surface of the pipe nor should it be raised above the pipe surface by more than one sixteenth of 1 in.
2. Cap passes which are raised above the parent metal by more than one sixteenth of an inch and which, in the opinion of the Inspector, may be suspect in terms of the reasons for the excessive reinforcement, may be ground down to one sixteenth of an inch above the pipe surface.
3. Undercut that has a depth greater than 1/64 in. regardless of length, must be repaired by welding.
4. Final cap pass width should not be over 1/8 in. wider than the width of the original groove.
5. Visible pinholes or porosity are not allowed and must be repaired by welding. Steel punches or peening are not permitted.
6. Cracks of any length are not allowed and must be cut out as a cylinder of pipe.
7. Arc burns on the weld or on the pipe are not allowed. (Refer to the Arc Burn Removal Procedure in Section 18).

### Pipe Fillet Welds

The Inspector shall inspect all fillet welds to assure compliance with the Owner approved welding procedure.

All fillet welds shall have a minimum of two weld passes. The purpose of this requirement is to eliminate any potential leak path.

Unless otherwise specified, the Inspector shall inspect fillet welds using the acceptance criteria listed below.

1. The fillet weld leg size shall be in conformance with the approved procedure.
2. Pinholes or porosity are not allowed.
3. Undercut greater than 1/64 in. deep is not allowed regardless of length.
4. Cracks of any length are not allowed.

## Records/Reports

Visual inspection records and reports will be developed by Owner as appropriate for compliance with this section on an individual project basis.

## Inspection Equipment

Visual inspection of pipe welding involves the use of certain instruments and inspection tools for the measurement of welding parameters and material defects.

A list of equipment that should be available to the Inspector is presented below:

* Amperage meter (digital or analog).
* Voltmeter for voltage measurement.
* Six-inch dial or digital caliper for accurate measurement of root face, pipe wall thickness at the ends, tensile specimens, etc.
* Pit measurement gage or dial indicator depth gage.
* Tempil Stiks (150, 200, 250, 300, 350, 400, and 450°F) or other acceptable temperature determining device.
* Six-foot tape measure for measuring weld deposit lengths.
* Stopwatch or watch with second hand for measuring weld travel speed.
* Ultrasonic thickness gauge for measuring wall thicknesses, such as after a gouge or arc burn is removed or before welding on in-service lines.
* "Pi" or Diameter tape for measuring pipe circumference.
* A gaussmeter with a probe for measuring the longitudinal magnetic field on pipe ends (or in the joint space) should be available in the event the pipe may have been inspected by electromagnetic methods, lifted by electromagnets or if an in-service line was previously inspected by a smart pig. Knowing whether or not the pipe is magnetized can help explain and deal with potential welding problems.
* Q-tips or cotton balls and a 20% solution of ammonium persulfate for use in determining the existence and removal of arc burns.

The above recommended equipment list provides the visual inspector with the equipment necessary to assure all welding activity is in compliance with the referenced codes and standards and Owner specifications and procedures.

# Arc Burn Removal Procedure

## Background

Technically, an arc burn or arc strike is the result of momentarily touching the electrode holder or ground clamp to the pipe surface. These arc burns are usually of short duration and the depth of heating is superficial; however, the area will contain a much harder metallurgical structure called "martensite" from which small cracks may initiate. In addition to the hard structure and rapid cooling, the thin, fused area of the arc burn is not properly protected from the atmosphere since the gas generated ingredients and slag formers in the electrode covering have not been heated and brought into use. For these reasons arc burns shall be cut out, or at the Inspector's option, removed from the pipe by another approved method.

The contractor or welder must notify the Inspector of any arc burns that have been made on the pipe. Failure to notify the Inspector of any arc burns shall be adequate cause to terminate the welder's qualification.

## Removal Sequence

Arc Burns shall be removed as follows:

1. Determine the minimum wall thickness required for the pipe containing an arc burn. Refer to API 5L, Table 9, presented herein for wall thickness tolerances. Measure the existing wall thickness surrounding the arc burn. Compare the existing wall thickness with the minimum required wall thickness. If there is adequate thickness remaining, grinding of the arc burn area may be performed.
2. Remove all evidence of the arc burn by grinding and/or filing.
3. Upon removal of all evidence, swab the ground area using a cotton swab or cotton ball with a 20% solution of ammonium persulfate (20% ammonium persulfate crystals and 80% water). If a blackened spot appears, the metallurgical notch (arc burn) has not been completely removed and additional grinding/filing should be performed and the application of ammonium persulfate repeated.
4. When the arc burn has been removed, measure the area using an ultrasonic thickness gauge or caliper to determine the remaining thickness of the pipe wall.
5. If the resulting wall thickness is less than required, the portion of the pipe that contained the arc burn should be removed as a cylinder. If the remaining wall thickness is equal to or greater than required, the arc burn has been successfully removed.

|  |
| --- |
| Wall Thickness Tolerances |
| Outside Diameter (OD)-in. | Type of Pipe | Tolerance, Percent |
| Grade B or Lower | Grade X42 or Higher |
| ≤ 27/8 in. | All | +20.0, −12.5 | +15.0, −12.5 |
| > 27/8 in. and < 20 in. | All | +15.0, −12.5 | +15.0, −12.5 |
| ≥ 20 in. | Welded | +17.5, −12.5 | +19.5, −8.0 |
| ≥ 20 in. | Seamless | +15.0, −12.5 | +17.5, −10.0 |

**Example Only:** Arc Burn on 5L X426-5/8 in. O.D. Pipe – 3/8 in. W.T.

1. The allowable wall thickness tolerance for Grade X42 pipe, > 27/8 in. and < 20 in. O.D. is +15.0% and −12.5%.
2. Based on this requirement, to completely remove the arc burn in this example, the maximum material thickness that can be removed is calculated as follows:

3/8 in. wall thickness = 0.375 in.

12.5% of 0.375 in. = 0.046 in.

1. Therefore, the maximum material thickness which can be removed = 0.046 in.
2. Which means that the minimum wall thickness as determined by a calibrated ultrasonic thickness gauge is the following:

|  |  |
| --- | --- |
|  | 0.375 in. |
| −  | 0.046 in. |
|  | 0.329 in. |

# Safety Procedures for Welding Operations

## General Considerations

1. All personnel working on pipeline repairs should be trained, qualified (OQ), and advised to understand the need for careful planning of the job. They should be briefed as to the procedure to be followed in accomplishing the repair. Any non-qualified personnel working on pipeline repairs will be required to work under the direct supervision of a qualified individual for the tasks being performed (See Operator Qualification Program).
2. Affected personnel should take action to insure the line is ready and safe for repair, including proper arrangements to control commodity flow and if necessary, shut down cathodic protection rectifiers in the immediate area.
3. Before moving to the job site, tools and equipment should be checked, including personal protective equipment (PPE), to make certain that they are adequate and in good condition.
4. Working personnel or equipment should not be permitted in the area of a leak or break until trained personnel have defined the contaminated area.
5. If a commodity at the repair site is known to be toxic, or has created an oxygen deficiency area, personnel shall be restricted from the area until the oxygen deficiency no longer presents a problem or appropriate PPE for the hazardous environment is donned and backup support and equipment are present.
6. When the situation warrants, warning signs may be used and placed in the immediate vicinity of the leak and caution signs may be used in outlying areas as the situation warrants.
7. Surface terrain, direction and velocity of prevailing winds, and proximity to possible sources of ignition should be observed and the necessary precautions taken.
8. Spectators should not be permitted within the defined work area at any time. They should be kept back at a reasonable safe distance.
9. Matches, lighters and smoking material should be placed in a designated safe area. If smoking is permitted, it will only be done at a safe location (See Section 4 of the Operating Procedures Manual).
10. Appropriate air monitoring, which may include analysis for H2S, O2, CO2, NH3, or flammable gas, should be used to determine if there are any hazards in the area.
11. The hazards of fire and explosion should be recognized throughout the repair work. Fire extinguishers should be available and ready for use while the work is in progress.
12. When welding, secure the ground lead to the pipe being welded by any means other than welding it to the pipe.

## Special Precautions

### Authorization

Before cutting or welding is permitted, the area shall be inspected by the Owner Representative responsible for authorizing such operations. He shall designate precautions to be followed in granting authorization to proceed in the form of a "Hot Work" permit when necessary.

### Prohibited Areas

Cutting or welding shall not be permitted in the following situations:

* In areas not authorized by the Owner Representative.
* In buildings with sprinklers while such protection is impaired.
* In areas near the storage of large quantities of exposed, readily ignitable materials.
* In areas monitored by fire detection systems, until such time that the detection system has been appropriately disabled and alternate means of fire protection have been provided.

Cutting or welding shall be permitted only in areas that are or have been made flammable vapor free, i.e., below 20% of the lower explosive limit (LEL), and fire safe. When work cannot be moved practically, as in some construction or repair work, the area shall be made safe by removing combustibles or protecting combustibles from ignition sources.

