



Training Program

ASME Sec IX

WELDING PROCEDURES

and

WELDERS QUALIFICATION

WELDING QUALIFICATIONS

Why Procedure Qualification required?



- **Design engineer:** Selects material for a specific application
- **Welding Engineer:** Verify that weldment also meet the design criteria
- **Welding :** Important and critical operation in fabrication of pressure vessels, piping, boiler.
- **ASME SEC- IX :** Establishes the basic criteria for welding which are observed while preparation of requirements which affect procedure and performance.

WELDING QUALIFICATIONS



- **A Mandatory Requirement from Codes /Standards / Regulations**
- **In accordance with the Applicable Code / Standard / Regulation.**
- **Acceptance Criteria of Test Results as per the Code of Construction**
- **Qualification Records and Test Results to be Documented**

WHY PROCEDURE QUALIFICATION REQUIRED ?



DESIGN REQUIREMENT :

- Mechanical strength and Chemical composition of Material at intended Pressure and temperature.**

WELD JOINT REQUIREMENT

- Part of the component**
- Shall be as strong as the parent material**
- Shall have the strength same as that of base material at intended pressure & Temperature**

PROOF FOR CONFIRMATION

- NDT (Only Indicates weld Soundness)**
- Destructive Testing (determines Strength of Welds)**
- Sample of the weld and test for the required properties.**
- Call for a testing, for every new job and every new joint.**
- Concept of welding procedures helps to reduce the number of tests and hence the cost.**

QUALIFICATION REQUIREMENTS

APPLICATION

- Equipments, Vessels & Piping to be fabricated as per ASME Boiler & Pressure Vessel Code, Process & Power piping, American Petroleum Institute etc**

APPLICABLE CODES / STANDARDS

- ASME Sec IX + Applicable Design Code
(ASME Sec. VIII Div I or II, Sec. I, Sec. III, API 650, ASME ANSI B 31.3 / 31.1, API 1104, API 650 etc)**

ASME Sec IX is applicable for

- Welding Procedure Qualification**
- Welders' or Welding Operators' Performance Qualification**

ASME SEC IX CODE INTRODUCTION



ASME Sec IX deals with

- **Part QW (Welding)**
- **Part QB (Brazing)**
- **Each part is divided into further 4 articles**
 - **1. General requirements**
 - **2. Procedure Qualification**
 - **3. Performance Qualification**
 - **4. Data**

ASME SEC IX CODE INTRODUCTION

LIMITATIONS:



- 1. To be referred only when the design code (such as SEC VIII div.1), cross-references to this section**
- 2. Does not guide in the selection of electrode**
- 3. Does not guide in the design of joints**
- 4. Does not specify the type and extent of radiography/ NDT to be used**
- 5. Does not specify the acceptance criteria (i.e. types and extent of discontinuities acceptable).**
- 6. Does not specify Energy value for impact testing**

Refer the Design code For points specified in 3,4,5 and 6

ASME SEC IX CODE INTRODUCTION

WELDING PROCEDURE QUALIFICATION

When A WPS / PQR is Qualified:

Proves the Quality / Properties of Weld Joint Prepared by a set of welding variables

- Welding Process
- Base Material
- Welding consumable
- Welding Parameters & Techniques (Position, Polarity, Preheat, Inter Pass Temp. Back Gouging etc)
- PWHT

Qualification is limited to the essential variables of the Specific Process

WELDING PROCEDURE SPECIFICATION [QW-482]

WPS

- Written document showing all the applicable welding variables
- Provide direction for making production welds which will meet code requirements.

WELDING VARIABLES

- **ESSENTIAL VARIABLE:** significant effect on the weld properties if changed
- **NON-ESSENTIAL VARIABLE:** No significant effect on weld properties if changed.
- **SUPPLEMENTARY ESSENTIAL VARIABLE:** When other Sections specify notch-toughness tests and are in addition to the essential variables

Variables are listed for each welding process in QW-252 to QW-265

WPS should be available for reference and review by the inspector.
It should also be made available with welding supervisors, welders

WELDING PROCEDURE QUALIFICATION

PROCEDURE QUALIFICATION RECORDS

- A mock up : Represent welding done in a shop under similar conditions.
- Some codes call for a production weld coupons as an additional measure.
- Production coupons also act as qualification tests for the PQR
- Prepare A Weld Coupon Using an Preliminary WPS.
- Weld Coupon Undergoes Destructive Test
- Testing Requirements are specified in Sec IX
- Acceptance norms shall be as per Construction Code.
- PQR is limited to the essential variables of the Specific Process

WELDER PERFORMANCE QUALIFICATION



- Process of testing capability of the welder is known as "Welder Performance Qualification test"
- Ascertain the skill of a welder or a welding operator to Produce defect free/Sound weld
- Makes A Weld Coupon Using an Approved WPS
- Weld Coupon Undergoes Soundness Test (NDT or DT)
- Each Qualified Welder Shall be Assigned by A Unique Welder Number
- Welders' Qualifications Records Are Documented
- Performance Qualification is limited to the essential variables of the Specific Welding Process

UNDERSTAND ASME SEC. IX REQUIREMENTS

- Section has two parts : welding and brazing. [UW & UB]
- Under Welding there are 4 chapters (Article I to V), in addition to initial introduction.

Article I: General.

- **Positions of welding**
- **Examinations (Various Types of Tests, Testing Procedures, Specimen Details, Acceptance Criteria) etc.**

Article II - Welding Procedure Qualifications.

- **WPS, PQR**
- **Their contents, Format**
- **List of variables**
- **Qualification ranges**
- **Type and number of examinations required**

UNDERSTAND ASME SEC. IX REQUIREMENTS

Article III - Welding Performance Qualifications

- WPQ
- List of Variables
- Qualification ranges
- Type and number of examinations required

Article IV –

- Compiled welding data meant for using with articles I, II, III

Hence, for example, one who wants to qualify a welder can directly refer article III.

UNDERSTAND ASME SEC. IX REQUIREMENTS

Article V – Standard Welding Procedure Specifications (SWPs)

- Useful for small manufacturers, whose knowledge of welding is minuscule
- SWPSs will have to purchase them from AWS
- Instead of performing more PQR tests, manufacturer to perform and document a demonstration weld following a typical SWPS.
- Manufacturer to demonstrate and document that he knows enough about welding to follow the SWPS.
- After welding and testing one demonstration coupon, many other SWPSs may typically be used without further demonstrations.
- Not permitted for construction where impact testing of the WPS is required
- The specific requirements of SWPSs are covered in Article V (i.e., QW-500)
- Sample form (QW 485) is demonstrated in non mandatory Appendix B.
- The permitted SWPSs are listed in Appendix E
- These SWPSs cover welding of P-1 and P-8 metals using SMAW, GTAW and GMAW-FC.
- Typical thickness ranges permitted are 1/8" to 1-1/2" and both as-welded and post weld heat treated procedures (for P-1 metals) are available

UNDERSTAND ASME SEC. IX REQUIREMENTS

Important points for reading the welding data:

- Never read the welding data given in article IV unless called upon to do so by articles I, II or III
- Normally adding "a new qualification shall be done when ..." before reading data against essential variable given in the tables of Article II and III (such as QW 253), makes the reading easy
- Normally adding "a new qualification is not required when ..." before reading the data against non-essential variable given in the tables of article II (such as QW 253), makes the reading easy

QW-253
WELDING VARIABLES PROCEDURE SPECIFICATIONS (WPS)
Shielded Metal-Arc Welding (SMAW)

Paragraph		Brief of Variables	Essential	Supplementary Essential	Nonessential
QW-402 Joints	.1	ϕ Groove design			X
	.4	— Backing			X
	.10	ϕ Root spacing			X
	.11	± Retainers			X
QW-403 Base Metals	.5	ϕ Group Number		X	
	.6	T Limits Impact		X	
	.8	ϕ T Qualified	X		
	.9	± Pass > $\frac{3}{2}$ In. (13 mm)	X		
	.11	ϕ P-No. qualified	X		

UNDERSTAND ASME SEC. IX REQUIREMENTS

- Welding Data - Essential, Non Essential & Supplementary Essential Variables.
- Parent Metal Grouping - “P” No
- Filler Metal Grouping – “ F” No
- Weld Metal Composition Grouping – “A” No
- Welding Positions, Groove & Fillet
- Types of Tests – Tension, Guided Bend, Notch Toughness
- Test Requirements & Acceptance Limits
- Test Specimen – Location, Dimension & Testing Procedure
- Qualifications – Range in Thickness & Diameter
- Record & Documentation of WPS , PQR & WP

UNDERSTAND ASME SEC. IX REQUIREMENTS

Understand ASME Sec.II Part C.

- Specification for Filler Analysis – SFA No
- AWS Classification of Welding Consumable
- Limits for Chemical Composition & Mechanical Properties (including capability after PWHT) of Consumables

UNDERSTAND ASME SEC. IX REQUIREMENTS

Selection of Filler metal:

- “Match” the base metal properties; (Ys & UTS are expected to meet or exceed the minimum specified properties)
- Matching filler metal is required for complete joint penetration groove welds in tension or fillet welds loaded in shear .
- Depending on the type of weld joint and loading, lower filler metal strengths may be acceptable or desirable for specific designs.
- Codes, specifications, or contract documents may require specific mechanical properties that these recommendations do not meet.
- In those cases, electrode selection should be limited to those products that meet the specific application requirements.

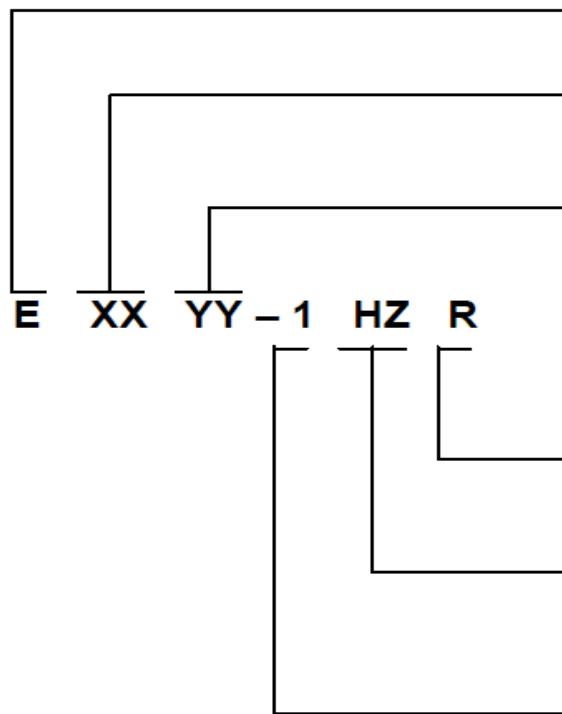
UNDERSTAND ASME SEC. IX REQUIREMENTS

- Check required levels of diffusible hydrogen in deposited weld metal
- The permissible H₂ level dependent on many factors, including preheat and inter pass temperatures intended to be used.
- The selected filler metals shall have proper preheat and inter pass temperatures
- Consider notch toughness (example Charpy V-Notch properties),
- PWHT (SR / Normalizing) requirements.

UNDERSTAND ASME SEC. IX REQUIREMENTS

Welding Filler Metal Designators:

1. Carbon Steel Electrodes:



Mandatory Classification Designators:

Designates an Electrode

Designates minimum tensile strength, in ksi, of the as-deposited weld metal

Designates the welding position, the type of covering and the type of welding current for which the electrodes are suitable (see table below)

Optional Supplemental Designators:

Designates that the electrode meets the requirements of absorbed moisture

Designates that the electrode meets the requirements of the diffusible hydrogen test—with an average value not exceeding “Z” mL of H₂ per 100gms of deposited metal

Designates that the electrode meet the requirements for improved toughness and ductility

UNDERSTAND ASME SEC. IX REQUIREMENTS

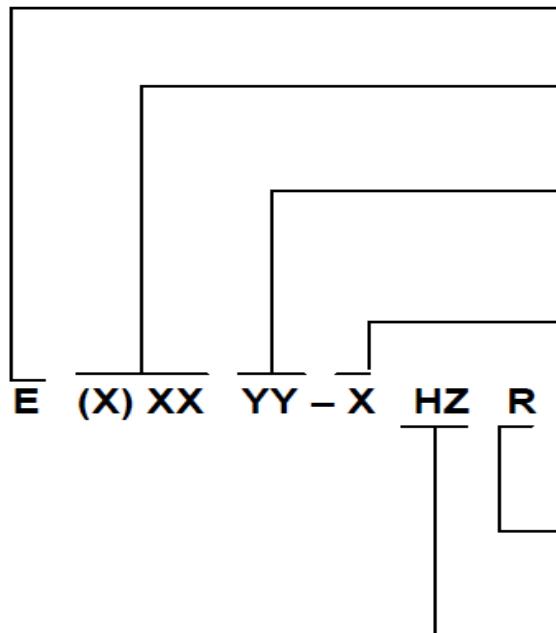
Electrode Classification			
AWS Classification	Type of Covering	Welding Position ^a	Type of current ^b
E 6010	High cellulose, sodium	F, V, OH, H	dcep
E 6011	High Cellulose, Potassium	F, V, OH, H	ac or dcep
E 7018	Low hydrogen, Potassium, Iron Powder	F, V, OH, H	ac or dcep
E 7024	Iron Powder, Titania	H-Fillets, F	ac, dcep or dcen

- Notes:
- a. The abbreviations indicate the welding positions
F=Flat; V= Vertical, OH= Overhead, H= Horizontal,
H-Fillets=Horizontal Fillets.
 - b. The term dcep refers to direct current electrode positive (dc, reverse polarity).
The term dcen is direct current electrode negative (dc, straight polarity)

Also note that the above electrode classifications are the most widely used and does not include all of the available classifications. Refer to AWS A 5.1 for complete listing.

UNDERSTAND ASME SEC. IX REQUIREMENTS

Alloy Steel Electrodes:



Mandatory Classification Designators:

Designates an Electrode

Designates minimum tensile strength, in ksi, of the as-deposited weld metal

Designates the welding position, the type of covering and the type of welding current for which the electrodes are suitable

Designates the chemical composition of the undiluted weld metal produced by the electrode using SMAW process

Optional Supplemental Designators:

Designates that the electrode meets the requirements of absorbed moisture

Designates that the electrode meets the requirements of the diffusible hydrogen test—with an average value not exceeding "Z" mL of H₂ per 100gms of deposited metal, where "Z" is 4, 8 or 16

UNDERSTAND ASME SEC. IX REQUIREMENTS

Table 1: Carbon and Low-Alloy Steel Welding Consumables for SMAW Process

Base Material	Carbon Steel	Carbon-Molybdenum Steel	1 and 1 1/4 Cr-1/2 Mo Steel	2 1/4 Cr-1Mo Steel	5Cr- 1/2 Mo Steel	9Cr-1Mo Steel
Carbon steel	AB	AC	AD	AE	AF	AG
Carbon-Molybdenum Steel		C	CD	CE	CF	CH
1 and 1 1/4 Cr - 1/2 Mo Steel			D	DE	DF	DH
2 1/4 Cr - 1 Mo Steel				E	EF	EH
5 Cr - 1/2 Mo Steel					F	FH
9 Cr- 1 Mo Steel						H

UNDERSTAND ASME SEC. IX REQUIREMENTS

Legend:

- A AWS A 5.1 Classification E 70XX low hydrogen (E7018 preferred)**
- B AWS A 5.1 Classification E6010**
- C AWS A 5.5 Classification E70XX - A1, low hydrogen**
- D AWS A 5.5 Classification E70XX-B2L or E80XX-B2, low hydrogen**
- E AWS A 5.5 Classification E80XX-B3L or E90XX-B3, low hydrogen**
- F AWS A 5.5 Classification E80XX-B6 or E80XX-B6L, low hydrogen**
- G AWS A 5.5 Classification E80XX-B7 or E80XX-B7L, low hydrogen**
- H AWS A 5.5 Classification E80XX-B8 or E80XX-B8L, low hydrogen**

WRITE A WELDING PROCEDURE SPECIFICATION

CONTENTS OF WPS

- Describes all essential and non-essential variables for each welding process used in WPS.**
- Also mention the supporting procedure qualification records.**

FORMAT OF WPS :

- May be written in any format suitable to the manufacturer.**
- Ensure that all essential and supplementary essential variables are listed**

STEP BY STEP PROCEDURE OF PREPARING A WPS

- **Selection of a suitable welding process**
- **Fill in the suggested format of PQR**
- **Ensure that all the welding variables are covered**
- **Make a preliminary WPS based on the above PQR**
- **Weld a coupon as per the above WPS**
- **Carry out the examinations**
- **Make final WPS & PQR if the results are satisfactory**
- **It Provides Direction for A Specific Welding**
- **WPS Format is Available in ASME Sec. IX**
- **Each WPS Shall be Assigned with A Unique Number**

STEP BY STEP PROCEDURE OF PREPARING A WPS

QW-482 SUGGESTED FORMAT FOR WELDING PROCEDURE SPECIFICATIONS (WPS) (See QW-200.1, Section IX, ASME Boiler and Pressure Vessel Code)

Company Name _____ By _____

Welding Procedure Specification No. _____ Date _____ Supporting PQR No.(s) _____

Revision No. _____ Date _____

Welding Process(es) _____ Type(s) _____
(Automatic, Manual, Machine, or Semi-Automatic)

JOINTS (QW-402)

Details

Joint Design _____

Root Spacing _____

Backing: Yes _____ No _____

Backing Material (Type) _____
(Refer to both backing and retainers)

Metal Nonfusing Metal

Nonmetallic Other

Sketches, Production Drawings, Weld Symbols, or Written Description
should show the general arrangement of the parts to be welded. Where
applicable, the details of weld groove may be specified.

[At the option of the manufacturer, sketches may be attached to illustrate
joint design, weld layers, and bead sequence (e.g., for notch toughness
procedures, for multiple process procedures, etc.)]

PREPARE A TEST COUPON AS PER WPS

- Coupon Size: Pair of 300 mm X 150 mm Plates or
Or Pipes 150 mm long as Specified in WPS
(Length of plate or diameter of pipes shall be capable of include all Mechanical tests)
- Keep every items ready required as per Written WPS
- Complete the Welding by Reasonably Skilled Welder
 - All Welding Variables Shall be Used Within the Limit Specified in WPS.
 - All Variables Actually Used Shall be Documented as Annexure to PQR

NDT Of Weld Coupon – Optional

- X-Ray / Radiograph the Weld Joint (Not a Code Requirement)
- Mark Transverse Tensile & Guided Bends As Per QW463
- Eliminate Defective Weld Portion If Any, While Marking the Test Specimens
- Preserve RT Report & X-Ray Film as Annexure to PQR

TYPE OF TEST REQUIRED

- Weld metal should also have the essential properties of the base metal.
- Qualification on grooves weld also qualifies for fillet welds.
- Procedure Qualification in any position qualify for all position, provided welding, process and electrodes are suitable for use in a specific position.
- Where notch-toughness is a requirement of construction code the PROCEDURE QUALIFICATION should be carried out in 3G or 6G only.
- Welder who makes successful procedure qualification test is qualified to weld in applicable position

TYPE OF TEST REQUIRED

6) Mechanical Tests – QW 451, Groove Weld.