### Fire Watch

A fire guard shall be required whenever welding is performed in locations where combustibles exist that might be ignited by sparks from the welding operation, or any of the following conditions exist:

* Combustible material, which is less than 35 ft to the point of operation.
* Appreciable combustibles that are more than 35 ft away but are easily ignited by sparks.
* Wall or floor openings within a 35 ft radius which expose combustible material in adjacent areas including concealed spaces in walls or floors.
* Combustible materials adjacent to the opposite side of metal partitions, walls, ceilings, or roofs, and are likely to be ignited by conduction or radiation.

The fire watch shall have the proper fire extinguishing equipment readily available and shall be trained in its use. They shall be familiar with facilities for sounding an alarm in the event of a fire.

They shall watch for fires in all exposed areas, try to extinguish them only when obviously within the capacity of the equipment available, or otherwise sound the alarm.

A fire watch shall be maintained until such time that the area has been completely inspected to preclude the possibility of smoldering fires.

### Relocation of Combustibles

Where practicable, all combustibles shall be relocated at least 35 ft from the work site. Where relocation is impracticable, combustibles shall be protected with flame proofed covers or otherwise shielded with metal guards or curtains.

### Supervision

Supervisors shall recognize their responsibility for the safe usage of cutting and welding equipment and:

1. Based on fire potentials of the facility, establish areas for routine cutting and welding, and establish additional procedures, if needed, for cutting and welding, in other areas.
2. May designate a qualified individual to be responsible for authorizing cutting and welding operations in areas not specifically designated for such processes.
3. Insist that cutters or welders are suitably trained in the safe operation of their equipment and the safe use of the process.
4. Advise all contractors about flammable materials or hazardous conditions of which they may not be aware.
5. Determine whether the work will be conducted in a confined space in accordance with Company procedures.

### Contractor's Responsibility

The Contractor:

1. Shall be responsible for the safe handling of the cutting or welding equipment and the safe application of the cutting or welding process.
2. Shall determine the flammable and combustible materials and hazardous areas present, or likely to be present, in the work location, to include the use of a portable gas detector if appropriate.
3. Shall protect flammable and combustible materials from ignition by the following:
	1. Have the work moved to a location free from dangerous materials.
	2. If the work cannot be moved, have the material moved a safe distance from the work or have the materials properly shielded against ignition.
	3. See that cutting and welding are scheduled so that operations that might expose flammable and combustible materials to ignition are not started during cutting or welding.
4. Shall secure authorization such as a "Hot Work" permit for the cutting or welding operations from appropriate supervision.
5. Shall determine that conditions are safe, before beginning welding operation.
6. Shall determine that fire protection and extinguishing equipment are properly located at the site, before beginning welding operation.
7. Shall see that fire watches, where they are required, are available at the site before beginning the welding operation.

## Welding or Cutting on Containers

### Used Portable Containers

No welding, cutting, or other hot work shall be performed on used drums, barrels, portable tanks or other containers unless specifically approved by Owner Maintenance Support and their Safety Representatives.

### Venting and Purging

Prior to cutting or welding, all hollow spaces, cavities, or containers shall be vented to permit the escape of air or gases. Purging the container with inert gas is recommended. Testing shall be conducted to assure the oxygen content is safe for welding.

## Protection of Personnel

### Railings

Anyone working on platforms, scaffolds, or runways more than 4 ft above ground, shall be protected against falling. This may be accomplished by the use of railings, body harnesses, or some other equally effective safeguards. The area below such work area shall be considered a hard hat area.

### Welding Cable

Welders shall place welding cable and other equipment so that it is clear of passageways, ladders, and stairways.

### Eye Protection

1. Welding helmets (hoods) shall be used during all arc welding operations. Helpers or attendants shall be provided with proper eye protection. Safety glasses should be worn under a welding hood or face shield.
2. Goggles or other suitable eye protection shall be used during all gas welding or oxygen cutting operations.
3. Helmets and hand shields shall be designed and positioned to protect the face, neck, and ears from direct radiant energy from the arc.
4. Welding helmets shall be used with filter plates and cover plates designed for easy removal.
5. The following is a guide for the selection of the proper shade numbers. These recommendations may be varied to suit the individual's needs.

| Welding Operation | Shade No. |
| --- | --- |
| Shielded Metal Arc Welding | 9–10 |
| Flux Core Arc Welding | 9–10 |
| Submerged Arc Welding | Shaded glasses (3–4) to guard against occasional arc flash |

All filter lenses and plates shall meet the test for transmission of radiant energy prescribed in ANSI/International Safety Equipment Association (ISEA) Z87.1.

### Protective Clothing

#### General Requirements

Employees exposed to the hazards created by welding, cutting, or brazing operations shall be protected by personal protective equipment. Appropriate protective clothing required for any welding operation will vary with the size, nature, and location of the work to be performed.

#### Selection

Clothing should provide sufficient coverage, and be made of suitable materials to prevent skin burns caused by sparks, spatter, or radiation.

Synthetic or plastic materials that can melt and cause severe burns are not recommended for use as clothing near arcs.

All outside clothing such as jumpers or overalls should be reasonably free from oil or grease.

Sparks may lodge in rolled up sleeves, pockets on clothing, or cuffs of overalls or trousers. It is therefore recommended that sleeves and collars be kept buttoned and pockets be eliminated from the front of clothing. When pockets are present, they should be emptied of flammable or readily combustible materials. Trousers or overalls should not have cuffs and should not be turned up on the outside.

#### Gloves

All welders and cutters shall wear protective flame resistant gloves. Gloves made of leather or other suitable material are recommended.

#### Capes and Sleeves

Cape sleeves or shoulder covers with bibs made of leather or other flame resistant material should be worn during overhead welding or cutting operations.

#### Grinding and Buffing

Face shields with safety glasses shall be worn during all grinding and buffing operations.

### Noise Control

The most direct way to control excessive noise is to reduce the intensity at the source. When control methods fail to bring noise exposure within allowable limits, personal protective devices such as earmuffs or earplugs shall be employed.

### Welding Screens and Booths

When welding is required in or around populated areas, welding screens/or booths shall be put in place to avoid the possibility of "arc burn" or other injury to the general public or fellow employees.

To minimize ventilation restriction, it is desirable to have the screens or booths mounted such that they are approximately 2 ft above the ground floor.

Screens must be secured to avoid being knocked over or displaced by windy conditions.

## Ventilation

### Adequate Ventilation

Adequate ventilation (natural or mechanical) must be provided for all welding, cutting, brazing, and related operations. Adequate ventilation means enough ventilation such that personnel exposures to hazardous concentrations of airborne contaminants are maintained below allowable levels.

### Natural Ventilation

Natural ventilation is acceptable for welding, cutting, and related processes where the necessary precautions are taken to keep the welder's breathing zone away from the clearly visible column of fume which rises directly from the spot of welding or cutting, and all of the following conditions are met:

1. Space of more than 10,000 cu ft per welder in an enclosed area (i.e., a building).
2. Ceiling height is more than 16 ft.
3. Welding is not done in confined space such as tanks, etc.
4. Welding space does not contain partitions, balconies, or other structural barriers that significantly obstruct cross ventilation.

### Mechanical Ventilation

Owner Maintenance Support and their Safety Representatives should be contacted when a question arises regarding the need for mechanical ventilation requirements.

Mechanical ventilation includes local exhaust, local forced air, or general area mechanical air movement.

Local exhaust ventilation is preferred, but precautions shall be taken to insure that excessive levels of contaminants are not dispersed to other work areas.

## Equipment

### Gas Bottles

Oxygen and acetylene cylinders shall be transported and handled with extreme care to avoid damage to the cylinders. Valve protection caps should be kept on the cylinders at all times when they are in transit and in storage.

Acetylene cylinders shall only be transported and used in the vertical (upright) position. This will assure that the liquid acetone within the cylinder will not get into the regulator and/or hose and create a potential for a fire or explosion.

All gas bottles shall be secured by chains or other adequate supports when being used to prevent them from being pulled or knocked over.

### Regulators

All regulators shall be turned off when not in use and the gas bottle valves (oxygen and acetylene) shall be turned off. Regulator pressure shall be relieved by opening the torch valves after the bottle valves are closed.

### Hoses

Oxygen and acetylene hoses shall be maintained in good condition and all fittings shall be checked for tightness. Oxygen hoses shall be green in color and acetylene hoses shall be red. Any question about the condition of the hose shall be cause for replacement.

In no case shall any oil or grease be used on any hose fittings or regulators.

### Welding Machines and Cables

All welding machines shall be operated in accordance with the manufacturer's safety practices. Ground connections and welding cables shall be of the proper size for the amperage to be used for welding. Damaged cables, worn spots, and loose cable connectors shall be repaired or replaced. Any connector or welding cable that is "more than warm to the hand during welding" is an indication of excessive resistance and the problem should be corrected.

### Electrode Holders

Electrode holders shall be designed for the amperage rating to be used for the specific procedure. Holders that are completely insulated are preferred for all Owner welding. The Owner Inspector may require the use of insulated holders for specific applications.

# Tank Welding

## Welding Requirements for Storage Tanks

All welding on storage tanks shall be in accordance with API 653 (latest DOT-approved editions and this section.

All welding shall be performed by welders with approved qualifications as described in Section 18.3.

All welding shall be performed in accordance with the appropriate the Company procedure or a contractor's procedure approved by the Company.

Welding equipment shall be maintained in good working order to ensure consistent weld quality. Welding equipment shall be of adequate amperage/voltage rating to sustain welding for a full day. Damaged weld leads should be replaced or repaired. Copper deposits from bare weld leads should be ground out and welded.

All welding electrodes shall be kept dry and not allowed to freeze. Low hydrogen electrodes (EXX18) shall be kept in electric ovens according to the manufacturer's recommendations. Low hydrogen electrodes should not be atmosphere more than 2 hours before use. Should this occur, the electrodes must be disposed of or dried according to the manufacturer's instructions.

Welds shall be made on clean, dry surfaces only. Wet or damp surfaces are not acceptable for welding. All dirt, oil, rust, etc. should be removed before welding.

Welds should not be made if the steel temperature is below 50ºF without preheating. If the steel temperature is below 50ºF, it should be preheated to remove moisture. If the steel thickness is greater than or equal to 0.50 in., the steel should be preheated to a minimum temperature of 150ºF.

For a given welder, excessive arc burns shall be just cause for disqualification.

## Welding Inspection of Storage Tanks

All welding on Company storage tanks shall be inspected to the requirements of API 650 and 653 (latest DOT-approved editions). These codes provide detailed requirements and acceptance standards for all inspections not covered here.

### Radiography – Butt Welds

All welds joining shell plates or insert plates into tank shells shall be full penetration welds. These welds shall be visually inspected and radiographed. The location of the radiographs and acceptance criteria shall be in accordance with the applicable codes.

### Vacuum Tests

Vacuum testing is performed by means of a metal box, 6 in. wide by 30 in. long with a glass window in the top. The open bottom is sealed against the tank surface with a sponge rubber gasket.

Before applying the vacuum, the weld seam shall be brushed with a soap solution or linseed oil. The vacuum box should then be placed over the weld seam and have the vacuum applied to the box. The presence of weld deficiencies will be indicated by bubbles or foam produced by air sucked through the weld seam

The vacuum should be at least 10 lbs per square inch.

Defective welds should be reworked and vacuum tested until satisfactory.

### Reinforcement Plate Welds (e.g., Manways and Nozzles)

All reinforcement plates shall have 1/4 in. telltale holes which are tapped to allow pressure testing. After the reinforcement plates are welded to the tank shell, the welds shall be visually inspected and pressure tested by applying 15 psig pressure through the telltale holes. While this pressure is applied, soap solution shall be applied to attachment welds around the reinforcement, both inside and outside of the tank. The telltale hole shall be tapped and plugged or welded shut.

### Visual Examination Requirements

Welds shall be examined visually to ensure proper size, and to identify unacceptable welds. All welds shall have slag and weld spatter removed by wire brushing or grinding.

All welds shall be free of cracks, porosity, pinholes, incomplete fusion cold roll and undercut. All weld surfaces shall be free of coarse ripples. Fillet welds shall be adequate size and throat without excessive reinforcement.

Butt welds shall also be free of excessive reinforcement and undercutting, and shall have a neat workmanlike appearance.

### Welding Inspector Requirements

On all pipeline welding inspection, including the pipe from the tank flange to the terminal, a qualified Certified Welding Inspector or Company Welding Inspector shall be used.

## Welder Qualification

Prior to welding on storage tanks, a welder must prove he is qualified to make good quality welds under conditions equal to or more demanding than the specific welds required on a given job.

This proof is obtained by having a welder make welds on test plates, and having these welds tested by an independent testing company. These tests shall be documented on the Company Welder Qualification Record.

### Company and Contractor Welder Qualification

All welders who are welding to the requirements of API 650 and API 653 (latest DOT-approved editions) must be qualified in accordance with ASME Section IX, latest DOT-approved edition.

All contractors performing tank welding operations shall be responsible for submitting welding procedures and welder qualifications for review and approval. All welder tests shall be witnessed by a Company Welding Inspector.

Contractor welders may qualify for welding at the job site or in the laboratory of an independent testing company.

The test welds shall meet the requirements of ASME Section IX as given below.

The Contractor shall be responsible for the qualification of welders.

### Minimum Requirements for Qualification

#### Variables

The variables which must be checked for welder qualifications are as follows:

* Weld Electrode Material
* Weld Position and Joint Configuration
* Base Material
* Base Material Thickness

#### Restrictions

The following restrictions apply for each category:

#### Weld Electrode Material

|  |
| --- |
|  ? |

Therefore, a welder qualified with an E6010 electrode can weld on the job with E7024, but not with E7018 electrodes.

##### Weld Position and Joint Configuration

1. The weld position encountered on storage tanks and flat, vertical, horizontal and overhead.
2. The joint configurations are fillet welds and groove welds.
3. The following requirements must be met:

|  |
| --- |
|  ? |

**Note:** Reference ASME Section IX QW – 46.9, Performance Qualification – Position and Diameter Limitations.

Therefore, for a welder to make all position welds on storage tanks, he should be qualified with horizontal, vertical and overhead groove welds.

1. The welds encountered on storage tanks are as follows:

|  |
| --- |
|  ? |

##### Base Material

A tank welder, who has qualified by welding A36 or other carbon steel plate coupons, does not have to be requalified when welding another grade of carbon steel. Other grades of carbon steel include, but are not limited to A283, A515, A516, A53B, A106, A135, etc.

##### Base Material Thickness

|  |
| --- |
|  ? |

## Bend Test Acceptance Criteria

The weld and heat affected zone of a transverse weld-bend specimen shall be completely within the bent portion of the specimen after testing. The guided-bend specimens shall have no open defects in the weld or heat affected zone exceeding 1/8 in., measured in any direction on the convex surface of the specimen after bending. Open defects occurring on the corners of the specimen during testing shall not be considered unless there is definite evidence that they result from lack of fusion, slag inclusions or other internal defects. For corrosion-resistant weld overlay cladding, no open defect exceeding 1/16 in., measured in any direction, shall be permitted in the cladding, and no open defects exceeding 1/8 in. shall be permitted in the bond line. (See ASME Section IX, QW-163.)

## Recommended Qualification Practice

Refer to Section 10 for the Company recommended practice for qualification of welders for tank maintenance and construction (all tank welds such as new tanks, new bottoms, nozzles, bottom repairs, shell repairs, etc.).

## Alternative Qualification Practice

An alternative to this recommended practice is to qualify welders using plate tests as described below:

* Weld electrode – E7018 (low hydrogen), Company Weld Procedure TWP-1
* Weld position and joint configuration horizontal, vertical, and overhead groove
* Base material – A36
* Base material size – 6 plates 1/2 in. (minimum thickness) x 6 in. wide x 12 in. long. The test plates shall be prepared as shown in Figure 1.

Procedure:

* Fit plates.
* Clean or grind tack welds.
* Weld per applicable procedures – interpass grinding is allowed for touch-up only; excessive grinding is prohibited.
* Cleaning by a power brush is preferred.
* Grind or back gouge back side to sound metal.
* Complete weld and clean.
* The test coupons for Company qualification shall be removed in accordance with Figure 2 of this section and subjected to the bend test in accordance with ASME Section IX, latest DOT-approved edition.
* Document welds and tests on welder qualification form QW-484.

To qualify for bottom welding only:

* Weld electrode E7024, Company Weld Procedure TWP-3
* Weld position and joint configuration – flat fillet
* Base material A36
* Base material size 2 plates 1/4 x 6 in.

Procedure:

* Fit plate into tee configuration.
* Clean or grind tack welds.
* Weld 1.4 in. fillets both sides of vertical plates.
* Clean and bend test.
* Document on qualification record bottom welding only.

## Weld Procedures

### Introduction

The following weld procedures are included for qualification and use by Company Welders only. API 350, API 653 and ASME Section IX require each contractor to develop and qualify his own weld procedures to be used by his employees.

### Index

TWP-1: This is a procedure for the use of Low Hydrogen (E7018) electrodes. This procedure may be used on all tank welds including bottoms, shell joints, nozzles, and structural steel.

**Note:** This procedure must be used on all welds when one of the members to be joined is thicker than 0.5 in. This includes the shell to bottom fillet welds.

TWP-2: This is a procedure for the use of E6010 (5P) electrodes. This procedure may be used for all tank welds except those which join parts thicker than 0.5 in.

TWP-3: This is a procedure for the use of electrodes classified as E7024 (Jet Rod). This procedure may be used for flat or horizontal fillet welds only, if the thickness of either piece welded does not exceed 0.5 in.

**Note:** The above procedures are included in the Procedures section.

# Weld Defects – Radiographic Image Descriptions and Solutions

## Isolated Slag Inclusions (ISI)

### Radiographic Image Description

The radiographic image of isolated slag particles appears darker than the surrounding area and is irregular in shape and form. The image density will vary from light to dark depending on the height and width of the particle inclusion. Isolated slag may occur anywhere in the weld.



### Causes

Flux coating particles trapped between weld passes or between the pipe bevel and the weld metal.