Up to 9 mm Thickness

- Transverse Tensile :- 2 No
- Root Bend :- 2 No
- Face Bend :- 2 No

From 10 mm to less than 19 mm Thickness

- Transverse Tensile :- 2 No
 - Root Bend :- 2 No
 - Face Bend :- 2 No
- OR Side Bend :- 4 No (in place of Face & root Bend)**

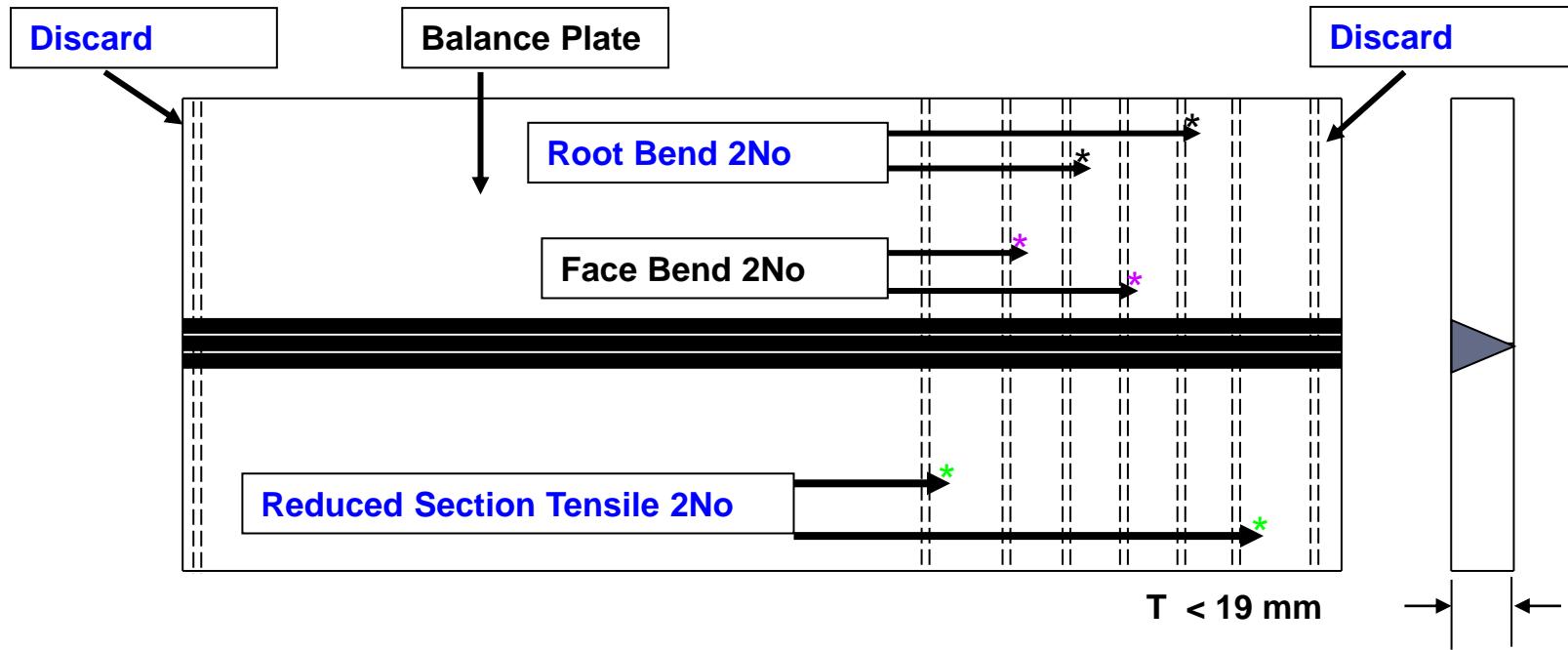
From 19 mm and above Thickness

- Transverse Tensile :- 2 No
- Side Bend :- 4 No

Location of Test Specimens From Test coupon

QW 463.1

Plates Less Than 19 mm



When Plate Thickness is 19 mm or more, In place of Root & Face, 4 Side
Bends shall be Taken

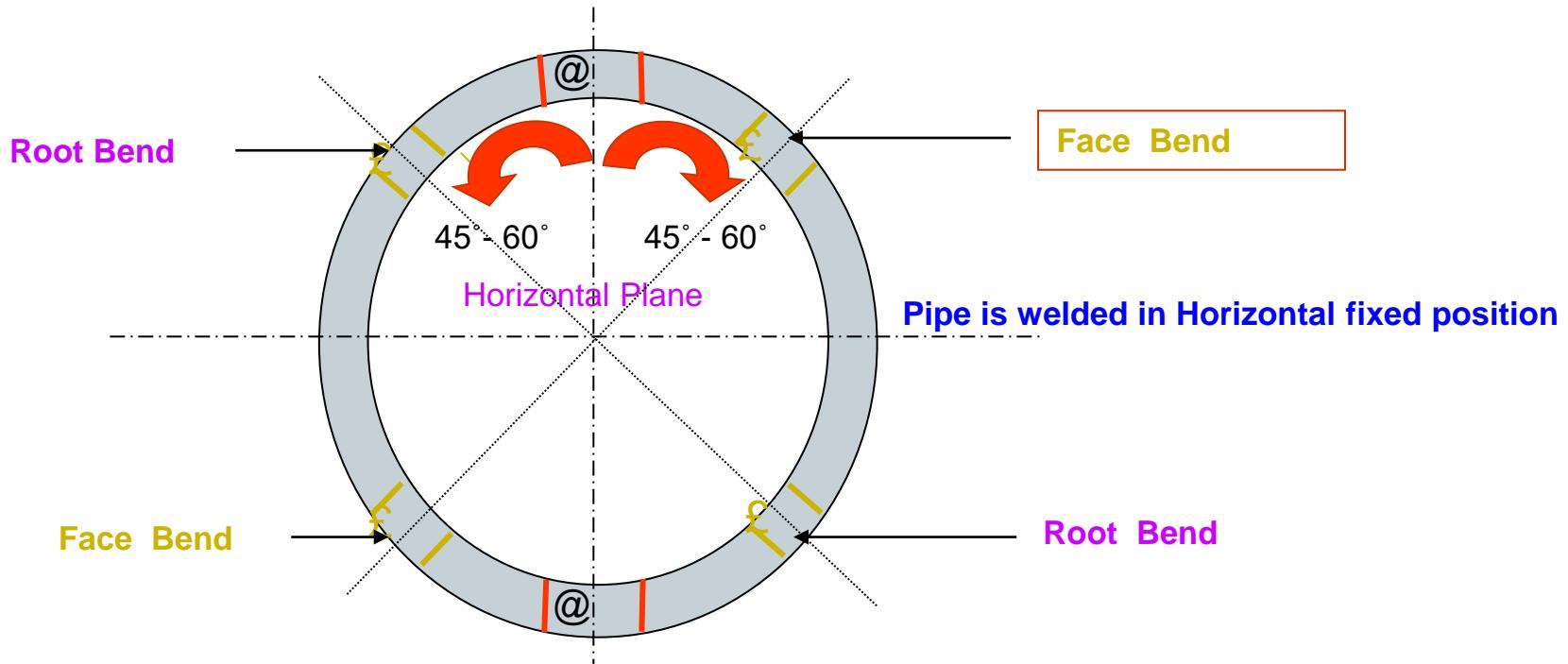
Location of Test Specimens From Test coupon

QW 463.1

Pipe

- **@ = Reduced section Tensile 2No**

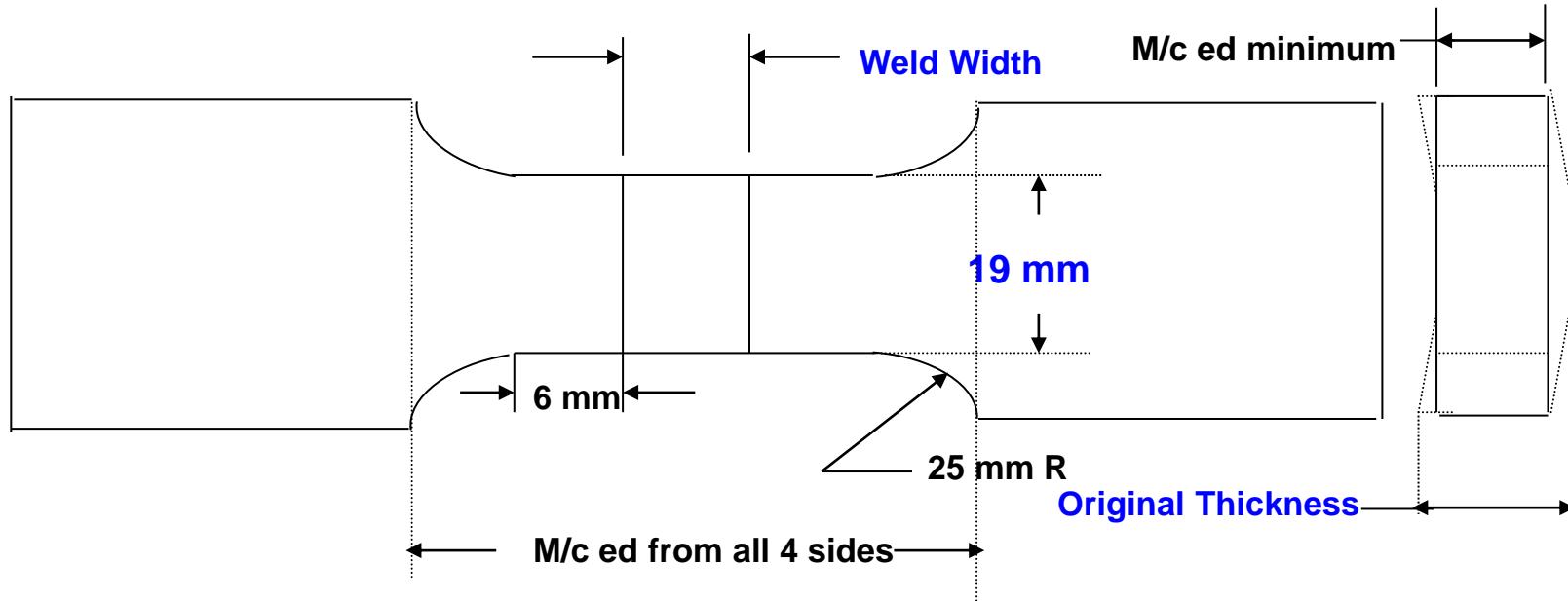
£ = Bends - Root & Face or Side



When Pipe Thickness is 19 mm or more, In place of Root & Face, 4 Side Bends shall be Taken

“Reduced Section” Tensile Specimen

From Pipe QW 462.1



Acceptance Criteria for Test Results

Tensile Strength (QW - 422) (QW 153)

- Minimum Tensile Strength of Material Used
- Minimum Tensile Strength of weaker Material when two different minimum tensile strength materials are used
- If the specimen breaks in the BM or HAZ, TS shall not be less than 95% below the minimum specified T.S of the BM

Bend Test (QW - 163)

- Opening Not More Than 3 mm in Any Direction on Convex Surface Within the Weld & HAZ

GENERAL NOTE: For Tensile tests, failure in HAZ is considered as 'base metal failure' whereas for bend tests, the failure in HAZ is considered as a 'weld metal failure'.

ACCEPTANCE CRITERIA FOR PROCEDURE

Fillet welds Macro examination (QW-183)

- **Cross sections of the weld metal and HAZ shall show complete fusion and freedom from cracks**
- There shall not be more than 1/8 in (3mm) difference in the legs of the fillet weld.

PQR – PROCEDURE QUALIFICATION RECORD

- PQR Format Available in Sec. IX (FORMAT QW- 483)**
- Record All Relevant Data in the Format.**
- Record Actual values/range of all essential, Non essential and supplementary essential(whenever required) variables**
- Record All Mechanical Test Results**
- Attach All Test Reports & Welding Parameters Used as Annexure to PQR**
- Assign Unique Number to Each PQR**
- WPS No Shall be Referred in PQR**

PROCEDURE QUALIFICATION RECORD (PQR)

- **Types of test conducted.**
- **Number of test conducted. Results of tests.**
- **A PQR should be certified by the Manufacturer.**
- **Changes to PQR are not permitted. However, correction can be made for example, if P No. or F No. or any other information is wrong then the same can be corrected.**
- **Additional information can be incorporated at a later date provided it can be substantiated as having been part of original qualification condition by some lab Record or similar document.**
- **PQR used for supporting WPS should be available for review by the inspector.**

PROCEDURE QUALIFICATION RECORD (PQR)

QW-483 SUGGESTED FORMAT FOR PROCEDURE QUALIFICATION RECORDS (PQR)

(See QW-200.2, Section IX, ASME Boiler and Pressure Vessel Code)

Record Actual Variables Used to Weld Test Coupon

Company Name _____

Procedure Qualification Record No. _____ Date _____

WPS No. _____

Welding Process(es) _____

Types (Manual, Automatic, Semi-Automatic) _____

JOINTS (QW-402)

Groove Design of Test Coupon

(For combination qualifications, the deposited weld metal thickness shall be recorded for each filler metal and process used.)

BASE METALS (QW-403)

Material Spec. _____

Type/Grade, or UNS Number _____

P-No. _____ Group No. _____ to P-No. _____ Group No. _____

Thickness of Test Coupon _____

Diameter of Test Coupon _____

Maximum Pass Thickness _____

POSTWELD HEAT TREATMENT (QW-407)

Temperature _____

Time _____

Other _____

THICKNESS LIMIT FOR GROOVE BUTT WELD PROCEDURE

QW451

Thickness "T" Of Test Coupon Welded in mm	Range Of Thickness "T" of BM Qualified in mm		Thickness "t" of Deposited Weld metal Qualified in mm
	Minimum	Maximum	Maximum
Less Than 1.6 (1/16")	T	2T	2t
1.6 to 10 (1/16" to" 3/8")	1.5 (1/16")	2T	2t
10 to 19 (3/8" to 3/4 ")	5 (3/16")	2T	2t
19 to 38 (3/4 " to 1 1/2")	5 (3/16")	2T	2t When $t < 19$
19 to 38 (3/4 " to 1 1/2")	5 (3/16")	2T	2T When $t \geq 19$
38 (1 1/2") and over	5 (3/16")	200 (8")	2t When $t < 19$
38 (1 1/2") and over	5 (3/16")	200 (8")	200 When $t \geq 19$
Over 200 (8") – QW 403.7	5 (3/16")	1.33 T	1.33 t

THICKNESS LIMIT FOR GROOVE BUTT WELD PROCEDURE

QW451

Thickness selection is the important and mostly confused parameter

Welding procedure

Following parameters governs in the selection of thickness

- **Test coupon thickness - governs the range**
- **Impact requirement - governs the lower limit**
- **Normalizing requirement - governs the upper limit**

Appendix-I describes thickness selection in more detail.

Welders qualification

One must preferably qualify a welder with a coupon of 13 mm thickness or more which will qualify him to weld deposit of any thickness.

THICKNESS LIMIT FOR GROOVE BUTT WELD PROCEDURE

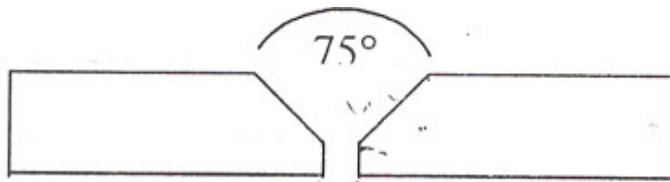
QW451

Appendix I

Determination of test coupon thickness for welding procedure qualification

Ideally one must start with tables such as QW-253/256, proceed to welding data such as QW-403.8 (as specified in the tables) and then proceed to QW-451(as specified in the data) and select the thickness in such a way as to cover the largest range.

Let us take an example to illustrate the above point



Process (assumption)

-2 layers (root and hot pass $t=5$ mm) of GTAW and rest by SMAW (fill-up and final).

-Thickness 16 mm (Case I) & 32 mm (Case II)

THICKNESS LIMIT FOR GROOVE BUTT WELD PROCEDURE

QW451

Step 1: Start with thickness same as the job.

Heat treatment - Normalizing

But, code does not permit dissimilar thickness for the Min. design temperature. - 48°C test coupon

Step 2: choose 16mm (arbitrary), This will qualify us for,

Reference	Thickness			
	T of base metal	t of weldmetal, max	GTAW	SMAW
From	To			
As per QW-450 (Based on Thickness of the coupon)	5	32	10	22
As per QW-407.4 (due to normalizing)	5	@18	5.5	12
As per QW-403.6 (due to impact test requirement)	16	32	10	22
Result	16	@18	5.5	12

THICKNESS LIMIT FOR GROOVE BUTT WELD PROCEDURE

QW451

Step 3: choose 32 mm (arbitrary), This will qualify us for,

Reference	Thickness			
	T of base metal	t of weld metal, max	GTAW	SMAW
	From	To		
As per QW-450 (Based on Thickness of the coupon)	5	64	10	64
As per QW-407.4 (due to normalizing)	5	35	5.5	@ 30
As per QW-403.6 (due to impact test requirement)	16	64	10	64
Result	16	35	5.5	@ 30

THICKNESS LIMIT FOR GROOVE BUTT WELD PROCEDURE

QW451

One must note that the step 3 gives us the largest range. One may, however, choose any thickness higher than 32 mm, but this would not yield any additional benefit due to the presence of normalizing in the job requirement in this example.

Additionally QW407.2 indirectly restrains us from choosing a thickness varying too much from that of job.

What happens when a production weld has two dissimilar metal thicknesses?