### Solutions

1. Check for proper cleaning between passes.
2. Check for proper amperage for the electrode diameter being used.
3. Check for proper ground connection and weld cable to assure voltage loss does not exceed four volts.
4. If ISI is located in or near the top portion of the pipe, check to see if the arc is started within 1 or 2 in. of the ground connection point. When the arc is initiated, a magnetic field is established around the ground. This field has the ability to deflect the molten puddle by pushing or pulling, creating a potential for slag entrapment. Starting the arc further from the ground (3 in. or more) will eliminate this problem.

## Inadequate Penetration (IP)

### Radiographic Image Description

The radiographic image of inadequate penetration is a straight, dark line occurring at the root of the weld where full penetration of the weld joint has not been achieved. The dark line may be continuous or intermittent. The indication may be a sharp single line or two parallel lines depending on the joint space and width of the discontinuity.



### Causes

Improper welding technique, insufficient joint space, or improper fit-up.

### Solutions

1. Check for conformance to proper welding procedure including amperage, travel speed and electrode diameter.
2. Check joint space and fit-up.
3. Measure root face to assure conformance to pipe end tolerance. (Root Face: 1/16 in. ± 1/32 in.)

## Elongated Slag Inclusion (ESI)

### Radiographic Image Description

The radiographic image of elongated slag varies in density (the slag particles appear darker than the surrounding area), is irregular in shape and may be elongated in the direction of the deposited weld metal. Depending on the amount or extent of the slag inclusion, the image may be quite dark (heavy slag inclusion) or very light (thin slag inclusion). When elongated slag is trapped be-tween the root and hot pass it is generally referred to as "wagon tracks" (usually thin, parallel irregular lines of slag). While generally associated with the root/hot pass, elongated slag can occur anywhere in the weld.



### Causes

Flux coating particles trapped between weld passes or between the pipe bevel and the weld metal.

### Solutions

1. Check for proper cleaning between passes.
2. Check for proper diameter electrode as required by the procedure.
3. Check for proper amperage for the electrode diameter being used.
4. Check for proper ground connection and weld cable to assure voltage loss does not exceed four volts.

## Inadequate Penetration Due to High-Low (IPD)

### Radiographic Image Description

The radiographic image of inadequate penetration due to high-low is a straight, dark line at the edge of the root bead. This line is actually the unwelded edge of the adjacent pipe root face or land.



### Cause

Misalignment of pipe ends.

### Solutions

1. Check internal alignment clamp for proper shims.
2. Measure pipe ends with diameter tape for conformance to pipe end tolerance presented in this handbook (see Section XVII).
3. Check for proper use and adjustment of outside clamps.

## Low Cap (LC)

### Radiographic Image Description

The radiographic image of a low cap appears as a dark, wide indication across the width of the cap pass. This indication may be short (between weld ripples) or be several inches long. In general, the darker the image, the deeper the concavity of the cap pass.



### Cause

Insufficient weld metal.

### Solutions

1. Welder technique problems.
2. Check welder vision.
3. Check for conformance to welding procedure.

## Hollow Bead (HB)

### Radiographic Image Description

The radiographic image of hollow bead is an elongated, dark indication with a smooth outline occurring in the root pass. The indication is usually in the center of the root pass image and may vary slightly in width. Hollow bead may be a very short but elongated indication, slightly longer but intermittent indication, or it may be up to several inches in length for one indication. In some cases, the indication may actually be located in the root pass melt-through or reinforcement on the inside of the pipe.



### Cause

Entrapped gas occurring in the root pass.

### Solutions

1. Check to assure pipe bevels and root faces (lands) are proper and are clean.
2. Make sure weld procedure is being followed in regards to travel speed and amperage.
3. Check root space to assure proper space is achieved prior to welding.
4. If necessary, use a wider space to eliminate the problem. The wider space slows the travel speed and allows for the entrapped gas to escape from the solidifying weld puddle (melt-thru).
5. Excessive moisture content in the electrode coating may contribute to "HB."

## Internal Undercut (IU)

### Radiographic Image Description

The radiographic image of internal undercut appears as a linear indication of indistinct outline at the edge of the root pass. The image will vary from light to dark depending on the depth and severity of the undercut. A darker image indicates the undercut is deeper with respect to the lighter images. Internal undercut can be located on one or both sides of the root pass.



### Causes

Improper welding technique, excessive arc force or magnetized pipe.

### Solutions

1. Check for proper welding technique including amperage, electrode angle & travel speed.
2. Check for proper machine setting regarding arc force. Refer to the Application Selection Guide in this handbook for the proper settings for the root pass. Using a low arc force or "pressure" will assist in reducing or eliminating (IU) on the root pass.
3. Check for magnetism on pipe ends. The gauss level should not be greater than 10 gauss at any point on the root face using a longitudinal probe with an F.W. Bell Gaussmeter. The gauss level in the root space in a joint aligned and ready for welding should not exceed 100. When gauss levels of 100 or higher are measured in the joint space, undercutting due to "arc blow" is likely and the pipe should be demagnetized (degaussed) for successful welding.

## External Undercut (EU)

### Radiographic Image Description

The radiographic image of external undercut appears as a linear, irregular, sometimes wavy indication along the edge of the cap pass. The image may be indistinct (very light) or it may be very distinct and dark with respect to the image of the adjacent pipe or weld material. The darker images of external undercut indicate the discontinuity has more depth than the lighter images. External undercut can be located on one or both sides of the cap pass.



### Causes

Improper welding technique or excessive arc force.

### Solutions

1. Check for proper welding technique including amperage, electrode angle and arc length.
2. Check machine setting for proper arc force (open circuit voltage). Refer to the Application Selection Guide in this handbook for proper settings for the cap pass. Reducing the arc force or "pressure" will soften the arc and allow for "capping" without "EU."

## Internal Concavity (IC)

### Radiographic Image Description

The radiographic image of internal concavity appears as a darker image replacing the lighter root pass image. It will generally be in the center of the weld image and be as wide as or wider than the original root space. Internal concavity will vary from light to dark depending on the degree of concavity (suck-back of the root pass). This discontinuity may be located anywhere around the pipe circumference. Depending on the welding process and the weld joint space, internal concavity may tend to be located near the bottom portion of the pipe.



### Causes

Improper welding technique or excessively wide space.

### Solutions

1. Check for conformance to the welding procedure.
2. Determine the stopping technique being used when pulling out of the weld puddle.
3. Change technique to weld out on bevel or weld back on weld deposit before breaking arc.
4. Joint space may be too wide allowing weld puddle to contract due to surface tension. Close joint space within weld procedure tolerance.

## Burn-Through (BT)

### Radiographic Image Description

The radiographic image of burn through appears as an individual darkened area of elongated or rounded contour that may be surrounded by a lighter ring. It will be in the center of the root pass image and may be as wide as or wider than the original root space. It will vary in density from light to dark depending on the degree of concavity.



### Cause

Excessive penetration in the root or hot pass (weld puddle blown into the pipe).

### Solution

1. Check for proper welding technique including amperage and travel speed. Root pass may be too thin.
2. Check for excessive or improper grinding of the root pass.
3. Examine pipe bevels to determine that the root face (land) conforms to the section. Confirm that root face is uniform around circumference of pipe.
4. Check pipe alignment for conformance to welding procedure.
5. Measure pipe circumference using diameter tape to assure conformance to

## Incomplete Fusion/Root (IFR)

### Radiographic Image Description

The radiographic image of incomplete fusion/root appears as a dark, straight line, which is actually one of the pipe lands that were not fused when the root pass was being made. It may be short and intermittent in length or be continuous for several inches. Although this indication will generally appear on one side of the root pass only, it is possible to have incomplete fusion/root on both sides of the root pass.



### Causes

Improper welding technique, damaged pipe ends or magnetized pipe

### Solutions

1. Check for conformance to welding procedure including amperage and travel speed.
2. Examine pipe bevels and root face for conformance to the pipe specification (See Section XVII).
3. Measure magnetic field in joint space when ready for welding. Use an F.W. Bell Gaussmeter with a longitudinal probe to obtain accurate measurements in the root space or gap (approximately 1/16 in.). A gauss level of 100 is sufficient to create arc blow or deflection. Gauss levels

## Incomplete Fusion/Cap (IFC)

### Radiographic Image Description

The radiographic image of incomplete fusion/cap appears as a dark, straight line, which is the top edge of one of the pipe bevels. This indication may be short and intermittent or may extend for several inches.



### Causes

Improper welding technique or poor vision.

### Solutions

1. Check for conformance to the welding procedure including joint design and number of passes.
2. Determine if welder has proper visual acuity. Corrective measures include wearing glasses or use of a magnification lens in the welding hood.
3. Determine if a multiple beaded cap would be beneficial on wide cap passes (heavy wall pipe).

## Incomplete Fusion Due to Cold Lap (IFD)

### Radiographic Image Description

The radiographic image of incomplete fusion due to cold lap appears as a dark indication usually elongated and varying in width. The image will be between the pipe and the weld metal or between the weld passes. A darker image generally indicates the discontinuity is more extensive in height or depth as compared to a lighter image.



### Cause

Improper welding technique.

### Solutions

1. Check for conformance to the welding procedure including amperage and travel speed.
2. Check for proper interpass cleaning.
3. Make sure proper cleaning equipment is on-site for power brushing between passes.
4. Check welder technique to determine proper electrode angle.
5. When using the GMAW process check for proper welding gun angle (90°).

## Crater Crack (CC)

### Radiographic Image Description

The radiographic image of a crater crack appears as a short, usually jagged line and originates at the stopping point of an electrode. The short crater crack may be oriented in several directions (radially, transverse or longitudinal) with respect to the actual crater. As in the case of the longitudinal and transverse cracks, the orientation of the crater crack to the beam of radiation has significant impact on the definition of the crater crack image.



### Cause

Weld Metal Shrinkage/Contraction.

### Solutions

1. Check welder stopping technique.
2. Check for conformance to pre-heat requirements.
3. Check for proper starting, stopping, and grinding techniques.
4. In unusual cases, check chemistry of weld metal.

## Longitudinal Crack (CR-L)

### Radiographic Image Description

The radiographic image of a longitudinal crack appears as jagged or straight line and may vary in density from very light to dark. As the plane of the crack deviates from the direction of the radiation beam the crack will become broader in appearance and less distinct. A crack may be short in length or may be quite long, depending on the cause of its existence. The longitudinal crack image will be parallel with the length of the weld.



### Causes

Improper welding technique or mechanical handling.

### Solutions

1. Check for conformance to welding procedure including travel speed and time between root and hot pass.
2. Check for early release of alignment clamp.
3. Check for excessive lifting of pipe by side boom tractor.
4. Check for proper skid support.
5. Check for proper fusion of both root faces during deposition of the root pass. A gauss level of 100 or more in the root space can prevent proper fusion of both root faces that in turn may lead to cracking during normal lifting and pipe movement incurred during construction.
6. In the event of delayed cracking, check for excessive hydrogen from electrode coating or pipe surface moisture.

## Transverse Crack (CR-T)

### Radiographic Image Description

The radiographic image of a transverse crack appears as a jagged or straight line and may vary in density from very light to dark. The transverse crack image will be perpendicular to the length of the weld. As in the case of the longitudinal crack, the orientation of the crack with respect to the beam of radiation has a significant impact on the sharpness and definition on the crack image. Transverse cracks may be very tight thereby resulting in light radiographic indications.



### Causes

Improper welding technique or excessive cooling rates.

### Solutions

1. Check for conformance to welding procedure including preheat requirements.
2. Check for balanced heat input and proper number of welders on joint. On pipe with a D/t ratio of 50 or less, two welders are required to assure balanced heat input and uniform girth weld shrinkage (Refer to D/t formula, Section VII).
3. Excessive weld cooling rates may be a factor. Weld blankets are recommended when temperatures exist which may contribute to transverse cracking. This becomes increasingly important with pipe having D/t ratios mentioned above.

## Porosity (P or GP)

### Radiographic Image Description

The radiographic image of porosity appears as a rounded (spherical) or elongated (wormhole) indication of various density. The images have a smooth outline and may be random, clustered or linear. The darker images are generally larger and/or elongated indicating porosity rising to the surface (wormhole). Porosity may appear as a single pore anywhere in the weld. A single pore or spot has been referred to as a "gas pocket" or "pinhole". Pinhole porosity is generally used to refer to porosity on or near the edge of the cap pass, while the "gas pocket" term is intended to describe an isolated pore within the body of the weld. Cluster porosity is simply a number of small pores within a group or cluster.



### Cause

Gas trapped in the weld metal during solidification of the weld puddle.

### Solutions

1. Check for proper cleaning of pipe bevels & root face.

Check condition of electrodes. Electrodes that are of questionable age may not have the proper moisture content which is 3-6% for cellulosic electrodes. A dry electrode coating will produce a weld having fine, scattered (salt and pepper type) of porosity. Electrodes that have been subjected to freezing temperatures.

1. Definitions

| Term | Definition |
| --- | --- |
| ASME Piping and Format | Any piping system designed in accordance with an ASME Code. These piping systems require welding procedure and welder qualification in accordance with ASME Section IX requirements. |
| Fabricator | A contractor or company engaged in the construction or building of components or piping systems which will be used in the handling, transportation or storage of gas or liquids. |
| In-Service Pipeline Welding | Welding on a pipeline or piping system that contains a gas or liquid such as natural gas, petroleum products or hydrostatic test water under static or flowing conditions. This welding activity was previously referred to as "Maintenance" welding. For purposes of identifying welding procedures, those with an "M" in the suffix or ending are those specifically prepared for use on "In-Service" welding applications. |
| Inspector | A person qualified to monitor the quality of work performed by a "welder" and for ensuring the "welder" is qualified according to the procedures established in this manual. |
| Welder | A person employed to specifically perform the function of welding pressure piping systems for Owner. Two types of welders will be referenced in this manual, "Company Welder" and "Contract Welder". A "Company Welder" is an employee of Owner and a "Contract Welder" is an employee of a contractor who has been contracted for the purpose of performing specific welding services for Owner. |
| Welder Qualification | All welders who perform welding on pressure piping systems must be qualified in accordance with the requirements of this manual. |
| Welding Procedure Specification (WPS) | A term used primarily within the ASME codes to describe a welding procedure document that provides direction to the welder. The WPS should be available to the welder as it presents the joint design, the type of electrode and parameters and the other conditions required to make the specific weldment. While the term WPS originates in ASME Section IX, it is applicable to API 1104 welding procedure documents as well. The WPS does not include the supporting test data or other information that is not relevant to actually making the weld. This supporting data is presented in the Procedure Qualification Record (PQR).* Procedure Qualification Record (PQR)—A separate document and is a record of the how the weld was made and the actual test results. In ASME codes, this PQR is usually not in the field or shop but rather maintained in the engineering office for reference if needed. It will provide all of the information regarding the manner of how the weld was made and tested. The PQR supports the WPS and they are both numbered to assure quick reference from one document to the other. One PQR may actually provide test results which support more than one WPS.
* Welding Procedure – API 1104— In contrast to ASME terminology and definitions, such as WPS and PQR, the terms Welding Procedure or Qualified Welding Procedure are typical of API 1104 descriptions and they are referred to within the API 1104 Standard as a "procedure specification". A Qualified Welding Procedure is a tested and proven method by which sound welds with suitable mechanical properties can be produced. API 1104 requires that the complete test results be recorded in the "qualified procedure" in addition to providing direction to the welder.

The primary difference between the two codes, in terms of defining the "Welding Procedure", is that ASME requires two documents, the WPS and the PQR, whereas API 1104 requires one all-inclusive document.The Project Manager shall ensure that the appropriate welding rods are used for the base material that is being welded. Using a rod that has a minimum strength that is higher than the maximum strength of the base metal may lead to brittle fracture in the heat affected zone. |

1. Acronyms

|  |  |
| --- | --- |
| Acronym | Description |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |

1. References

| Document Number | Document Title |
| --- | --- |
| 49 CFR 195 | Transportation of Hazardous Liquids by Pipeline |
| ANSI/ISEA Z87.1 | American National Standard Occupational and Educational Personal Eye and Face Protection Devices |
| API SPEC 5L | Line Pipe |
| API SPEC 6D | Pipeline Valves |
| API STD 1104 or API STD 1107 | Pipeline Maintenance Welding Practices |
| API STD 1104 or API STD 1107 | Welding of Pipelines and Related Facilities |
| API STD 1104 or API STD 1107 | Welding of Pipelines and Related Facilities, Appendix B: In-Service Welding |
| ASME B16.5 | Pipe Flanges and Flanged Fittings |
| ASME B31.1 | Power Piping |
| ASME B31.3 | Process Piping |
| ASME B31.4 | Pipeline Transportation Systems for Liquid Hydrocarbons |
| ASME Section I | Power Boilers |
| ASME Section V | Nondestructive Examination |
| ASME Sec VIII | Boiler and Pressure Vessel Code, Section VIII: Rules for the Construction of Unfired Pressure Vessels, Divisions 1 & 2 |
| ASME Sec IX | Boiler and Pressure Vessel Code, Section IX: Qualification Standard for Welding and Brazing Procedures, Welders, Brazers, and Welding and Brazing Operators |
| ASNT TC-1A | Recommended Practice, Personnel Qualification and Certification in Nondestructive Testing |
| ASTM E 94 | Standard Guide for Radiographic Examination |
| ASTM E 165 | Standard Recommended Practice for Liquid Penetrant Inspection Methods |
| ASTM E 709 | Standard Recommended Practice for Magnetic Particle Examination |
| AWS A3.0 | Welding Terms and Definitions |
| AWS A5.1 | Specification for Covered Carbon Steel Arc Welding Electrodes |
| AWS A5.5 | Specification for Low Alloy Steel Covered Arc Welding Electrodes |
| MSS SP-44 | Steel Pipeline Flanges |
|  | Radiography in Modern Industry, Fourth Edition, by Eastman Kodak Co. |