This shall be arrived at in two steps

1. Thickness of the thinner member shall be as permitted by QW-451
2. Thickness of the thicker member shall be
 - i. Unlimited for specified material provided
 - a) material are of same P number.
 - b) qualification is made on $>\frac{1}{4}$ "
 - ii. limited within the range of QW-451

PROCEDURE QUALIFICATION

QW-253 SMAW Variable

Group of Variables	Brief Of Variables	Essential	Supplementary Essential	Nonessential
QW 402 Joints	Change in Groove Design	--	--	*
	Addition / Deletion of Backing	--	--	*
QW 403 Base Metals	Change in group Of P No	--	*	--
	T Limits Impact	--	*	--
	T/t Limits \odot 203 mm	*	--	--
	Change in T Qualified	*	--	--
	"t" pas \odot 13 mm	*	--	--
	Change of P Number Qualified	*	--	--
QW 404 Filler Metals	Change in F No	*	--	--
	Change in A No	*	--	--
	Change in Dia	--	--	*
	Change in Dia \odot 6 mm	--	*	--
	Change in AWS classification	--	*	--
	Change in t qualified	*	--	--

PROCEDURE QUALIFICATION

QW-253 SMAW Variable

Group of Variables	Brief Of Variables	Essential	Supplementary Essential	Nonessential
QW 405 Positions	Addition of Position	--	--	*
	Change in Position	--	*	--
QW 406 Preheat	Decrease \ominus 56°C	*	--	--
	Increase \oplus 56°C IP	--	*	--
QW 407 PWHT	Addition / Deletion of PWHT	*	--	--
	Change in Time & Temp. Qualified	--	*	--
QW 409 Electrical Characteristics	Increase in Heat Input	--	*	--
	Change in Current / Polarity	--	*	--
	Change in Current / Voltage	--	--	*
QW 410 Technique	Change from String / Weave	--	--	*
	Method of Cleaning	--	--	*
	Method of Back Gouging	--	--	*
	Change From Multiple to Single Pass	--	*	--

PROCEDURE QUALIFICATION

QW-253
 WELDING VARIABLES PROCEDURE SPECIFICATIONS (WPS)
 Shielded Metal-Arc Welding (SMAW)

Paragraph		Brief of Variables	Essential	Supplementary Essential	Nonessential
QW-402 Joints	.1	ϕ Groove design			X
	.4	- Backing			X
	.10	ϕ Root spacing			X
	.11	\pm Retainers			X
QW-403 Base Metals	.5	ϕ Group Number		X	
	.6	T Limits Impact		X	
	.8	ϕ T Qualified	X		
	.9	t Pass > $\frac{1}{2}$ In. (13 mm)	X		
	.11	ϕ P-No. qualified	X		
QW-404 Filler Metals	.4	ϕ F-Number	X		
	.5	ϕ A-Number	X		
	.6	ϕ Diameter			X
	.7	ϕ Diameter > $\frac{1}{4}$ In. (6 mm)		X	
	.12	ϕ Classification		X	
	.30	ϕ t	X		
	.33	ϕ Classification			X
QW-405 Positions	.1	+ Position			X
	.2	ϕ Position		X	
	.3	ϕ ↑↓ Vertical welding			X

PROCEDURE QUALIFICATION

QW-406 Preheat	.1	Decrease > 100°F (55°C)	X		
	.2	ϕ Preheat maint.			X
	.3	Increase > 100°F (55°C) (IP)		X	
QW-407 PWHT	.1	ϕ PWHT	X		
	.2	ϕ PWHT (T & T range)		X	
	.4	T Limits	X		
QW-409 Electrical Characteristics	.1	> Heat Input		X	
	.4	ϕ Current or polarity		X	X
	.8	ϕ I & E range			X
QW-410 Technique	.1	ϕ String/weave			X
	.5	ϕ Method cleaning			X
	.6	ϕ Method back gouge			X
	.9	ϕ Multiple to single pass/side		X	X
	.25	ϕ Manual or automatic			X
	.26	± Peening			X
	.64	Use of thermal processes	X		

Legend:

+ Addition	> Increase/greater than	↑ Uphill	← Forehand	ϕ Change
- Deletion	< Decrease/less than	↓ Downhill	→ Backhand	

PROCEDURE QUALIFICATION CLAUSES

QW-402.11 The addition or deletion of nonmetallic retainers or nonfusing metal retainers.

QW-403.5 Welding procedure specifications shall be qualified using one of the following:

- (a) *the same base metal (including type or grade) to be used in production welding*
- (b) *for ferrous materials, a base metal listed in the same P-Number Group Number in table QW/QB-422 as the base metal to be used in production welding*
- (c) *for nonferrous materials, a base metal listed with the same P-Number UNS Number in table QW/QB-422 as the base metal to be used in production welding*

For ferrous materials in table QW/QB-422, a procedure qualification shall be made for each P-Number Group Number combination of base metals, even though procedure qualification tests have been made for each of the two base metals welded to itself. If, however, two or more qualification records have the same essential and supplementary essential variables, except that the base metals are assigned to different Group Numbers within the same P-Number, then the combination of base metals is also qualified.

PROCEDURE QUALIFICATION CLAUSES

QW-404.4 A change from one F-Number in table QW-432 to any other F-Number or to any other filler metal not listed in table QW-432.

QW-404.5 (Applicable only to ferrous metals.) A change in the chemical composition of the weld deposit from one A-Number to any other A-Number in table QW-442. Qualification with A-No. 1 shall qualify for A-No. 2 and vice versa.

QW-407.1 A separate procedure qualification is required for each of the following:

(a) *For P-Numbers 1 through 6 and 9 through 15F materials, the following post weld heat treatment conditions apply:*

- (1) *no PWHT*
- (2) *PWHT below the lower transformation temperature*
- (3) *PWHT above the upper transformation temperature (e.g., normalizing)*
- (4) *PWHT above the upper transformation temperature followed by heat treatment below the lower transformation temperature (e.g., normalizing or quenching followed by tempering)*
- (5) *PWHT between the upper and lower transformation temperatures*

(b) *For all other materials, the following post weld heat treatment conditions apply:*

- (1) *no PWHT or*
- (2) *PWHT within a specified temperature range*

PROCEDURE QUALIFICATION

QW-256 GTAW Variable

Group of Variables	Brief Of Variables	Essential	Supplementary Essential	Nonessential
QW 402 Joints	Change in Groove Design	--	--	*
	Addition / Deletion of Backing	--	--	*
QW 403 Base Metals	Change in group Of P No	--	*	--
	T Limits Impact	--	*	--
	T / t Limits \odot 203 mm	*	--	--
	Change in T Qualified	*	--	--
	Change From T Qualified	*	--	--
	Change From P Number Qualified	*	--	--
QW 404 Filler Metals	Change in F No	*	--	--
	Change in A No	*	--	--
	Change in AWS Classification	--	*	--
	Addition / Deletion of Filler	*	--	--
	Addition / Deletion of Consumable Insert	--	--	*
	Change From Solid – Flux / Powder Cored	*	--	--

PROCEDURE QUALIFICATION

QW-256 GTAW Variable

Group of Variables	Brief Of Variables	Essential	Supplementary Essential	Nonessential
QW 405 Positions	Addition of Position	--	--	*
	Change in Position	--	*	--
QW 406 Preheat	Decrease \triangle 56°C	*	--	--
	Increase \triangle 56°C IP	--	*	--
QW 407 PWHT	Addition / Deletion of PWHT	*	--	--
	Change in Time & Temp. Qualified	--	*	--
	Change in T thickness Qualified	*	--	--
QW 408 Gas	Addition / Deletion / Change in Trailing Gas	--	--	*
	Addition / Deletion / Change in Shielding Gas	*	--	--
	Change in Flow Rate of Shielding / Backing Gas	--	--	*
	Deletion of Backing Gas	*	--	--

PROCEDURE QUALIFICATION

QW-256 GTAW Variable

Group of Variables	Brief Of Variables	Essential	Supplementary Essential	Nonessential
QW 409 Electrical Characteristics	Increase in Heat Input	--	*	--
	Change in Tungsten Electrode Size	--	--	*
	Addition / Deletion of Pulsing	--	--	*
	Change in Current or Polarity	--	*	--
QW 410 Technique	Change in Nozzle / Gas Cup Size	--	--	*
	Method of Cleaning	--	--	*
	Change in Oscillation	--	--	*
	Method of Back Gouging	--	--	*
	Change From Single to Multi Electrode	--	*	--
	Change From Closed Chamber to Out Side	*	--	--
	Change From Manual to Auto / Auto to Manual	--	--	*
	Addition or Deletion of Preening	--	--	*

P – NUMBER GROUPING

Base Metal For Qualification

P number is the grouping : Based on BM chemical composition, weldability and mechanical properties etc.

P stands for Parent metal.

Table QW422 lists the P numbers of various materials.

QW423 and QW424 describe the rules for using the P numbers for qualifications. With the help of P numbers the number of qualification tests required are greatly reduced. For example all plain carbon steels (SA105, SA106, SA515, SA516 etc.) are assigned a P number of 1.

Group number is a sub-grouping of ferrous Base Materials having specified impact test requirements, within a P number. Table QW422 lists the Group numbers of various materials. Group number depends on strength of material. This will be an additional restriction on P number when impact testing is required for the base / weld metal in the job specification.

P – NUMBER GROUPING

Base Metal For Qualification

Example:

A procedure qualified using a plates confirming to SA516 Gr.60 can be used to weld a joint between the pipes confirming to SA106 Gr. B assuming that all other parameters remain unaffected.

In the WPS it is enough if only P number and group number are specified.

When they are not known, material specification shall be written (ex.. if base material IS2062). When specification also is not known, chemical composition shall be written. The latter options actually reduce the range qualified

S – NUMBER GROUPING

Base Metal For Qualification

S Numbers

S-Numbers: Assigned to materials that were acceptable for use by the ASME B31 Code for Pressure Piping, or by selected Boiler and Pressure Vessel Code Cases, but which were not included within ASME Boiler and Pressure Vessel Code Material Specifications (Section II).

P – NUMBER GROUPING (SAMPLE : CS)

Base Metal For Qualification

P- No	Group No	Met. Spec.	Grade	Met. Quality & Form
P1	1	SA 515 / SA 516	60	CS – Plate
	2	SA 515 / SA 516	70	CS – Plate
P1	1	SA 106	A / B	CS – Pipe
	2	SA 106	C	CS - Pipe
P1	1	SA333	6	CS – Pipe
	3	SA 333	10	CS - Pipe
P1	1	SA 234	WPB	CS Pipe Fitting
	2	SA 234	WPC	CS Pipe Fitting
P1	1	SA 285	C / B	CS Plate
P1	1	SA 179	---	CS Tube
P1	2	SA 105	---	CS Forging
	2	SA 181	Cl 70	CS Forging

P – NUMBER GROUPING (SAMPLE : C + Mo /Mn))

(Base Metal For Qualification)

P- No	Group No	Met. Spec.	Grade	Met. Quality & Form
P3	2	SA 302	A	Mn – 0.5 Mo – Plate
	3	SA 302	B,C,D	Mn – 0.5 Mo – Plate
P3	1	SA 335	P1 / P2	C – 0.5 Mo – Pipe
P3	3	SA 533	TP- B, Cl- 1 or 2	C – 0.5 Mo – Plate
P3	1	SA 209	T1, T1a, T1b	C – 0.5 Mo – Tube
P3	2	SA 282	F1	C – 0.5 Mo – Forging

P – NUMBER GROUPING (SAMPLE : LAS)

Base Metal For Qualification

P- No	Group No	Met. Spec.	Grade	Met. Quality & Form
P4	1	SA 387	12, Cl – 1 / 2	1Cr. 0.5 Mo – Plate
	3	SA 387	11, Cl – 1 / 2	1.25 Cr. 0.5 Mo – Plate
P4	1	SA 335	P12 / P11	1Cr (1.25 Cr) – 0.5 Mo – Pipe
P4	2	SA 423	TP - 1 / 2	1.25 Cr. 0.5 Mo – Tube
P4	1	SA 282	F12, Cl- 1 / 2	1. Cr – 0.5 Mo – Forging
		SA 336	F11, Cl – 1 / 2 / 3	1.25 Cr – 0.5 Mo – Forging

P – NUMBER GROUPING (SAMPLE : LAS)

Base Metal For Qualification

P- No	Group No	Met. Spec.	Grade	Met. Quality & Form
P5A	1	SA 387	22, Cl –1 / 2	2. 25 Cr. 1 Mo – Plate
P5B	1	SA 387	5, Cl - 2	5 Cr. 0.5 Mo - Plates
P5A	1	SA 335	P22	2. 25 Cr. 1 Mo – Pipe
P5A	1	SA 213	TP - 22	2. .25 Cr. 1 Mo – Tube
P5B	1	SA 182	F5	5 Cr – 0.5 Mo – Forging
P5C	1	SA 182	F22V	2. 25 Cr – 1 Mo,V – Forging
P5A	1	SA 336	F22, Cl –1 / 3	2. 25 Cr – 1 Mo – Forging

P – NUMBER GROUPING (SAMPLE : High Alloy)

Base Metal For Qualification

P- No	Group No	Met. Spec.	Grade	Met. Quality & Form
P6	2	SA 240	TP 429	15Cr. – Plate
P6	4	SA 731	S41500	13Cr., 4.5 Ni, Mo - Pipe
P6	1	SA 268	TP410	13Cr. – Tube
P6	3	SA 336	F6	13Gr.– Forging
P7	2	SA182	F430	17Cr. - Forging
P7	2	SA 240	TP 430	17Cr. - Plate
P7	2	SA 268	TP430	17Cr. Tube
P7	2	SA 731	TP439	18Cr., Ti – Pipe

P – NUMBER GROUPING (SAMPLE : SS)

Base Metal For Qualification

P- No	Group No	Met. Spec.	Grade	Met. Quality & Form
P8	1	SA 312	TP321	18Cr., 10Ni, Ti - Pipe
	1	SA 312	TP347	18Cr., 10Ni, Cb - Pipe
P8	1	SA336	TP316	18Cr., 8 Ni, 2Mo -Forging
	1	SA 336	TP310	25Cr., 20 Ni, Forging
P8	1	SA 240	TP304	18Cr, 8Ni - Plates
	2	SA 204	TP309S	23Cr. 12Cr. - Plates
P8	1	SA 249	TP317	18Cr, 13Ni, 3Mo –Tube
	1	SA 249	TP316L	16Cr, 12Ni, 2Mo - Tube

P – NUMBER GROUPING (SAMPLE : Ni based LTCS)

Base Metal For Qualification

P- No	Group No	Met. Spec.	Grade	Met. Quality & Form
P9B	1	SA 333	3	3.5Ni - Pipe
P9A	1	SA334	7	2.5Ni - Tube
P9A P9B	1	SA 350	LF5, Cl. 2	1.5Ni - Forging
	1	SA 350	LF3	3.5Ni. - Forging
P9A P9B	1	SA 203	A	2.5Ni. - Plate
	1	SA 203	E	3.3Ni. - Plate

P – NUMBER GROUPING (SAMPLE : Ni + Alloy based)

Base Metal For Qualification

P- No	Group No	Met. Spec.	Grade	Met. Quality & Form
P11A	1	SA 333	8	9Ni - Pipe
P11A	1	SA334	8	9Ni - Tube
P11A	5	SA 508	4N, Cl. 2	3.5Ni –1.75 Cr.-0.5Mo.- V, Forging
P11A	5	SA 508	5, Cl. 2	3.5Ni –1.75 Cr.-0.5Mo.- V, Forging
P11A	4	SA 533	TP B, Cl. 3	Mn, 0.5 Mo, 0.5Ni – Plate
P11A	4	SA 533	TP C, Cl. 3	Mn, 0.5 Mo, 0.75Ni - Plate

P – NUMBER GROUPING

P Numbers SS

materials

10)

QW/QB-422 FERROUS/NONFERROUS P-NUMBERS (CONT'D)

Grouping of Base Metals for Qualification

Spec. No.	Type or Grade	UNS No.	Minimum Specified Tensile, kSI (MPa)	Ferrous (CONT'D)		ISO 15608 Group	Nominal Composition	Product Form
				P-No.	Group No.			
SA-240	Type 310Cb	S31040	75 (515)	8	2	102	8.2	25Cr-20NI-Cb
SA-240	Type 310HCb	S31041	75 (515)	8	2	102	8.2	25Cr-20NI-Cb
SA-240	Type 310MoLN	S31050	80 (550)	8	2	102	8.2	25Cr-22NI-2Mo-N
SA-240	S31200	S31200	100 (690)	10H	1	102	10.2	25Cr-6NI-Mo-N
SA-240	S31254	S31254	94 (650)	8	4	102	8.2	20Cr-18NI-6Mo
SA-240	S31260	S31260	100 (690)	10H	1	102	10.2	25Cr-6.5NI-3Mo-N
SA-240	S31277	S31277	112 (770)	45	...	111	8.2	27NI-22Cr-7Mo-Mn-Cu
SA-240	Type 316	S31600	75 (515)	8	1	102	8.1	16Cr-12NI-2Mo
SA-240	Type 316L	S31603	70 (485)	8	1	102	8.1	16Cr-12NI-2Mo
SA-240	Type 316H	S31609	75 (515)	8	1	102	8.1	16Cr-12NI-2Mo
SA-240	Type 316TI	S31635	75 (515)	8	1	102	8.1	16Cr-12NI-2Mo-TI
SA-240	Type 316Cb	S31640	75 (515)	8	1	102	8.1	16Cr-12NI-2Mo-Cb
SA-240	Type 316N	S31651	80 (550)	8	1	102	8.1	16Cr-12NI-2Mo-N
SA-240	Type 316LN	S31653	75 (515)	8	1	102	8.1	16Cr-12NI-2Mo-N
SA-240	Type 317	S31700	75 (515)	8	1	102	8.1	18Cr-13NI-3Mo
SA-240	Type 317L	S31703	75 (515)	8	1	102	8.1	18Cr-13NI-3Mo

F – NUMBER GROUPING

Filler Metal For Qualification



F number

- **Grouping of electrodes and filler materials**
- **Based on their usability characteristics**
- **Governed by flux or shielding medium used (which also govern their electrical characteristics).**
- F stands for Filler metal.
- These are described in QW430 / QW 432

QW-432
F-NUMBERS

Grouping of Electrodes and Welding Rods for Qualification

F-No.	ASME Specification	AWS Classification	UNS No.
Steel and Steel Alloys			
1	SFA-5.1	EXX20	...
1	SFA-5.1	EXX22	...
1	SFA-5.1	EXX24	...

F – NUMBER GROUPING

Filler Metal For Qualification



F No	Carbon Steel	Low Alloy Steel	Stainless steel & Duplex steel	Product form
F5			E-308 L 16 E 316 L 15 E-309 -16	Electrodes
F4	E-7018 , E-7016 E-8018-G (SFA 5.1)	E-8018 B2, E-9018 C3 (SFA 5.5)		Electrodes
F-3	E-6010, E-7010 E-6011 (SFA-5.1)	E-6010, E-7010 E-6011 (SFA-5.1)		Electrodes
F-2	E-6013	E(X)XX13-X		Electrodes
F-1	EXX20	EXX20-X		Electrodes
F-6	ER 70 S2 ER 70 S6 (SFA-5.18)	ER 80S B2 ER 90 S C3 (SFA-5.28)	ER 308 L, ER 309 L, ER 316 (SFA- 5.9)	Bare filler wire

F – NUMBER GROUPING

QW-432

F-NUMBERS

Grouping of Electrodes and Welding Rods for Qualification

F-No.	ASME Specification	AWS Classification	UNS No.
Steel and Steel Alloys			
1	SFA-5.1	EXX20	...
1	SFA-5.1	EXX22	...
1	SFA-5.1	EXX24	...
1	SFA-5.1	EXX27	...
1	SFA-5.1	EXX28	...
1	SFA-5.4	EXXX(X)-26	...
1	SFA-5.5	EXX20-X	...
1	SFA-5.5	EXX27-X	...
2	SFA-5.1	EXX12	...
2	SFA-5.1	EXX13	...
2	SFA-5.1	EXX14	...
2	SFA-5.1	EXX19	...
2	SFA-5.5	E(X)XX13-X	...
3	SFA-5.1	EXX10	...
3	SFA-5.1	EXX11	...
3	SFA-5.5	E(X)XX10-X	...
3	SFA-5.5	E(X)XX11-X	...