1. Forms and Records

|  |  |
| --- | --- |
| Document Number | Document Title |
| WEL-3000 | API 1104 Single Qualification |
| WEL-3001 | API 1104 Multiple Qualification |
| WEL-3002 | API 1104 In-Service Qualification |
| WEL-3003 | ASME Welder Qualification |
| WEL-3004 | Daily Radiographic Report |
| WEL-3005 | Dye Penetrant Procedure – PT-1 |
| WEL-3006 | Dye Penetrant Test Form |
| WEL-3007 | Exothermic (CAD-Weld) Process |
| WEL-3008 | Mag Particle Procedure – MT-1 |
| WEL-3009 | Mag Particle Procedure – MT-2 |
| WEL-3010 | Mag Particle Procedure – MT-3 |
| WEL-3011 | Mag Particle Test Form |
| WEL-3012 | Mag Yoke Weight Verification Form |
| WEL-3013 | Ultrasonic Thickness Record |

1. Tables and Formulas
	1. Electrode Strength Properties

|  |  |  |  |
| --- | --- | --- | --- |
| AWS Electrode Classification | Tensile Strength (psi Minimum) | Yield Strength (psi Minimum) | Elongation (% Minimum) |
| E6010 | 60,000 | 48,000 | 22 |
| E7010-G | 70,000 | 57,000 | 22 |
| E8010-G | 80,000 | 67,000 | 19 |
| E9010-G | 90,000 | 77,000 | 17 |
| E7018 | 70,000 | 57,000 | 25 |
| E8018-C3 | 80,000 | 68,000-80,000 | 24 |

* 1. Pipe Strength Properties

|  |  |  |
| --- | --- | --- |
| API Pipe Grade | Yield Strength (psi Minimum) | Tensile Strength \*(psi Minimum) |
| B | 35,000 | 60,000 |
| X42 | 42,000 | 60,000 |
| X46 | 46,000 | 63,000 |
| X52 | 52,000 | 66,000 |
| X56 | 56,000 | 71,000 |
| X60 | 60,000 | 75,000 |
| X65 | 65,000 | 77,000 |
| X70 | 70,000 | 82,000 |
| X80 | 80,000 | 90,000\* |
| \* The maximum tensile for all PSL 2 pipe grades is 110,000 PSI, except for X80 which is 120,000 PSI. PSL 1 pipe has the same minimum values stated above but there is no maximum value. |

* 1. Copper Weld Cable Size

|  |
| --- |
| Copper Weld Cable Size Guide for SMAW Welding – 60% Duty Cycle |
| Amperage | 50 ft | 100 ft | 150 ft | 200 ft | 300 ft | 400 ft |
| 75 | 6 | 6 | 4 | 3 | 2 | 1 |
| 100 | 4 | 4 | 3 | 2 | 1 | 1/0 |
| 150 | 3 | 3 | 2 | 1 | 2/0 | 3/0 |
| 200 | 2 | 2 | 1 | 1/0 | 3/0 | 4/0 |
| 250 | 2 | 2 | 1/0 | 2/0 | 4/0 | -- |
| 300 | 1 | 1 | 2/0 | 3/0 | -- | -- |
| **Note:** The length of cable is the length of the electrode lead plus the ground or work lead. |

* 1. Commercial Pipe Dimensions per ANSI/ASME B36.10M and ANSI/ASME B36.19M

| Pipe Sizes | Wall Thicknesses (in.) |
| --- | --- |
| Stainless Steel | Wrought Steel |
| Nominal Pipe Size | Outside Diameter (in.) | Schedule5S | Schedule10S | Schedule 5 | Schedule10 | Schedule20 | Schedule30 | Standard | Schedule40 | Schedule60 | XS | Schedule80 | Schedule100 | Schedule120 | Schedule140 | Schedule160 | XXS |
| 1 | 1.315 | 0.065 | 0.109 | 0.065 | 0.109 | -- | 0.114 | 0.133 | 0.133 | -- | 0.179 | 0.179 | -- | -- | -- | 0.250 | 0.358 |
| 11/2 | 1.900 | 0.065 | 0.109 | 0.065 | 0.109 | -- | 0.125 | 0.145 | 0.145 | -- | 0.200 | 0.200 | -- | -- | -- | 0.281 | 0.400 |
| 2 | 2.375 | 0.065 | 0.109 | 0.065 | 0.109 | -- | 0.125 | 0.154 | 0.154 | -- | 0.218 | 0.218 | -- | -- | -- | 0.344 | 0.436 |
| 21/2 | 2.875 | 0.083 | 0.120 | 0.083 | 0.120 | -- | 0.188 | 0.203 | 0.203 | -- | 0.276 | 0.276 | -- | -- | -- | 0.375 | 0.552 |
| 3 | 3.500 | 0.083 | 0.120 | 0.083 | 0.120 | -- | 0.188 | 0.216 | 0.216 | -- | 0.300 | 0.300 | -- | -- | -- | 0.438 | 0.600 |
| 31/2 | 4.000 | 0.083 | 0.120 | 0.083 | 0.120 | -- | 0.188 | 0.226 | 0.226 | -- | 0.318 | 0.318 | -- | -- | -- | -- | -- |
| 4 | 4.500 | 0.083 | 0.120 | 0.083 | 0.120 | -- | 0.188 | 0.237 | 0.237 | -- | 0.337 | 0.337 | -- | 0.438 | -- | 0.531 | 0.674 |
| 5 | 5.563 | 0.109 | 0.134 | 0.109 | 0.134 | -- | -- | 0.258 | 0.258 | -- | 0.375 | 0.375 | -- | 0.500 | -- | 0.625 | 0.750 |
| 6 | 6.625 | 0.109 | 0.134 | 0.109 | 0.134 | -- | -- | 0.280 | 0.280 | -- | 0.432 | 0.432 | -- | 0.562 | -- | 0.719 | 0.864 |
| 8 | 8.625 | 0.109 | 0.148 | 0.109 | 0.148 | 0.250 | 0.277 | 0.322 | 0.322 | 0.406 | 0.500 | 0.500 | 0.594 | 0.719 | 0.812 | 0.906 | 0.875 |
| 10 | 10.750 | 0.134 | 0.165 | 0.134 | 0.165 | 0.250 | 0.307 | 0.365 | 0.365 | 0.500 | 0.500 | 0.594 | 0.719 | 0.844 | 1.00 | 1.125 | 1.00 |
| 12 | 12.750 | 0.156 | 0.180 | 0.156 | 0.180 | 0.250 | 0.330 | 0.375 | 0.406 | 0.562 | 0.500 | 0.688 | 0.844 | 1.000 | 1.125 | 1.312 | 1.00 |
| 14 | 14.000 | 0.156 | 0.188 | 0.156 | 0.250 | 0.312 | 0.375 | 0.375 | 0.438 | 0.594 | 0.500 | 0.750 | 0.938 | 1.094 | 1.250 | 1.406 | -- |
| 16 | 16.000 | 0.165 | 0.188 | 0.165 | 0.250 | 0.312 | 0.375 | 0.375 | 0.500 | 0.656 | 0.500 | 0.844 | 1.031 | 1.219 | 1.438 | 1.594 | -- |
| 18 | 18.000 | 0.165 | 0.188 | 0.165 | 0.250 | 0.132 | 0.438 | 0.375 | 0.562 | 0.750 | 0.500 | 0.938 | 1.156 | 1.375 | 1.562 | 1.781 | -- |
| 20 | 20.000 | 0.188 | 0.218 | 0.188 | 0.250 | 0.375 | 0.500 | 0.375 | 0.594 | 0.812 | 0.500 | 1.031 | 1.281 | 1.500 | 1.750 | 1.969 | -- |
| 22 | 22.000 | 0.188 | 0.218 | 0.188 | 0.250 | 0.375 | 0.500 | 0.375 | -- | 0.875 | 0.500 | 1.125 | 1.375 | 1.625 | 1.875 | 2.125 | -- |
| 24 | 24.000 | 0.218 | 0.250 | 0.218 | 0.250 | 0.375 | 0.562 | 0.375 | 0.688 | 0.969 | 0.500 | 1.219 | 1.531 | 1.812 | 2.062 | 2.344 | -- |
| 26 | 26.000 | -- | -- | -- | 0.312 | 0.500 | -- | 0.375 | -- | -- | 0.500 | -- | -- | -- | -- | -- | -- |
| 28 | 28.000 | -- | -- | -- | 0.312 | 0.500 | 0.625 | 0.375 | -- | -- | 0.500 | -- | -- | -- | -- | -- | -- |
| 30 | 30.000 | 0.250 | 0.312 | 0.250 | 0.312 | 0.500 | 0.625 | 0.375 | -- | -- | 0.500 | -- | -- | -- | -- | -- | -- |
| 32 | 32.000 | -- | -- | -- | 0.312 | 0.500 | 0.625 | 0.375 | 0.688 | -- | 0.500 | -- | -- | -- | -- | -- | -- |
| 34 | 34.000 | -- | -- | -- | 0.312 | 0.500 | 0.625 | 0.375 | 0.688 | -- | 0.500 | -- | -- | -- | -- | -- | -- |
| 36 | 36.000 | -- | -- | -- | 0.312 | 0.500 | 0.625 | 0.375 | 0.750 | -- | 0.500 | -- | -- | -- | -- | -- | -- |