A -NUMBER GROUPING

Filler Metal For Qualification



A number

- **Grouping of electrodes and filler material**
- **Based on the weld metal chemical composition.**
- **'A' stands for weld metal Analysis.**
- **Described in QW440 / QW 442**

QW-440 WELD METAL CHEMICAL COMPOSITION

QW-441 General

Identification of weld metal chemical composition designated on the PQR and WPS shall be as given in QW-404.5.

**QW-442
A-NUMBERS**
Classification of Ferrous Weld Metal Analysis for Procedure Qualification

A-No.	Types of Weld Deposit	Analysis, % [Note (1)]					
		C	Cr	Mo	Ni	Mn	Si
1	Mild Steel	0.20	1.60	1.00
2	Carbon-Molybdenum	0.15	0.50	0.40–0.65	...	1.60	1.00
3	Chrome (0.4% to 2%)–Molybdenum	0.15	0.40–2.00	0.40–0.65	...	1.60	1.00

A -NUMBER GROUPING

QW-442
A-NUMBERS

Classification of Ferrous Weld Metal Analysis for Procedure Qualification

A-No.	Types of Weld Deposit	Analysis, % [Note (1)]					
		C	Cr	Mo	Ni	Mn	Si
1	Mild Steel	0.20	1.60	1.00
2	Carbon-Molybdenum	0.15	0.50	0.40–0.65	...	1.60	1.00
3	Chrome (0.4% to 2%)–Molybdenum	0.15	0.40–2.00	0.40–0.65	...	1.60	1.00
4	Chrome (2% to 4%)–Molybdenum	0.15	2.00–4.00	0.40–1.50	...	1.60	2.00
5	Chrome (4% to 10.5%)–Molybdenum	0.15	4.00–10.50	0.40–1.50	...	1.20	2.00
6	Chrome-Martensitic	0.15	11.00–15.00	0.70	...	2.00	1.00
7	Chrome-Ferritic	0.15	11.00–30.00	1.00	...	1.00	3.00
8	Chromium–Nickel	0.15	14.50–30.00	4.00	7.50–15.00	2.50	1.00
9	Chromium–Nickel	0.30	19.00–30.00	6.00	15.00–37.00	2.50	1.00
10	Nickel to 4%	0.15	...	0.55	0.80–4.00	1.70	1.00
11	Manganese–Molybdenum	0.17	...	0.25–0.75	0.85	1.25–2.25	1.00
12	Nickel–Chrome—Molybdenum	0.15	1.50	0.25–0.80	1.25–2.80	0.75–2.25	1.00

TESTING REQUIREMENTS FOR WPS/PQR



QW-451.1

GROOVE-WELD TENSION TESTS AND TRANSVERSE-BEND TESTS

Thickness T of Test Coupon, Welded, In. (mm)	Range of Thickness T of Base Metal, Qualified, In. (mm) [Notes (1) and (2)]		Maximum Thickness t of Deposited Weld Metal, Qualified, In. (mm) [Notes (1) and (2)]	Type and Number of Tests Required (Tension and Gated-Bend Tests) [Note (2)]			
	Min.	Max.		Tension, QW-150	Side Bend, QW-160	Face Bend, QW-160	Root Bend, QW-160
Less than $\frac{1}{16}$ (1.5)	T	$2T$	$2t$	2	...	2	2
$\frac{1}{16}$ to $\frac{3}{8}$ (1.5 to 10), Incl.	$\frac{1}{16}$ (1.5)	$2T$	$2t$	2	Note (5)	2	2
Over $\frac{3}{8}$ (10), but less than $\frac{3}{4}$ (19)	$\frac{3}{16}$ (5)	$2T$	$2t$	2	Note (5)	2	2
$\frac{3}{4}$ (19) to less than $1\frac{1}{2}$ (38)	$\frac{3}{16}$ (5)	$2T$	$2t$ when $t < \frac{3}{4}$ (19)	2 [Note (4)]	4
$\frac{3}{4}$ (19) to less than $1\frac{1}{2}$ (38)	$\frac{3}{16}$ (5)	$2T$	$2T$ when $t \geq \frac{3}{4}$ (19)	2 [Note (4)]	4
$1\frac{1}{2}$ (38) to 6 (150), Incl.	$\frac{3}{16}$ (5)	8 (200) [Note (3)]	$2t$ when $t < \frac{3}{4}$ (19)	2 [Note (4)]	4
$1\frac{1}{2}$ (38) to 6 (150), Incl.	$\frac{3}{16}$ (5)	8 (200) [Note (3)]	8 (200) [Note (3)] when $t \geq \frac{3}{4}$ (19)	2 [Note (4)]	4
Over 6 (150)	$\frac{3}{16}$ (5)	$1.33T$	$2t$ when $t < \frac{3}{4}$ (19)	2 [Note (4)]	4
Over 6 (150)	$\frac{3}{16}$ (5)	$1.33T$	$1.33T$ when $t \geq \frac{3}{4}$ (19)	2 [Note (4)]	4

NOTES:

TESTING REQUIREMENTS FOR WPS/PQR



QW-451.3 FILLET-WELD TESTS

Type of Joint	Thickness of Test Coupons as Welded, in.	Range Qualified	Type and Number of Tests Required [QW-462.4(a) or QW-462.4(d)]
Fillet	Per QW-462.4(a)	All fillet sizes on all base metal thicknesses and all diameters	Macro 5
Fillet	Per QW-462.4(d)		4

QW-451.4 FILLET WELDS QUALIFIED BY GROOVE-WELD TESTS

Thickness T of Test Coupon (Plate or Pipe) as Welded	Range Qualified	Type and Number of Tests Required
All groove tests	All fillet sizes on all base metal thicknesses and all diameters	Fillet welds are qualified when the groove weld is qualified in accordance with either QW-451.1 or QW-451.2 (see QW-202.2)

WELDING PERFORMANCE QUALIFICATIONS



ASME Sec IX:

-Variables For Different Processes – QW 350

-Limits Of Positions Qualified & Diameter – QW 461

-Testing Requirements – QW 304-1

WELDER QUALIFICATION



Train The Welder For The Process To Be Qualified

- Shall Posses Adequate Skill In Performing the Process.**
- Shall have Necessary Knowledge In**
 - Operation Of Machine**
 - Precautions In Storage & Usage Of Consumable,**
 - Defects In Welding, Their Causes And Remedy.**
- Shall Practice Welding In The Particular Position In Which He Is To Be Tested / Qualified**

WELDER QUALIFICATION



Preparation Of Test Coupon

- Prepare A Test Coupon Out of 300 x 150 x 13 mm Plates Or Pipe Of 150mm long As Per Applicable WPS.
- WEP (Angle, Root Face & Root Opening) Shall Be As Per The WPS
- Provide Run in & Run Out Coupons on plate & Fix the Test Coupon In In Any One Of The Positions To Be Qualified.
- Weld The Groove Fully In The Position
- All Welding Variables Shall be Strictly Within The Qualified WPS

WELDER QUALIFICATION

Type Of Test Required On Welded Coupon (QW-302)

- **Visual Examination – QW 302.4**

Completed Coupon Shall be Subjected To Visual Inspection

- **Mechanical Test - QW 452**

Root Bend :-1 No, Face Bend :-1 No (<19 mm Thick)

Or

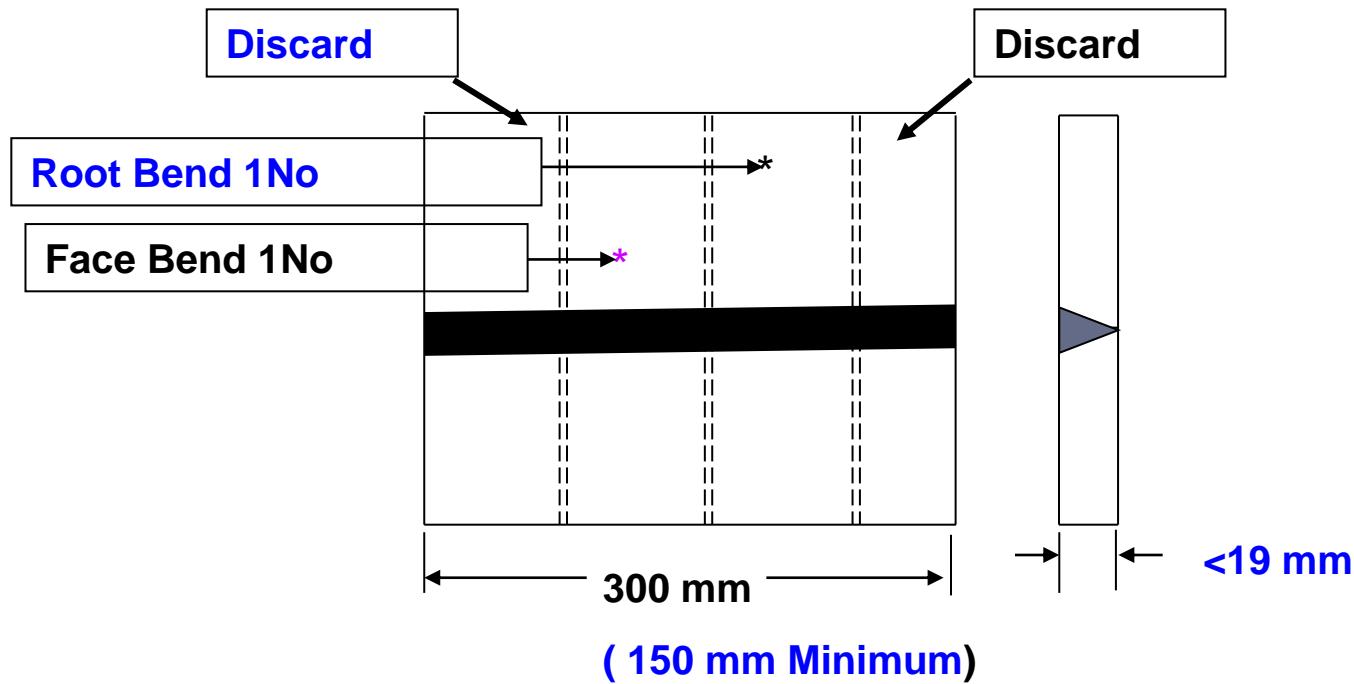
Side Bend :- 2 No (\geq 19 mm Thick)

(For 5G / 6G – 2 Face & 2 Root Or 4 Side Bends)

- **Alternate to Mechanical Tests, Radiograph the Coupon**
 - **6 " Minimum Length**

WELDER QUALIFICATION

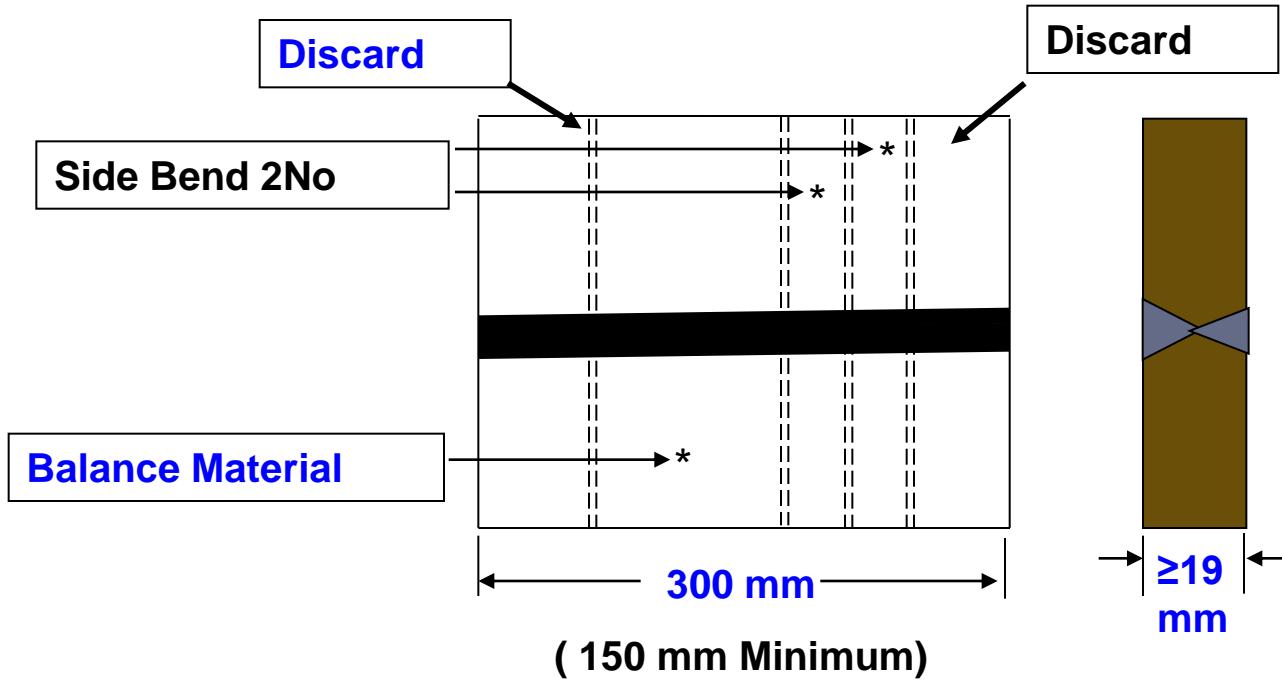
Location of Test Specimens From Test coupon – QW463.2 Plates Less Than 19 mm



Welder Qualification



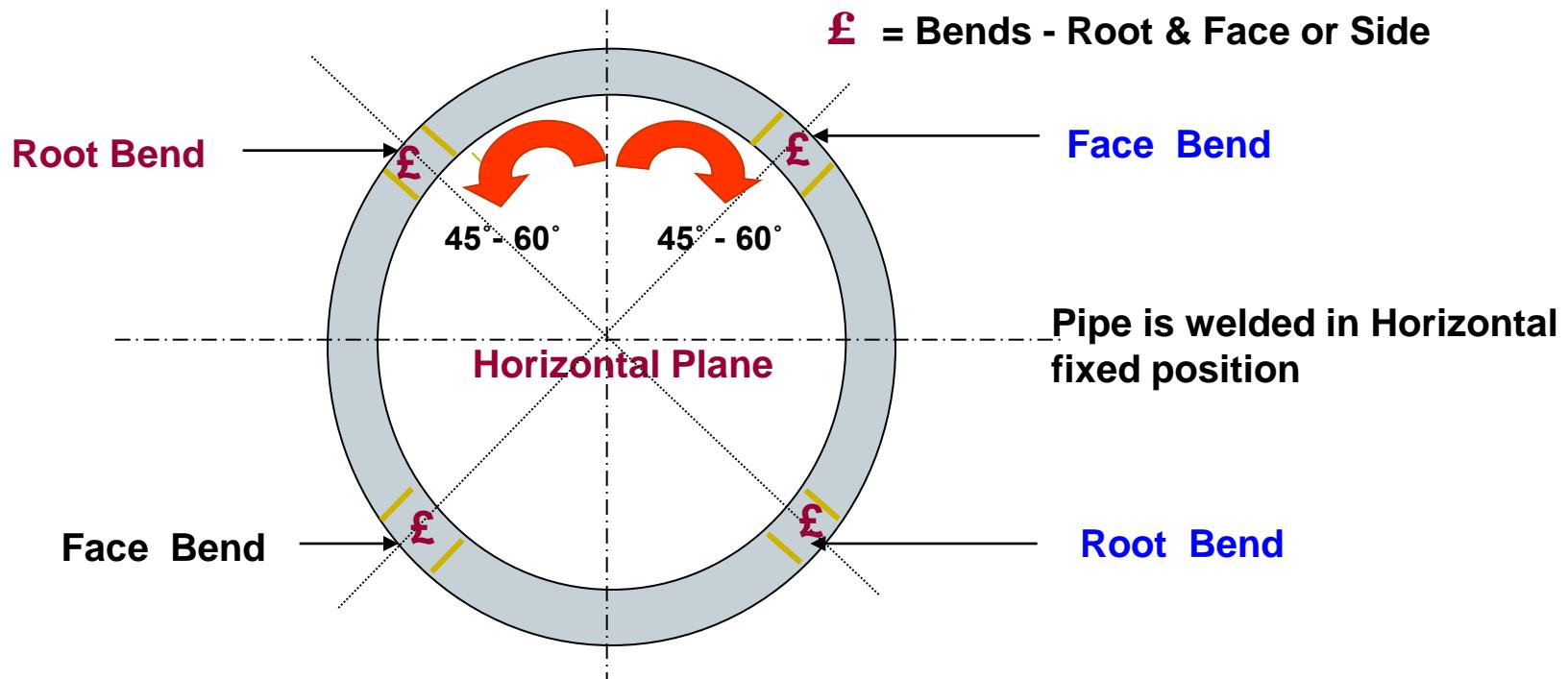
Location of Test Specimens From Test coupon – QW463.2
Plates thickness 19 mm or more.



WELDER QUALIFICATION

Location of Test Specimens From Test coupon – QW463.2

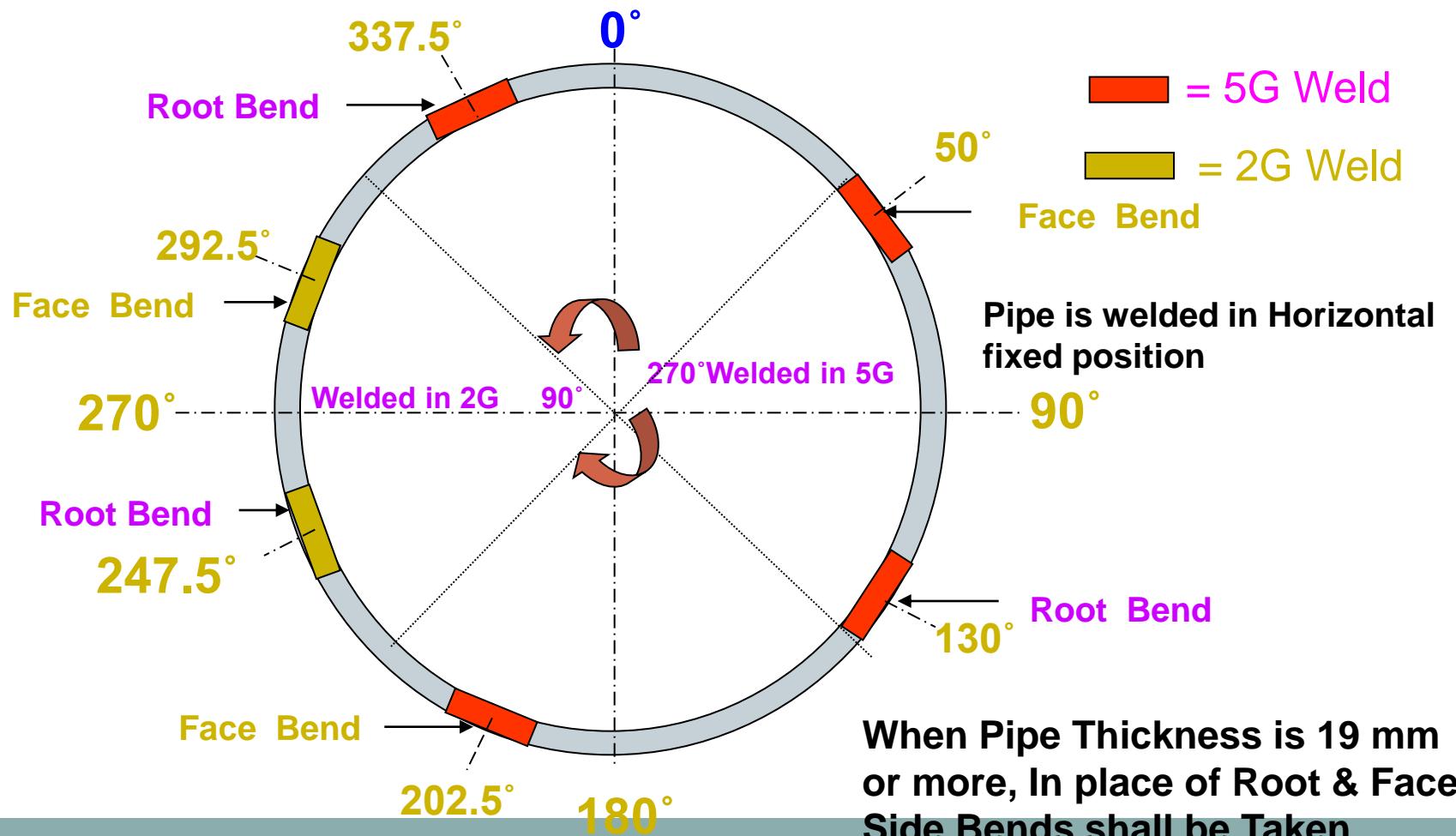
Pipe in 5G or 6G position



When Pipe Thickness is 19 mm or more, In place of Root & Face, 4 Side Bends shall be Taken

WELDER QUALIFICATION

Location of Test Specimens From Test Pipe 6 NPS
Welded in Combination of 5G & 2G – QW 463.2



WELDER QUALIFICATION

Acceptability Criteria For Tests

- **Visual Examination – Qw 302.4**

Free From Incomplete Fusion / Penetration and Surface Defect

- **Bend Test - QW 163**

Opening not more than 3 mm in any direction on Convex Surface Within the Weld & HAZ

- **Radiographic Testing – QW 191.2**

No Crack, L/F & Incomplete Penetration

No Slag, Cluster Of Porosity & Other Inclusions Beyond Specified Limit

GENERAL NOTE: For Tensile tests, failure in HAZ is considered as ‘base metal failure’ whereas for bend tests, the failure in HAZ is considered as a ‘weld metal failure’.

WELDER QUALIFICATION

Acceptability Criteria For Fracture test (Fillet weld test) QW 182

- The stem of 4 in. fracture test specimen centre shall be loaded laterally in such a way that the root of the weld is in tension. The load shall be steadily increased until the specimen fractures or bends flat upon itself. The stem shall not peel off from the base surface, which happens when the fusion is only skin deep
- If the specimen fractures, the fractured surface shall show no evidence of cracks or incomplete root fusion, and the sum of the lengths of the inclusions and porosity visible on the fractured surface shall not exceed 3/8 in. (10 mm)

Welder Qualification

Acceptance Criteria For Performance Macro Examination (Fillet Weld) QW 184

The smoothened and etched surface of the specimen should give a clear definition of the weld metal and HAZ. In order to pass the test:

- **Visual examination of the cross section of the weld metal and HAZ shall show complete fusion and freedom from cracks, except that linear indications at the root not exceeding $1/32$ in. shall be acceptable**
- **The weld shall not have a concavity or convexity greater than $1/16$ in.**
- **There shall not be more than $1/8$ in. difference in the lengths of the legs of the fillet.**

WELDER QUALIFICATION

Performance Qualification

Thickness Limits – QW 452.1(b)

Thickness “t” of Weld Metal in the Coupon	Thickness of Weld metal Qualified
Less than 13 mm (1/2”)	$2t$
13 mm (1/2”) and Over With Minimum Three Layers	Maximum To Be Welded

Note: There is no minimum limit for thickness for WPQ

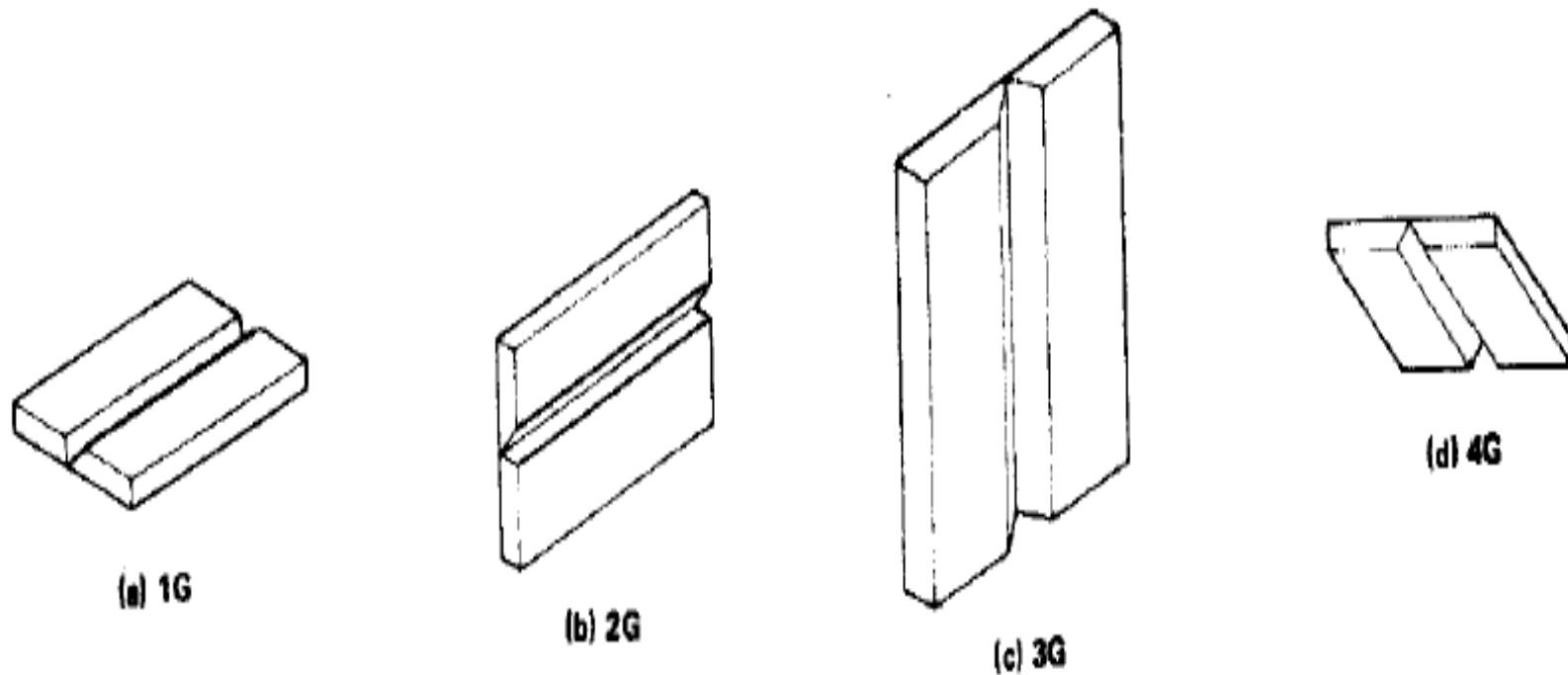
WELDER QUALIFICATION

Groove Weld Positions – QW461

Sr No.	Groove Position	Base Metal Position		Inclination of Axis in °
		Plate	Pipe	
1	1G Flat	Horizontal	Pipe Axis Horizontal – in Rotation	0 -15
2	2G Horizontal	Vertical	Pipe Axis Vertical	0 - 15
3	3G Vertical	Vertical	NA	80 – 90 15 - 80
4	4G Over Head	Horizontal	NA	0 - 80
5	5G	NA	Pipe Axis Fixed Horizontally	0 -15
6	6G	NA	Pipe Axis Fixed 45° inclined	+ or - 5

Welder Performance Qualification

Plate Groove Weld Positions – QW461



QW-461.3 GROOVE WELDS IN PLATE – TEST POSITIONS

WELDER PERFORMANCE QUALIFICATION

Pipe Groove Weld Positions – QW461



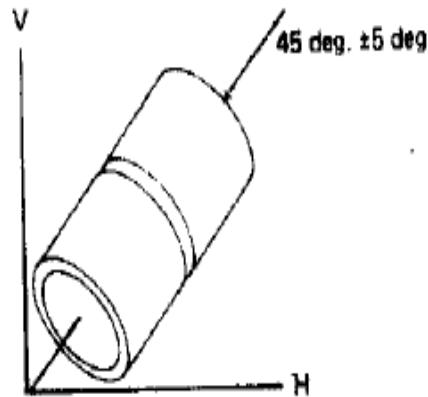
(a) 1G Rotated



(b) 2G



(c) 5G



(d) 6G

QW-461.4 GROOVE WELDS IN PIPE – TEST POSITIONS

WELDER PERFORMANCE QUALIFICATION

Position & Diameter Limits- QW461.9

Qualification Test		Position & Type of Weld Qualified		
Weld	Position	Plate & Pipe Over 24"	Pipe ≤ 24"	Fillet Plate & Pipe
Plate Groove	1G	F	F*	F
	2G	F, H	F*&H*	F,H
	3G	F,V	F*	F,H,V
	4G	F,O	F*	F,H,O
	2G, 3G &4G	ALL	F*&H*	ALL
	Special. Position	SP & F	SP & F	SP & F
Pipe Groove	1G	F	F	F
	2G	F,H	F,H	F,H
	5G	F,V,O	F,V,O	ALL
	6G	ALL	ALL	ALL
	2G &5G	ALL	ALL	ALL
	Special. Position	SP & F	SP & F	SP& F

* Pipe 2 $\frac{7}{8}$ " OD and Over

\$ Pipe OD Restrictions As Per QW 452.3, 452.4 and 452.6

Welder Performance Qualification

Performance Qualification

Groove-Weld, Pipe Dia. Limits QW 452.3

Out Side Dia. Of Test Coupon in mm (in)	Out Side Dia. Qualified	
	Min.	Max.
Less Than 25 (1")	Size Welded	Unlimited
25 (1") to 73 (2 $\frac{7}{8}$ ")	25 (1")	Unlimited
Over 73 (2 $\frac{7}{8}$ ")	73 (2 $\frac{7}{8}$ ")	Unlimited

Notes:-

- 1) Type & Number of Tests as per QW-452.1
- 2) 73 mm OD is equivalent to 2 $\frac{1}{2}$ " NB Pipe
- 3) Welders Qualified on Groove, Are Also Qualified for making Fillets of all Sizes on Any Thickness & Any Pipe Dia.

WELDER PERFORMANCE QUALIFICATION

Welding Variables- Qw 416

Group of Variable S	Brief Of Variables	Essential Variables			
		SMAW QW -353	SAW. QW-354	GMAW QW-355	GTAW QW-356
QW 402 Joints	Deletion of Backing	+	+	+	+
QW 403 Base Metal	Change in Pipe Dia.	+	+	+	+
	Change in P Number	+	+	+	+
QW 404 Filler Metal	Deletion /Addition of FM	---	---	---	+
	Change in F Number	+	+	+	+
	Dele. /Addi. of Consumable Insert	---	---	---	+
	Solid – Metal/Flux Cored	---	---	---	+
	Change in t deposit Qualified	+	+	+	+
	“t” deposit for Short Cir.Transfer	---	---	+	---

WELDER PERFORMANCE QUALIFICATION

Welding Variables- Qw 416

Group of Variables	Brief Of Variables	Essential Variables			
		SMAW QW -353	SAW. QW-354	GMAW QW-355	GTAW QW-356
QW 405 Position	Addition of New Position	+	+	+	+
	Change from up hill to Down hill – 3G	+	---	+	+
QW 408 Gas	Deletion of Inert Gas Backing	---	---	+	+
QW 409 Electric Charact.	Change in Mode of Metal Transfer	---	---	+	---
	Change in Type of Current / Polarity	---	---	---	+

WELDER PERFORMANCE QUALIFICATION



FORMAT QW 484

- **WPQ test:** To determine the ability of the welder to deposit sound welds using qualified WPS.
- **RECORD OF TESTS :**
The record of WPQ contain
 - Reference WPS
 - Personal details of the welders,
 - Essential variable
 - Type of tests, and test results
 - Range qualified

WELDER PERFORMANCE QUALIFICATION

FORMAT QW 484 (Cont.....)

- A welder may be qualified as under.
- i) **A welder may weld a test coupon using previously qualified WPS.**
 - Pre-heating or post-heating , PWHT required by WPS may be omitted
 - **Specimens required for mechanical test shall be removed from test coupon and will be tested.**
 - All the results should meet the requirements as mentioned earlier.
- ii) **A test coupon, minimum length of which should be 6" in case of plate and entire circumference of pipe (min 6") shall be radiographed.**

WELDER PERFORMANCE QUALIFICATION

FORMAT QW 484 (Cont.....)



iii) Alternatively, at the manufacturer's option a welder may be qualified on the job by Radiography examination of his first 6" of production weld (for SAW 3 feet).

REQUALIFICATION AFTER FIRST FAILURE:

- A welding supervisor/engineer may terminate the performance test at any stage if it becomes apparent that the welder/welding operator does not have the requisite skill.**
- If a welding operator /welder fails in performance test immediate re-test can be taken.**

WELDER PERFORMANCE QUALIFICATION

REQUALIFICATION AFTER FIRST FAILURE (Cont.....)

- If the mechanical test have failed then the welder will make two consecutive sample and all mechanical tests from both samples shall meet test requirements.
- If the qualification test have failed radiography examination then 2 additional 6" long plate coupon or 2 pipe coupons total circumstance of weld of which will 12" long shall be made and all shall meet the requirements of radiography.
- In case of radiography of first 6" failure of production weld then at the manufactures option further 12" of weld shall be radiographed and shall meet the radiography requirement.

Welder Performance Qualification

REQUALIFICATION AFTER FIRST FAILURE (Cont.....)



- If on radiography re-test a welder meets the requirement then the area on which the welder failed to meet the requirement shall be repaired by him or other qualified welder.
- In case the welder fails in re-test or the manufacturer does not wish to offer for re-test then the entire weld made by this welder shall be radiographed and all defective areas shall be repaired by other qualified welder.

WELDER PERFORMANCE QUALIFICATION FORMAT QW 484



QW-484A SUGGESTED FORMAT A FOR WELDER PERFORMANCE QUALIFICATIONS (WPQ) (See QW-301, Section IX, ASME Boiler and Pressure Vessel Code)

Welder's name _____ Identification no. _____

Test Description

Identification of WPS followed _____ Test coupon Production weld

Specification and type/grade or UNS Number of base metal(s) _____ Thickness _____

Testing Variables and Qualification Limits

Welding Variables (QW-350)

Actual Values

Range Qualified

Welding process(es)

Type (i.e.; manual, semi-automatic) used

Backing (with/without)

Plate Pipe (enter diameter if pipe or tube)

Base metal P-Number to P-Number

Filler metal or electrode specification(s) (SFA) (info. only)

Filler metal or electrode classification(s) (info. only)

Filler metal F-Number(s)

Consumable insert (GTAW or PAW)

Filler Metal Product Form (solid/metal or flux cored/powder) (GTAW or PAW)

Deposit thickness for each process

Process 1 _____ 3 layers minimum Yes No

Process 2 _____ 3 layers minimum Yes No

RENEWAL OF QUALIFICATION

- The performance qualification of welder/welding operator shall expire when he has not welded with a process for a period of 3 months or more. However when he has welded with another process, the period may be extended to six months.
- Renewal of qualification can be made for any process by welding a single coupon of either plate or pipe, of any material and by testing of that coupon.
- When there is a specific reason to doubt the ability of the welder to make welds that meet specification, requirements, his qualification which support the welding which he is doing shall be revoked.

RENEWAL OF QUALIFICATION

- In such case the welder or welding operator will have to weld a test coupon for re-qualification which will be tested as required by the code before he is put on the job.
- Performance qualification-position and diameter limitations are mentioned in QW- 461-9 and QW-454 (see Annexures).
- Performance Qualification, tests can be carried out by using a combination of welding process on single test coupon limits of thickness for which he will be qualified will depend upon the amount of weldment thickness deposited by each process.

RENEWAL OF QUALIFICATION (cont....)

- **Two or more welders can be qualified on a single test coupon using same or different welding processes** limits of qualification for each welder will be related to weld metal deposited by him with his specific welding process.
- **The requirements for welding Procedure Specification (WPS), Procedure Qualification Record (PQR) and welders performance Qualification (WPQ) are given in ASME Sec. IX Article I, II and III respectively.**

IMPORTANT POINTS FOR WPS/ PQR & WPQ

- A double welded (welded from both the sides after B/G) joint is considered as a joint with backing. Weld metal becomes the Backing material.
- Size of base metal, normally designated as T and size of weld deposit normally designated as t must be considered separately.

WPS/PQR

- A procedure qualified using plates can be used for welding the pipes, provided the P number - Group number criteria is met.
- A procedure qualified in any one position can be used to weld in any other position provided job specifications do not specify impact test.
- A procedure qualified using groove welds can be used for fillet welds of any size.
- One must always carry out impact testing at the lowest possible temperature, in the procedure qualification test. This can be used for the jobs having impact requirement or not

IMPORTANT POINTS FOR WPS/ PQR & WPQ

- Technically, a procedure qualification test, which has failed to meet the required tensile strength can be used for jobs with materials of lower strength. For example, if the tensile test results showed a value of 65 ksi when tested with a coupon material of SA516 Gr.70, E7018 electrode, on normalizing can be used for welds made on equipment of SA516 Gr.60, provided, all other parameters remain same
- A test coupon of thickness 40mm used for procedure qualification test covers largest range from 5 mm to 200mm (without heat treatment or impact requirements).
- The format recommended by Sec IX, commonly used for WPS/ PQR, is common for processes SMAW, GTAW, SAW and GMAW. Hence, one must be careful when using them, since, some of the points are not applicable for some processes.