* 1. Typical Amperage/Voltage Ranges

|  |
| --- |
| Low Hydrogen Electrodes(E7018, E8018, E9018) |
| **Diameter** | **Amperage (Current)** | **Voltage** |
| 3/32 in. | 80–100 | 20–23 |
| 1/8 in. | 115–135 | 20–23 |
| 5/32 in. | 140–190 | 20–23 |
| Cellulose Coated Electrodes(E6010, E7010-G, E8010-G, E9010-G) |
| 3/32 in. | 50–90 | 22–25 (20–23 for Root Pass) |
| 1/8 in. | 90–120 | 22–25 (20–23 for Root Pass) |
| 5/32 in. | 130–160 | 25–28 (20–23 for Root Pass) |
| 3/16 in. | 160–190 | 25–30 |
| **Note:** Voltage numbers presented herein are typical of measured values across the arc. When measuring at machine terminals, voltage may be 2–3 volts higher due to circuit resistance. |

* 1. Pipe Dimensions and Tolerances per API 5L–"Line Pipe"

|  |
| --- |
| Diameter of Pipe Body |
| **Size** | **Tolerances** |
| < 23/8 | + 0.016 in., − 0.031 in. |
| ≥ 23/8 and ≤ 41/2, continuous welded | ± 1.00% |
| ≥ 23/8 and < 20 | ± 0.75% |
| ≥ 20, seamless | ± 1.00% |
| ≥ 20 and ≤ 36, welded | + 0.75%, − 0.25% |
| > 36, welded | + 1/4 in., − 1/8 in. |
| Pipe Straightness |
| Deviation from a straight line shall not exceed 0.2% of the length. |
| Diameter at Pipe Ends |
| ≤ 103/4 | − 1/64 in., + 1/16 in. |
| > 103/4 and ≤ 20 | − 1/32 in., + 3/32 in. |
| > 20 and ≤ 42 | − 1/32 in., + 3/32 in. |
| > 42 | − 1/32 in., + 3/32 in. |
| **Note:** The above pipe end tolerances are valid for a distance of 4 in. only from the end of the pipe. |
| Pipe Out-Of-Roundness |
| Up to 4 in. from end of pipe > 20, ± 1% of actual O.D. |
| Root Face or Land |
| 1/16 in. ± 1/32 in. |
| Wall Thickness |
| **Size and Type of Pipe** | **Tolerances, Percent of Actual W.T.** |
| **Grade B or Lower** | **Grade X42 or Higher** |
| ≤ 27/8, All | + 20.0, − 12.5 | + 15.0, − 12.5 |
| >27/8 and < 20, All | + 15.0, − 12.5 | + 15.0, − 12.5 |
| ≥ 20, Welded | + 17.5, − 12.5 | + 19.5, − 8.0 |
| ≥ 20, Seamless | + 15.0, − 12.5 | + 17.5, − 10.0 |

* 1. Suggested Machine Setting Guide for 200/250 Lincoln Machine

| Fine Selector | Amperage Range for Various Electrode Diameters with Coarse Selector @ | OCV |
| --- | --- | --- |
|  | **80–130** | **120–190** | **160–240** | **220–Max** |  |
|  | 1/8 in. | 5/32 in. | 3/16 in. | 1/8 in. | 5/32 in. | 3/16 in. | 1/8 in. | 5/32 in. | 3/16 in. | 1/8 in. | 5/32 in. | 3/16 in. |  |
| 10 | < 50 | < 50 | < 50 | < 50 | < 50 | < 50 | 40–60 | 50–70 | 60–80 | 110–120 | 135–145 | 140–150 | 50 |
| 20 | < 50 | < 50 | < 50 | < 50 | < 50 | < 50 | 55–65 | 60–80 | 100–110 | 115–125 | 140–150 | 150–160 | 54 |
| 30 | < 50 | < 50 | < 50 | 50–60 | 55–65 | 75–85 | 85–95 | 105–115 | 115–125 | 130–140 | 160–170 | 170–180 | 60 |
| 40 | 40–60 | 50–60 | 50–70 | 80–90 | 90–100 | 75–105 | 105–115 | 120–130 | 130–140 | 155–165 | 180–190 | 195–205 | 67 |
| 50 | 80–90 | 80–90 | 85–95 | 100–110 | 105–115 | 110–120 | 125–135 | 150–160 | 155–165 | 175–185 | 210–220 | 230–240 | 71 |
| 60 | 90–100 | 95–105 | 90–110 | 110–120 | 125–135 | 125–135 | 150–160 | 165–175 | 170–180 | 190–200 | 230–240 | 240–250 | 77 |
| 70 | 100–110 | 105–115 | 110–120 | 125–135 | 140–150 | 145–155 | 165–175 | 185–195 | 190–200 | > 200 | > 240 | > 250 | 84 |
| 80 | 105–115 | 115–125 | 120–130 | 135–145 | 150–160 | 160–170 | 180–190 | 200–210 | 210–220 | > 200 | > 240 | > 250 | 88 |
| 90 | 115–125 | 125–135 | 130–140 | 145–155 | 165–175 | 175–185 | 200–210 | 220–230 | 225–235 | > 200 | > 240 | > 250 | 92 |
| 100 | 120–130 | 140–150 | 145–155 | 165–175 | 175–185 | 185–195 | > 210 | > 230 | > 235 | > 200 | > 240 | > 250 | 95 |
| **Notes:** |
| (1) | The amperage ranges presented for each electrode diameter may vary with machine condition and age. |
| (2) | The shaded areas are considered improper settings for the specific electrode diameter. |
| (3) | As the chart shows, there are four possible combinations of machine settings for each electrode diameter. Each combination, however, provides a different open circuit voltage and results in different arc forces and characteristics. Refer to Section XIII, Application Selection Guide, when selecting the optimum setting range for each weld pass. |
| (4) | For Best Root and Cap Pass Results - Select machine settings which provide OCV values between 54-71 (The Fine Selector will be in the 20-50 range). |
| (5) | For Best Hot and Fill Pass Results - Select machine settings which provide OCV values of 77-88 (The Fine Selector will be in the 60-80 range). |
| Prepared by National Welding Inspection School, 6/25/90. Revised 3/10/94. |

* 1. To Determine if Pipeline Is Operating at 20% of SMYS or More



If the pipeline operating pressure is equal to or greater than "X", then the pipeline system is operating at or above 20% of SMYS.

* 1. To Find Ultimate Tensile Strength



Where "S" equals the ultimate tensile strength (in PSI), "P" equals the load in pounds (lbs.), and "A" equals the cross-section of the coupon before testing (width x thickness) in square inches.

* 1. To Find Heat Input of Each Weld Pass



Where "A" is amperage, "V" is voltage, "60" is a constant, and "IPM" is travel speed in inches per minute. J/IN. is the units of measurement and represents joules per inch.

* 1. To Find Hoop Stress



Where "S" equals the hoop stress, "P" is the operating pressure, "D" is the outside diameter, and "T" is the wall thickness.

* 1. To Find Travel Speed



* 1. To Find Percent Elongation of Specimen



1. Before bending or tensile testing, lightly center-punch two gauge marks 2 in. apart at approximately the center of the sample with the weld in the center of the 2 in. gauge length.
2. After testing, put pieces together and measure the distance between gauge marks.
3. Calculate percent elongation using above formula.
	1. To Find Percent Reduction of Tensile Specimen



1. Measure and record original cross-section of specimen.
2. After testing, put pieces together and measure the cross-sectional area of necked-down portion of broken sample.
3. Calculate percent reduction of area using above formula.
	1. Diameter to Wall Thickness Ratio



"D" is the pipe diameter and "t" is the wall thickness.

**Comment:** Two welders, each welding on opposite sides of the pipe (referred to as the "brother-in-law" technique), are usually recommended to balance the weld heat input and weld shrinkage. This is not always possible. However, it has been found that when the D/t ratio approaches 50 or is below 50, two welders should definitely be used to complete the pipe weld to eliminate the possibility of transverse cracking created by uneven weld shrinkage stresses. When conditions prevent the use of two welders on one weld and the D/t ratio is near or below 50, a limit should be placed on the maximum number of passes which can be completed on one side of the pipe before moving to the other side to complete the weld.

**Note:** This D/t ratio of 50 is generally applicable to size 20 pipe or greater.

* 1. To Determine Power Loss

PL = (V1 - V2) x I

Where "PL" is the Power Loss (Watts), "V1" is the voltage at terminals, "V2" is the voltage at electrode holder (across arc), and I is the current (amperage).

**Note:** Weld cable length and ground (work) connections should be selected so that the voltage drop in the welding circuit does not exceed 4 volts.