IMPORTANT POINTS FOR WPQ

- Normally a welder can be qualified using only a radiographic test. In GMAW, welder who welds with short circuiting method shall be qualified with bend tests only.
- A change of filler metal (F number) needs a re-qualification of welder. A welder qualified with F4 is allowed to weld F1, F2 & F3 with backing.
- Presence or absence of impact test or PWHT / normalizing does not affect the welder's skill and hence the qualification.
- A small diameter pipe requires more skill for welding. Hence, a welder qualified on lower diameters can always weld higher diameters (plate is a pipe with infinite diameter).

ASME Sec IX WELDING VARIABLES

Variables for WPQ



QW-353

SHIELDED METAL-ARC WELDING (SMAW) Essential Variables

Paragraph		Brief of Variables
QW-402 Joints	.4	– Backing
QW-403 Base Metals	.16	ϕ Pipe diameter
	.18	ϕ P-Number
QW-404 Filler Metals	.15	ϕ F-Number
	.30	ϕ t Weld deposit
QW-405 Positions	.1	+ Position
	.3	ϕ $\uparrow\downarrow$ Vertical welding

QW-403.16 A change in the pipe diameter beyond the range qualified in QW-452, except as otherwise permitted in QW-303.1, QW-303.2, QW-381.1(c), or QW-382(c).

F Number Qualification For Welders

QW-433 Alternate F-Numbers for Welder Performance Qualification

The following tables identify the filler metal or electrode that the welder used during qualification testing as "Qualified With," and the electrodes or filler metals that the welder is qualified to use in production welding as "Qualified For." See table QW-432 for the F-Number assignments.

F NUMBER QUALIFICATION FOR WELDERS

Qualified With	Qualified For
Any F-No. 6	All F-No. 6 [Note (1)]
Any F-No. 21 through F-No. 25	All F-No. 21 through F-No. 25
Any F-No. 31, F-No. 32, F-No. 33, F-No. 35, F-No. 36, or F-No. 37	Only the same F-Number as was used during the qualification test
F-No. 34 or any F-No. 41 through F-No. 46	F-No. 34 and all F-No. 41 through F-No. 46
Any F-No. 51 through F-No. 55	All F-No. 51 through F-No. 55
Any F-No. 61	All F-No. 61
Any F-No. 71 through F-No. 72	Only the same F-Number as was used during the qualification test

NOTE:

- (1) Deposited weld metal made using a bare rod not covered by an SFA Specification but which conforms to an analysis listed in QW-442 shall be considered to be classified as F-No. 6.

PERFORMANCE TEST QUALIFICATION RANGE

QW-452.1(b)

THICKNESS OF WELD METAL QUALIFIED

Thickness, t , of Weld Metal in the Coupon, in. (mm) [Notes (1) and (2)]	Thickness of Weld Metal Qualified [Note (3)]
All	$2t$
$\frac{1}{2}$ (13) and over with a minimum of three layers	Maximum to be welded

NOTES:

- (1) When more than one welder and/or more than one process and more than one filler metal F-Number is used to deposit weld metal in a coupon, the thickness, t , of the weld metal in the coupon deposited by each welder with each process and each filler metal F-Number in accordance with the applicable variables under QW-404 shall be determined and used individually in the "Thickness, t , of Weld Metal in the Coupon" column to determine the "Thickness of Weld Metal Qualified."
- (2) Two or more pipe test coupons with different weld metal thickness may be used to determine the weld metal thickness qualified and that thickness may be applied to production welds to the smallest diameter for which the welder is qualified in accordance with QW-452.3.
- (3) Thickness of test coupon of $\frac{3}{4}$ in. (19 mm) or over shall be used for qualifying a combination of three or more welders each of whom may use the same or a different welding process.

PERFORMANCE TEST QUALIFICATION

RANGE

QW-452.3

GROOVE-WELD DIAMETER LIMITS

Outside Diameter of Test Coupon, in. (mm)	Outside Diameter Qualified, in. (mm)	
	Min.	Max.
Less than 1 (25)	Size welded	Unlimited
1 (25) to $2\frac{7}{8}$ (73)	1 (25)	Unlimited
Over $2\frac{7}{8}$ (73)	$2\frac{7}{8}$ (73)	Unlimited

GENERAL NOTES:

- Type and number of tests required shall be in accordance with QW-452.1.
- $2\frac{7}{8}$ in. (73 mm) O.D. is the equivalent of NPS $2\frac{1}{2}$ (DN 65).

QW-452.4

SMALL DIAMETER FILLET-WELD TEST

Outside Diameter of Test Coupon, in. (mm)	Minimum Outside Diameter, Qualified, in. (mm)	Qualified Thickness
Less than 1 (25)	Size welded	All
1 (25) to $2\frac{7}{8}$ (73)	1 (25)	All
Over $2\frac{7}{8}$ (73)	$2\frac{7}{8}$ (73)	All

GENERAL NOTES:

- Type and number of tests required shall be in accordance with QW-452.5.
- $2\frac{7}{8}$ in. (73 mm) O.D. is considered the equivalent of NPS $2\frac{1}{2}$ (DN 65).

PERFORMANCE TEST QUALIFICATION RANGE

QW-452.5 FILLET-WELD TEST

Type of Joint	Thickness of Test Coupon as Welded, in. (mm)	Qualified Range	Type and Number of Tests Required [QW-462.4(b) or QW-462.4(c)]	
			Macro	Fracture
Tee fillet [Note (1)]	$\frac{3}{16}$ (5) or greater	All base material thicknesses, fillet sizes, and diameters $2\frac{7}{8}$ (73) O.D. and over [Note (2)]	1	1
	Less than $\frac{3}{16}$ (5)	T to $2T$ base material thickness, T maximum fillet size, and all diameters $2\frac{7}{8}$ (73) O.D. and over [Note (2)]	1	1

GENERAL NOTE: Production assembly mockups may be substituted in accordance with QW-181.2.1. When production assembly mockups are used, range qualified shall be limited to the fillet sizes, base metal thicknesses, and configuration of the mockup.

NOTE:

- (1) Test coupon prepared as shown in QW-462.4(b) for plate or QW-462.4(c) for pipe.
- (2) $2\frac{7}{8}$ in. (73 mm) O.D. is considered the equivalent of NPS $2\frac{1}{2}$ (DN 65). For smaller diameter qualifications, refer to QW-452.4 or QW-452.6.

QW-452.6 FILLET QUALIFICATION BY GROOVE-WELD TESTS

Type of Joint	Thickness of Test Coupon as Welded, in. (mm)	Qualified Range	Type and Number of Tests Required
Any groove	All thicknesses	All base material thicknesses, fillet sizes, and diameters	Fillet welds are qualified when a welder/welding operator qualifies on a groove weld test

PERFORMANCE TEST QUALIFICATION RANGE



QW-461.9

PERFORMANCE QUALIFICATION — POSITION AND DIAMETER LIMITATIONS (Within the Other Limitations of QW-303)

Qualification Test		Position and Type Weld Qualified [Note (1)]			
		Groove		Fillet	
Weld	Position	Plate and Pipe Over 24 in. (610 mm) O.D.	Pipe ≤ 24 in. (610 mm) O.D.	Plate and Pipe	
Plate — Groove	1G	F	F [Note (2)]	F	
	2G	F,H	F,H [Note (2)]	F,H	
	3G	F,V	F [Note (2)]	F,H,V	
	4G	F,O	F [Note (2)]	F,H,O	
	3G and 4G	F,V,O	F [Note (2)]	All	
	2G, 3G, and 4G	All	F,H [Note (2)]	All	
	Special Positions (SP)	SP,F	SP,F	SP,F	
Plate — Fillet	1F	F [Note (2)]	
	2F	F,H [Note (2)]	
	3F	F,H,V [Note (2)]	
	4F	F,H,O [Note (2)]	
	3F and 4F	All [Note (2)]	
	Special Positions (SP)	SP,F [Note (2)]	
Pipe — Groove [Note (3)]	1G	F	F	F	
	2G	F,H	F,H	F,H	
	5G	F,V,O	F,V,O	All	
	6G	All	All	All	
	2G and 5G	All	All	All	
	Special Positions (SP)	SP,F	SP,F	SP,F	
Pipe — Fillet [Note (3)]	1F	F	
	2F	F,H	
	2FR	F,H	
	4F	F,H,O	
	5F	All	
	Special Positions (SP)	SP,F	

PERFORMANCE TEST QUALIFICATION RANG (P numbers)

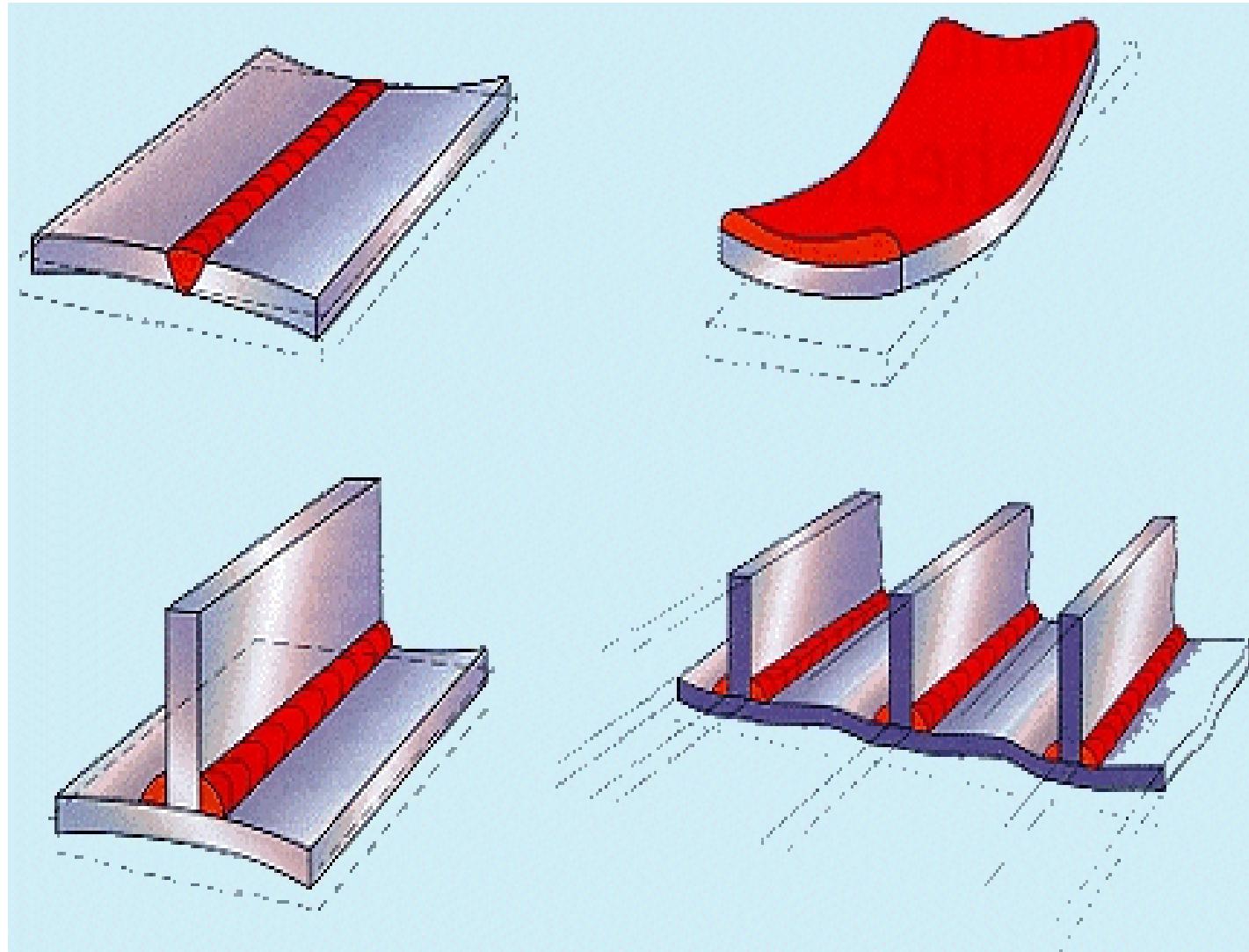
QW-423

Alternate Base Materials for Welder Qualification

QW-423.1 Base metal used for welder qualification may be substituted for the metal specified in the WPS in accordance with the following table. When a base metal shown in the left column is used for welder qualification, the welder is qualified to weld all combinations of base metals shown in the right column, including unassigned metals of similar chemical composition to these metals.

Base Metals for Welder Qualification	Qualified Production Base Metals
P-No. 1 through P-No. 15F, P-No. 34, and P-No. 41 through P-No. 49	P-No. 1 through P-No. 15F, P-No. 34, and P-No. 41 through P-No. 49
P-No. 21 through P-No. 26	P-No. 21 through P-No. 26
P-No. 51 through P-No. 53 or P-No. 61 and P-No. 62	P-No. 51 through P-No. 53 and P-No. 61 and P-No. 62

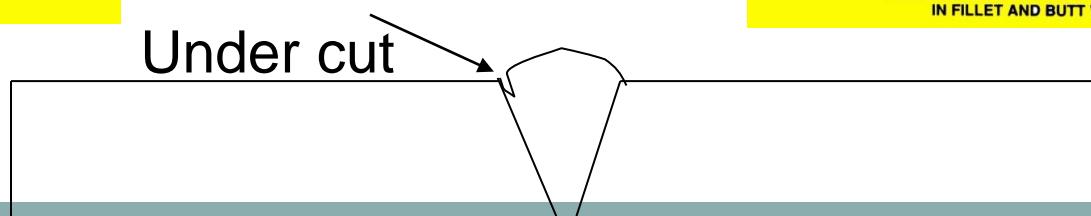
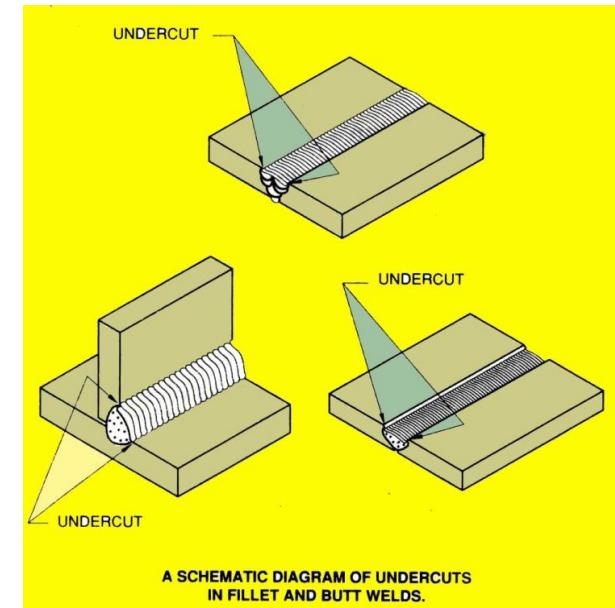
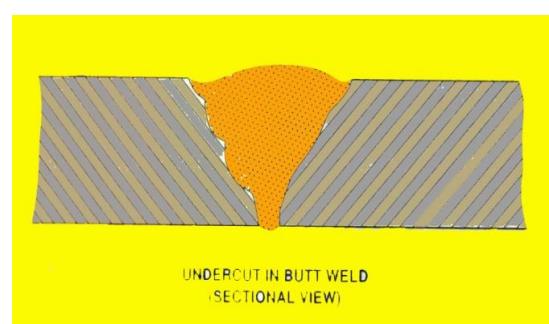
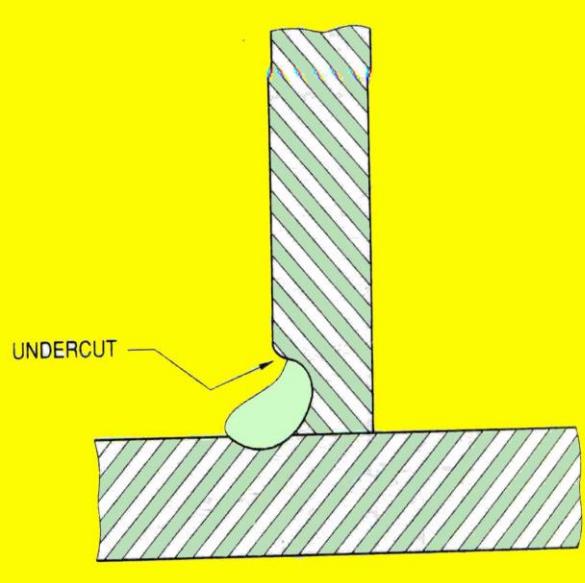
Distortion & Residual Stress – The Problems



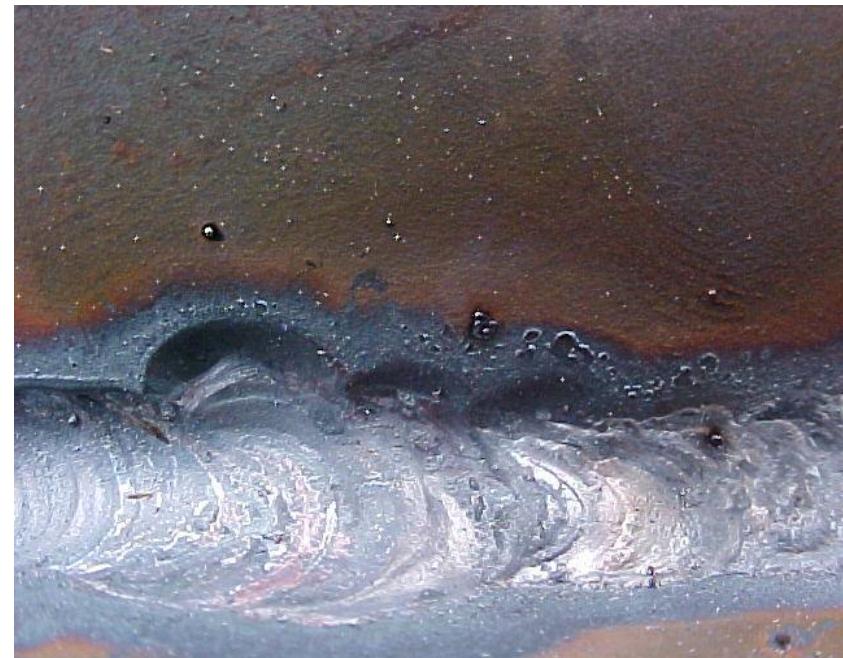
External Defects --- UNDERCUT

Undercut

A groove or channel formed in the parent metal at the toe of the weld. (Fig 1, 2 & 3)

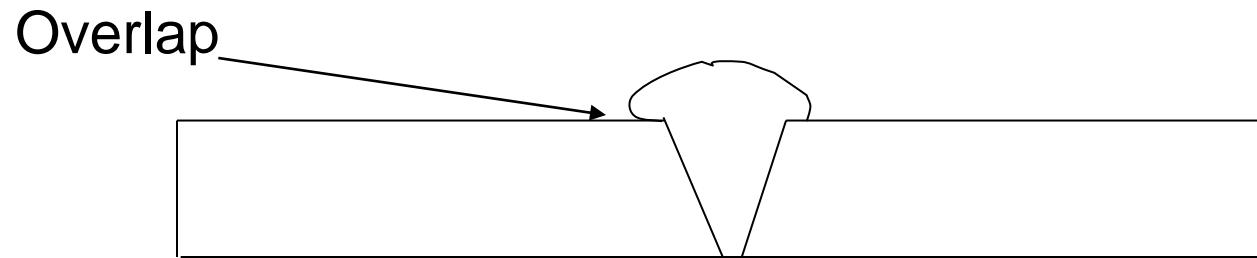
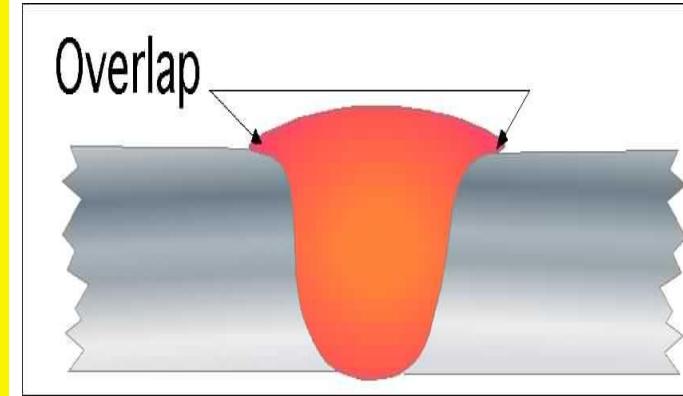
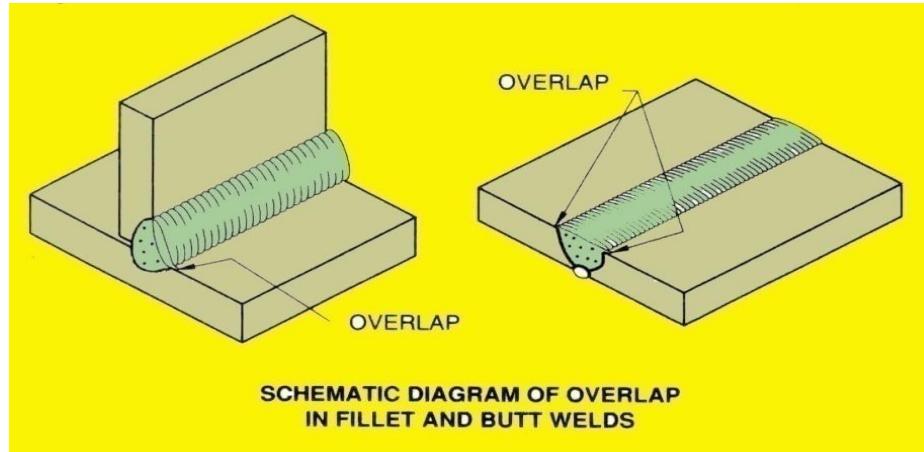


UNDERCUT

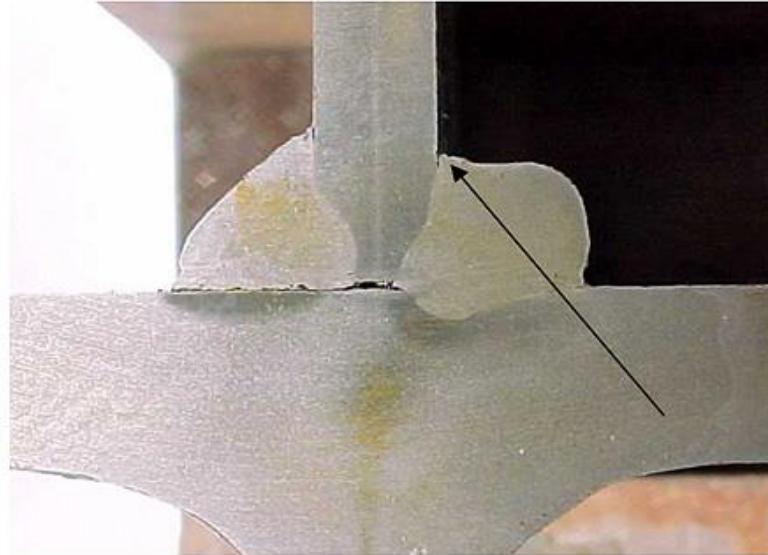


OVERLAP

An overlap occurs when the molten metal from the electrode flows over the parent metal surface without fusing into it.



OVERLAP

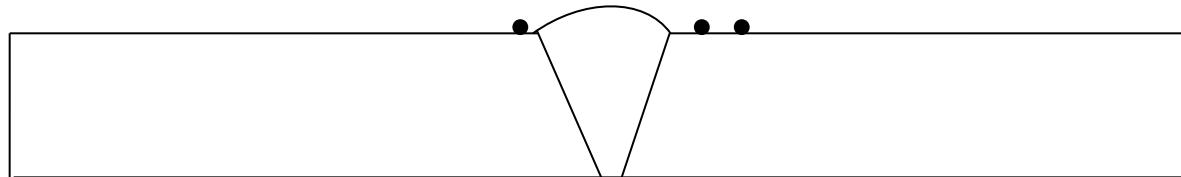
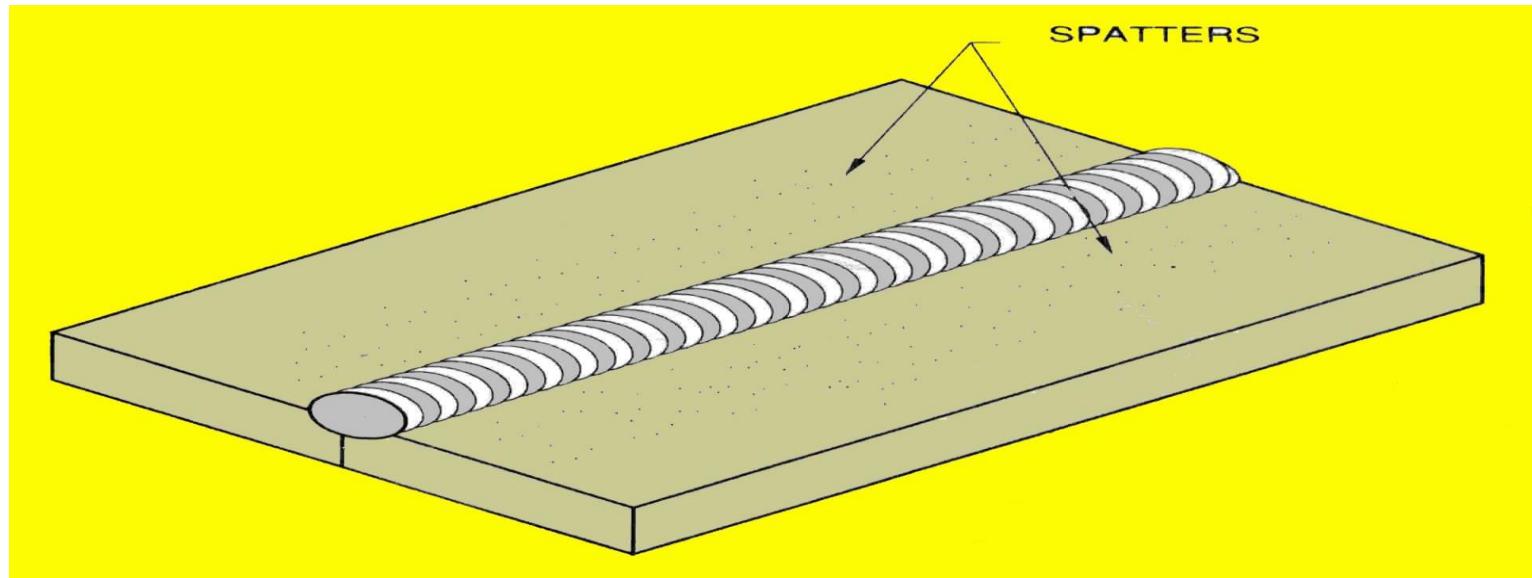


Overlap (Arrowed) and lack of fusion



SPATTER

Small metal particles which are thrown out of the arc during welding along the weld.

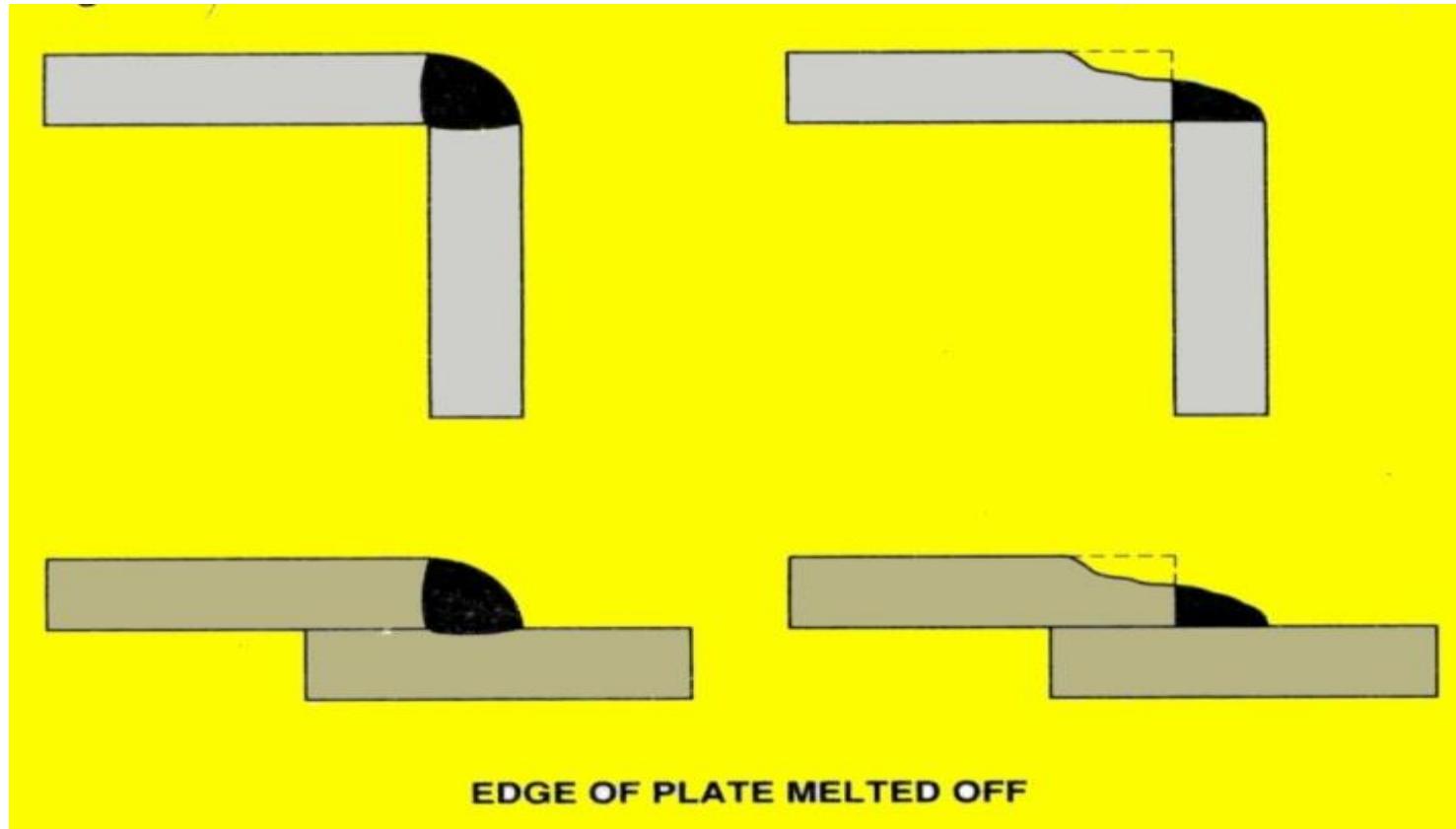


SPATTERS



EDGE OF PLATE MELTING OFF

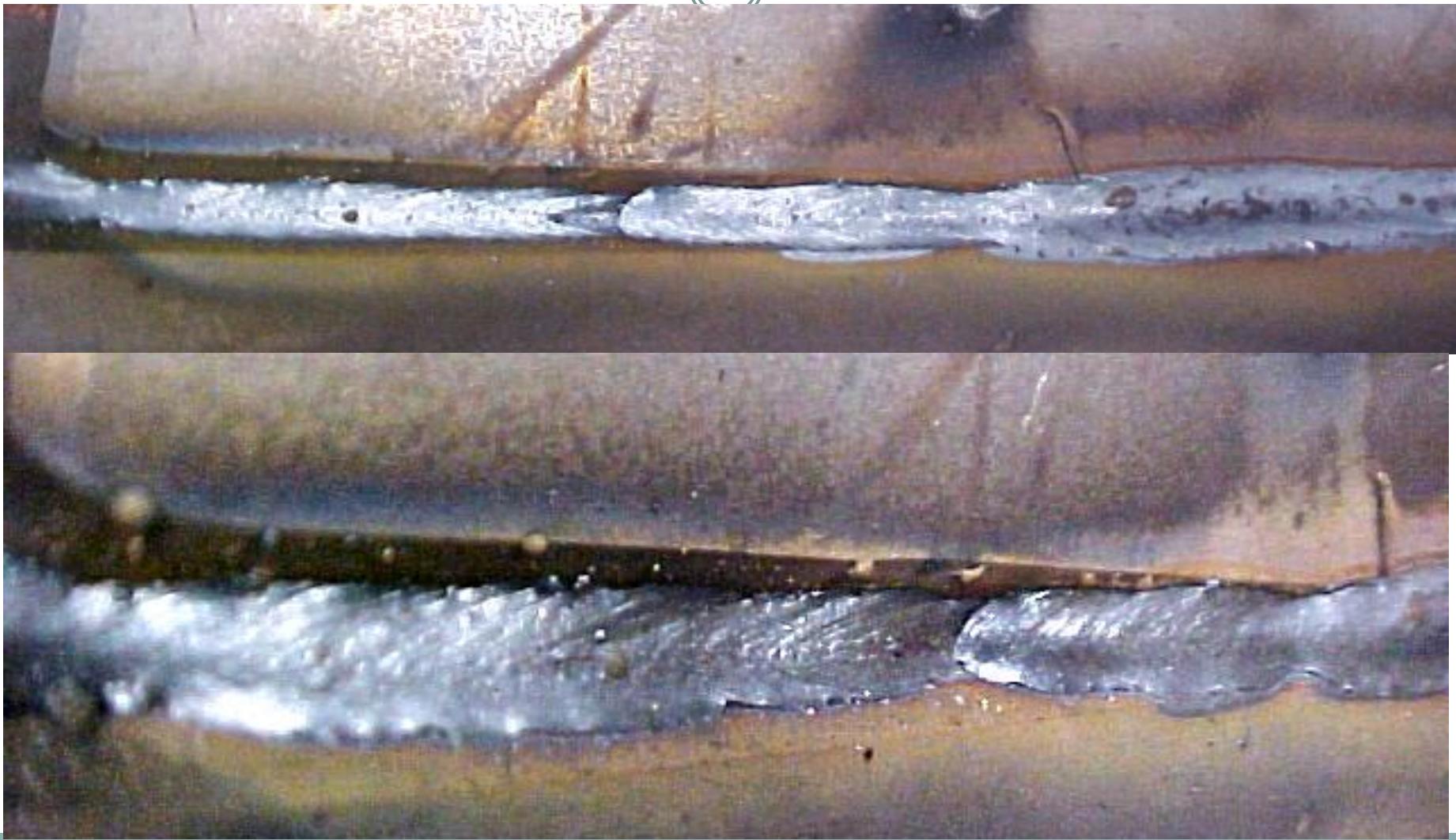
Edge of plate melted off in lap and corner joints only.