* 1. Electrical Circuit Factors

The basic arc welding electrical circuit consists of three factors:

* Current – The rate of flow or amount of electricity that flows through a wire in one second. One ampere (A) is the amount of current per second that flows in a circuit. The letter "I" is used to designate current in amperes.
* Pressure – The force that causes current to flow. The measure of electrical pressure is the "volt". The voltage between two points in an electrical circuit is called the "difference" in potential. The difference in potential or voltage causes current to flow in an electrical circuit. The letter "E" is used to designate voltage or electromotive force (EMF).
* Resistance – The resistance to current flow in an electrical circuit. Resistance depends on the material, the cross-sectional area, and the temperature of the conductor. It is designated by the letter "R". The unit of electrical resistance is the "Ohm". Copper has the lowest electrical resistivity of common metals. Carbon steel has only one-seventh of the electrical conductivity of copper.

The relationship between these three factors is expressed by "Ohm's Law":

Current = Pressure/Resistance – or – Amps = Volts/Ohms

* 1. Welder Identification System



|  |
| --- |
| Legend |
| 1. | Root Pass – Ditch Side | Option for 4 Root Pass Welders: |
| 2. | Root Pass – Top of Pipe (If 3 Bead Welders Are Used) | A. | Root Pass – Ditch Side Top |
| 3. | Root Pass – ROW Side | B. | Root Pass – ROW Side Top |
| 4. | Hot Pass – Ditch Side | C. | Root Pass – Ditch Side Bottom |
| 5. | Hot Pass – ROW Side | D. | Root Pass – ROW Side Bottom |
| 6. | Second Hot Pass or Hot Filler – Ditch Side |  |
| 7. | Second Hot Pass or Hot Filler – ROW Side |  |
| 8. | Fill/Cap – Ditch Side |  |
| 9. | Fill/Cap – ROW Side |  |

* 1. Application Selection Guide

| Front Panel Settings, 200/250 AMP Lincoln Machine |
| --- |
| **Application** | **Electrode** | **Diameter** | **Coarse Selector** | **Fine Selector(± 5)** | **Desired Amperage** |
| Root Pass (Butt/Branch) | E6010, E7010, E8010, E9010 | 1/8 in. | 120-190 | 50 | 110 |
| 5/32 in. | 160-240 | 50 | 150 |
| Hot Pass (Butt/Branch) | E6010, E7010, E8010, E9010 | 1/8 in. | 120-190 | 60 | 120 |
| 5/32 in. | 120-190 | 80 | 170 |
| Fill Passes (Butt/Branch) | E6010, E7010, E8010, E9010 | 5/32 in. | 120-190 | 70 | 150 |
| 3/16 in. | 160-240 | 60 | 175 |
| Cap Passes (Butt/Branch) | E6010, E7010, E8010, E9010 | 5/32 in. | 160-240 | 50 | 150 |
| 3/16 in. | 220-Max | 30 | 175 |
| Sleeve Groove & Fillet | E7018 | 3/32 in. | 80-130 | 60 | 90 |
| Sleeve Groove & Fillet | E7018 | 1/8 in. | 120-190 | 60 | 125 |
| **Note:** It is recognized that each machine is different in terms of condition, cables, etc.; therefore, the above settings are only suggestions. Prepared by National Welding Inspection School, 6/25/90. Revised 3/10/94. |

* 1. Hardness and Approximate Tensile Strength

| Brinell Hardness No. | Vickers Hardness No. | Rockwell | Approximate Tensile Strength 1,000 psi |
| --- | --- | --- | --- |
| C150-kg Load120º Diamond Cone | B100-kg Load1/16 in.-dia. Ball |
| 780 | 1150 | 70 |  | 384 |
| 712 | 960 | 66 |  | 352 |
| 653 | 820 | 62 |  | 324 |
| 601 | 717 | 58 |  | 298 |
| 555 | 633 | 55 | 120 | 276 |
| 514 | 567 | 52 | 119 | 256 |
| 477 | 515 | 49 | 117 | 238 |
| 444 | 472 | 46 | 115 | 220 |
| 415 | 437 | 44 | 114 | 204 |
| 388 | 404 | 41 | 112 | 189 |
| 363 | 375 | 38 | 110 | 176 |
| 341 | 350 | 36 | 109 | 165 |
| 321 | 327 | 34 | 108 | 155 |
| 302 | 305 | 32 | 107 | 146 |
| 285 | 287 | 30 | 105 | 138 |
| 269 | 270 | 28 | 104 | 131 |
| 255 | 256 | 25 | 102 | 125 |
| 241 | 241 | 23 | 100 | 119 |
| 229 | 229 | 21 | 98 | 113 |
| 217 | 217 | 18 | 96 | 107 |
| 207 | 207 | 16 | 95 | 101 |
| 197 | 197 | 13 | 93 | 97 |
| 187 | 187 | 10 | 91 | 93 |
| 179 | 179 | 8 | 89 | 89 |
| 170 | 170 | 6 | 87 | 85 |
| 163 | 163 | 3 | 85 | 82 |
| 156 | 156 | 1 | 83 | 78 |
| 149 | 149 |  | 81 | 75 |
| 143 | 143 |  | 79 | 72 |
| 137 | 137 |  | 77 | 70 |
| 131 | 131 |  | 74 | 66 |
| 126 | 126 |  | 72 | 64 |
| 121 | 121 |  | 70 | 62 |
| 116 | 116 |  | 68 | 60 |
| 112 | 112 |  | 66 | 58 |
| 107 | 107 |  | 64 | 56 |
| 103 | 103 |  | 61 | 53 |
| 99 | 99 |  | 59 | 51 |
| 95 | 95 |  | 56 | 49 |

* 1. Decimal Equivalents

| Fraction | Decimal | Millimeters | Fraction | Decimal | Millimeters |
| --- | --- | --- | --- | --- | --- |
|  |  | 1/64 | .01563 | 0.397 |  |  | 33/64 | .51563 | 13.097 |
|  | 1/32 |  | .03125 | 0.794 |  | 17/32 |  | .53125 | 13.494 |
|  |  | 3/64 | .04688 | 1.191 |  |  | 35/64 | .54688 | 13.891 |
| 1/16 |  |  | .0625 | 1.588 | 9/16 |  |  | .5625 | 14.288 |
|  |  | 5/64 | .07813 | 1.984 |  |  | 37/64 | .57813 | 14.684 |
|  | 3/32 |  | .09375 | 2.381 |  | 19/32 |  | .59375 | 15.081 |
|  |  | 7/64 | .10938 | 2.778 |  |  | 39/64 | .60938 | 15.478 |
| 1/8 |  |  | .125 | 3.175 | 5/8 |  |  | .625 | 15.785 |
|  |  | 9/64 | .14063 | 3.572 |  |  | 41/64 | .64063 | 16.272 |
|  | 5/32 |  | .15625 | 3.969 |  | 21/32 |  | .65625 | 16.669 |
|  |  | 11/64 | .17188 | 4.366 |  |  | 43/64 | .67188 | 17.066 |
| 3/16 |  |  | .1875 | 4.763 | 11/16 |  |  | .6875 | 17.463 |
|  |  | 13/64 | .20313 | 5.159 |  |  | 45/64 | .70313 | 17.859 |
|  | 7/32 |  | .21875 | 5.556 |  | 23/32 |  | .71875 | 18.256 |
|  |  | 15/64 | .23438 | 5.953 |  |  | 47/64 | .73438 | 18.653 |
| 1/4 |  |  | .250 | 6.350 | 3/4 |  |  | .750 | 19.050 |
|  |  | 17/64 | .26563 | 6.747 |  |  | 49/64 | .76563 | 19.447 |
|  | 9/32 |  | .28125 | 7.144 |  | 25/32 |  | .78125 | 19.844 |
|  |  | 19/64 | .29688 | 7.541 |  |  | 51/64 | .79688 | 20.241 |
| 5/16 |  |  | .3125 | 7.938 | 13/16 |  |  | .8125 | 20.638 |
|  |  | 21/64 | .32813 | 8.334 |  |  | 53/64 | .82813 | 21.034 |
|  | 11/32 |  | .34375 | 8.731 |  | 27/32 |  | .84375 | 21.431 |
|  |  | 23/64 | .35938 | 9.128 |  |  | 55/64 | .85938 | 21.828 |
| 3/8 |  |  | .375 | 9.525 | 7/8 |  |  | .875 | 22.225 |
|  |  | 25/64 | .39063 | 9.922 |  |  | 57/64 | .89063 | 22.622 |
|  | 13/32 |  | .40625 | 10.319 |  | 29/32 |  | .90625 | 23.019 |
|  |  | 27/64 | .42188 | 10.716 |  |  | 59/64 | .92188 | 23.416 |
| 7/16 |  |  | .4375 | 11.113 | 15/16 |  |  | .9375 | 23.813 |
|  |  | 29/64 | .45313 | 11.509 |  |  | 61/64 | .95313 | 24.209 |
|  | 15/32 |  | .46875 | 11.906 |  | 31/32 |  | .96875 | 24.606 |
|  |  | 31/64 | .48438 | 12.303 |  |  | 63/64 | .98438 | 25.003 |
| 1/2 |  |  | .500 | 12.700 | 1 |  |  | 1.00000 | 25.400 |

History of Revisions