INCOMPLETE FUSION



UNDERFILL



EXCESSIVE CONVEXITY



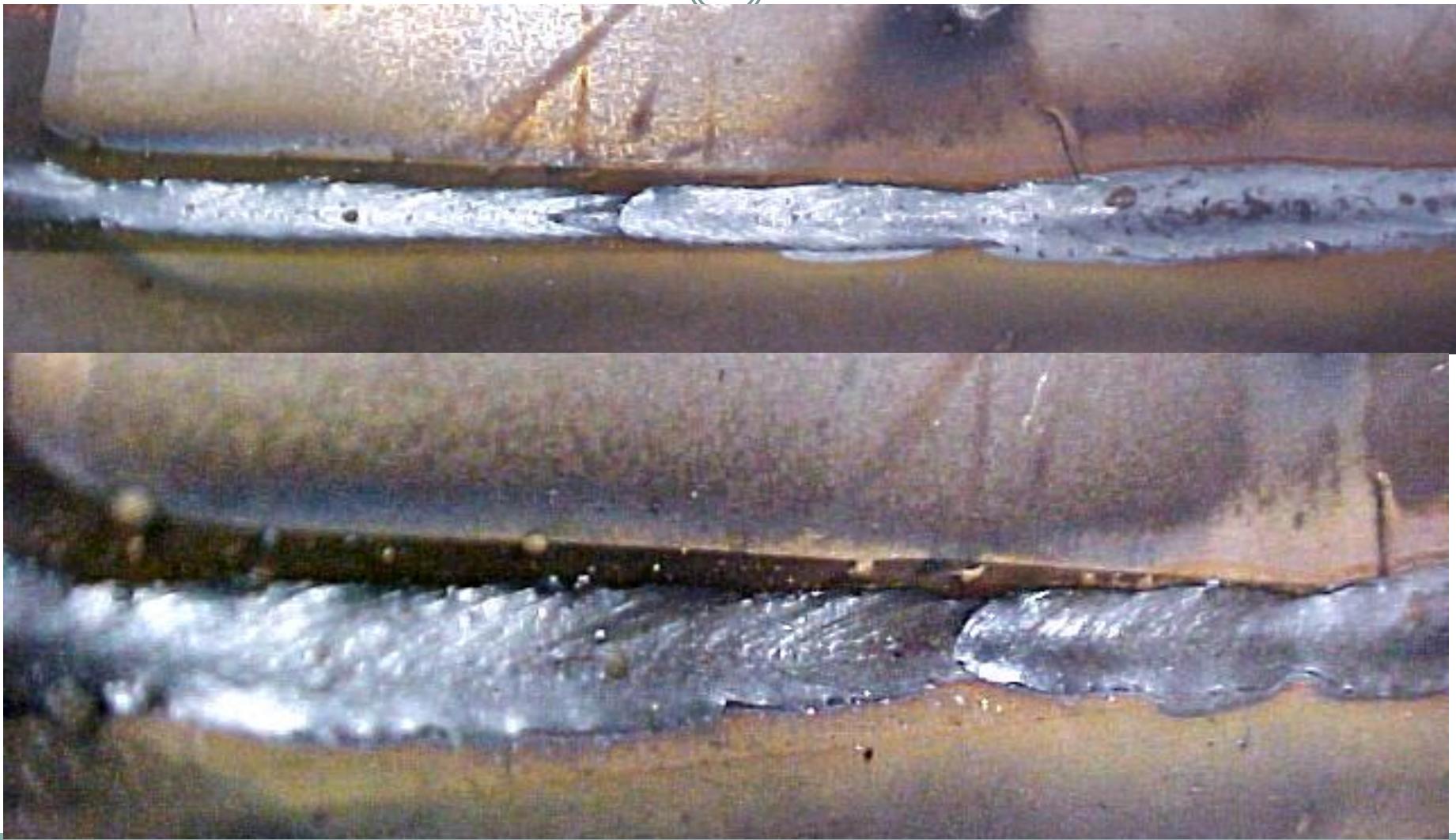
EXCESSIVE CONCAVITY



EXCESSIVE WELD REINFORCEMENT



UNDERFILL

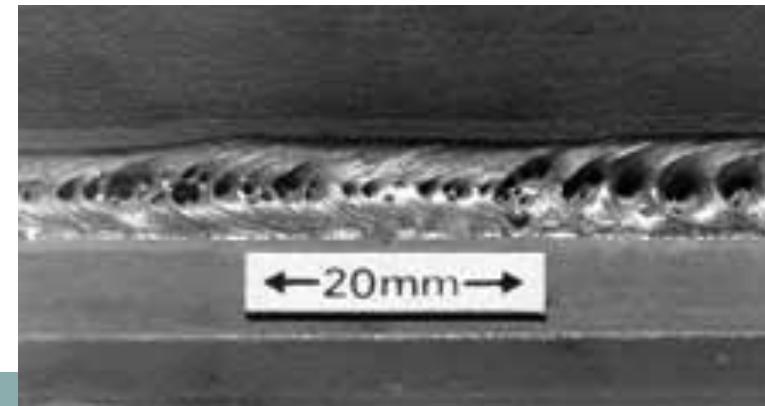
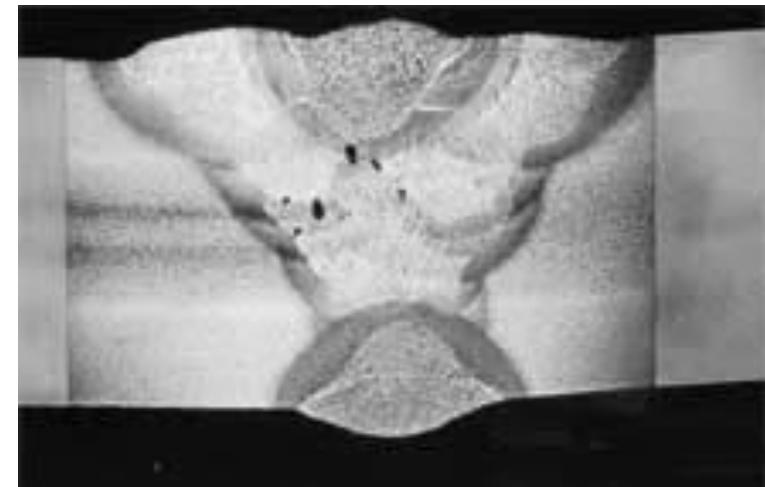
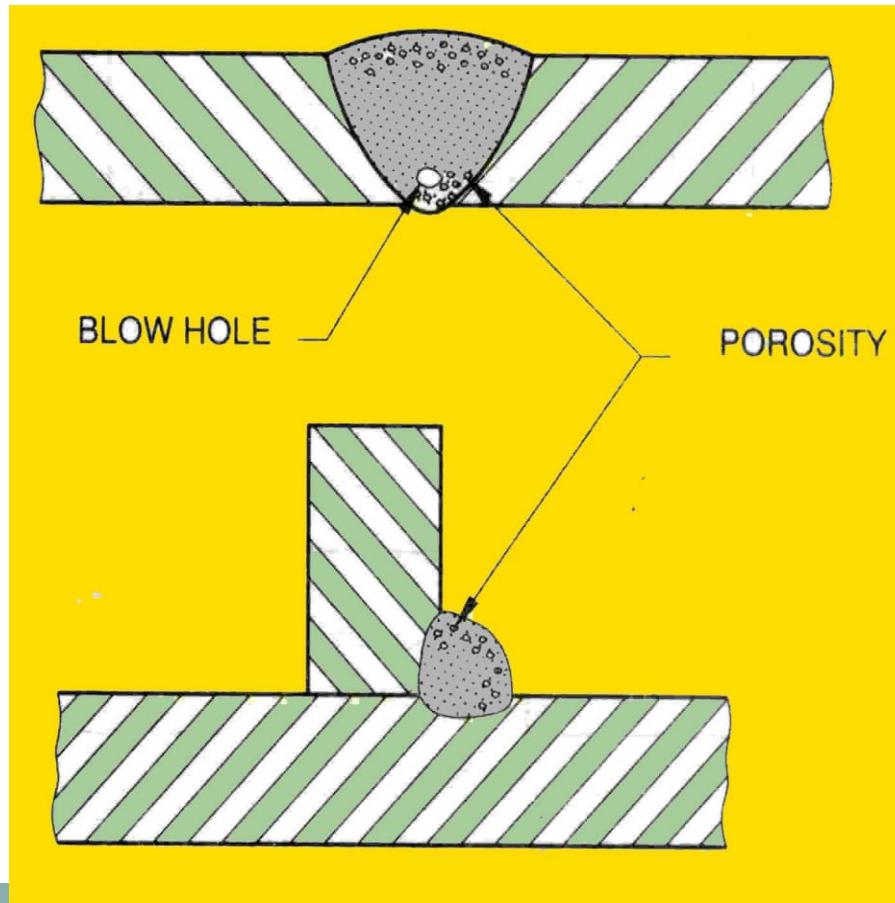


UNACCEPTABLE WELD PROFILE WELD PROFILES



POROSITY (PIN HOLES)

Blow hole or gas pocket Or group of pin holes on the surface or inside of the weld caused by gas entrapment.



POROSITY



Porosity

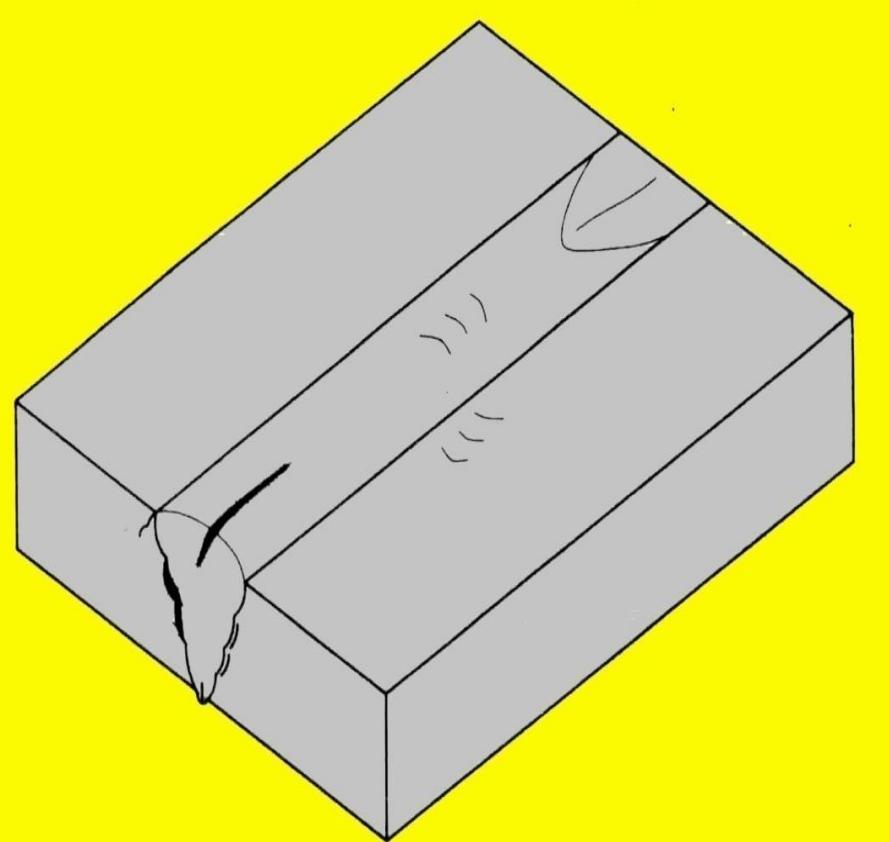


Craters

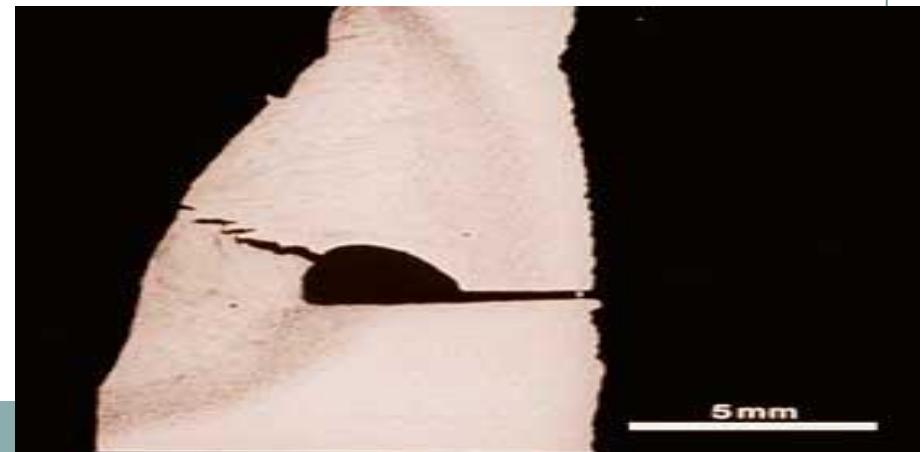
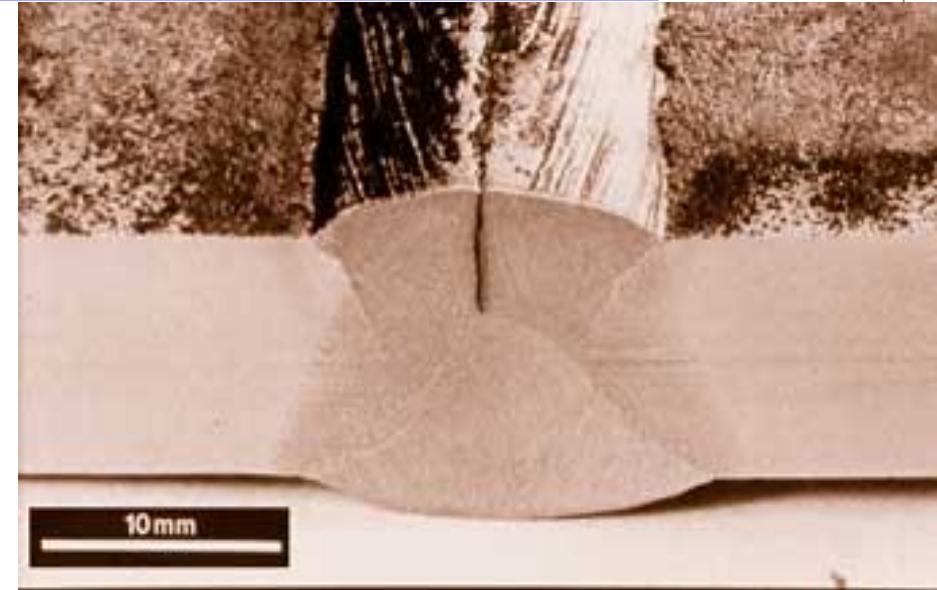


CRACK

A hairline separation exhibits in the root or middle or surface of the weld metal or parent metal.

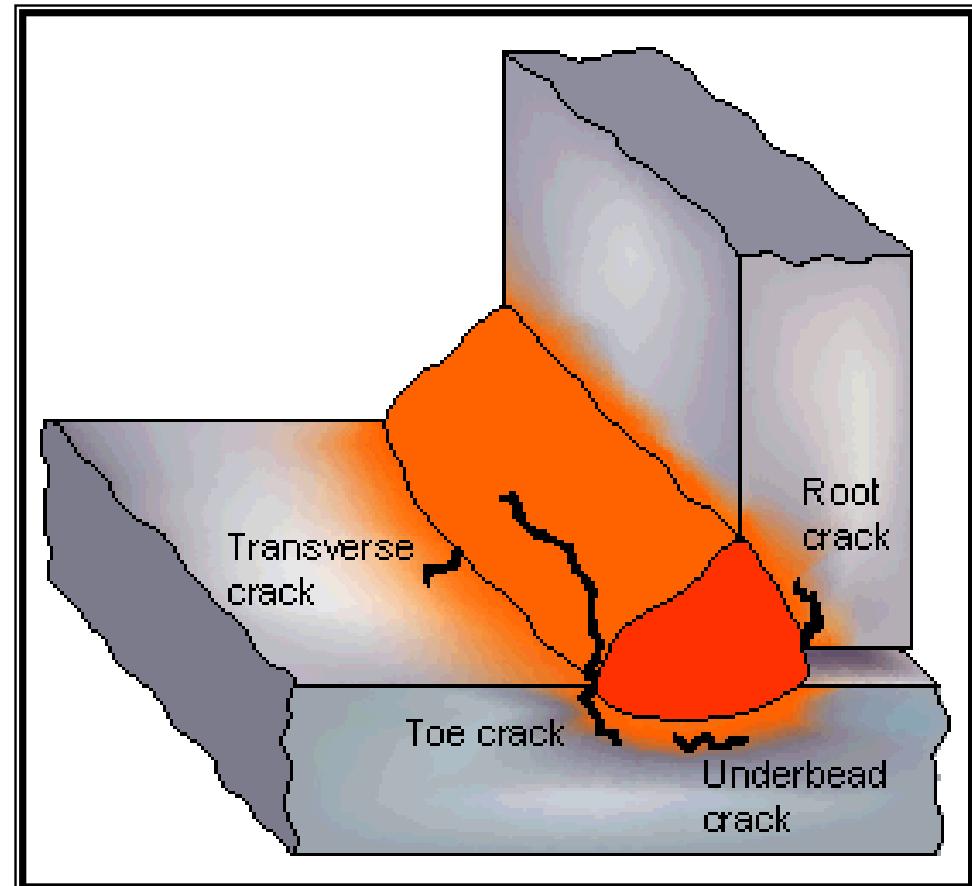
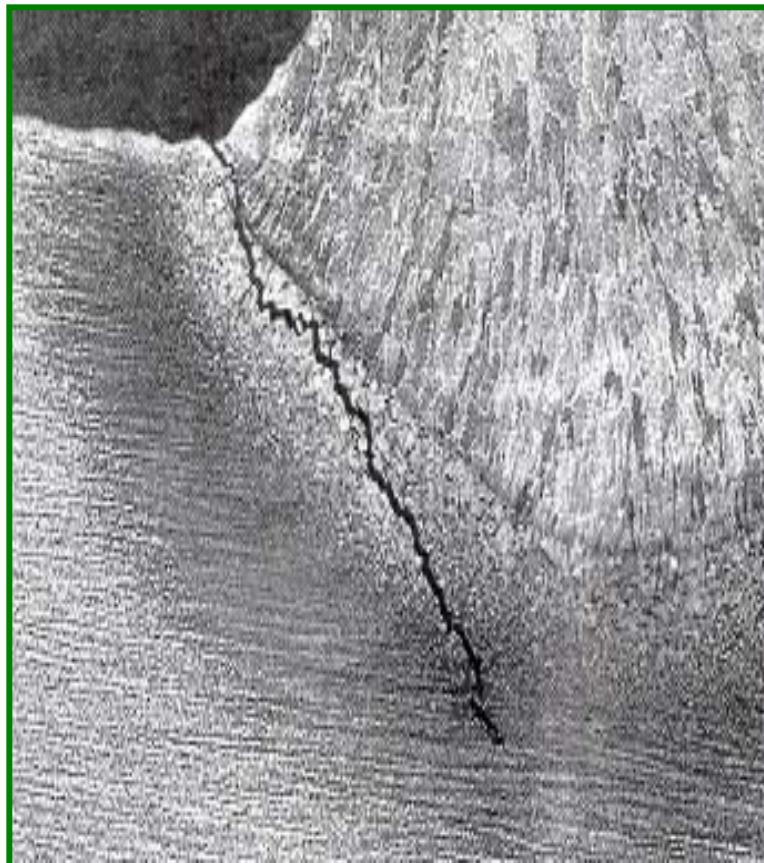


DIFFERENT TYPES OF CRACKS.



CRACK

❖ Crack which is visible on the surface is called a surface crack and a crack which can only be detected by radiography or fracturing, say by nick break test, is called Internal crack.

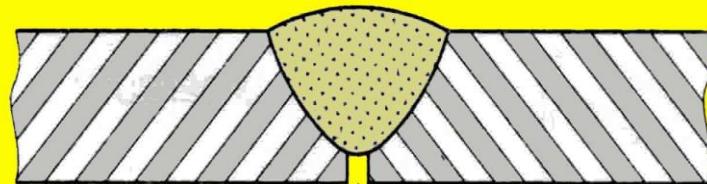




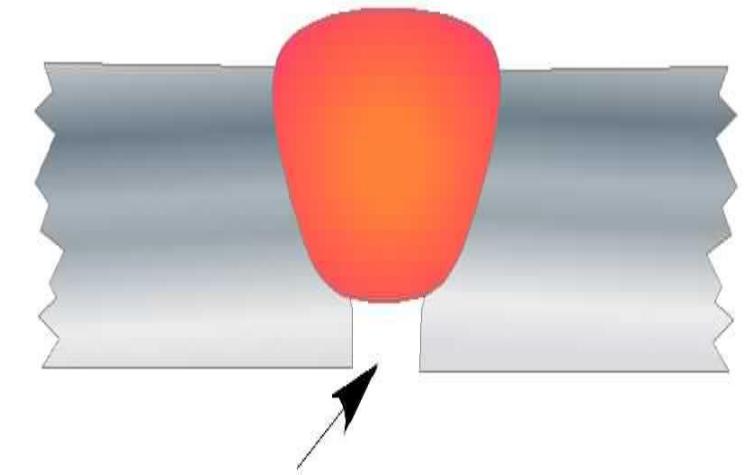
INTERNAL DEFECTS

Incomplete

Failure of weld penetration to reach the root of the joint



INCOMPLETE
PENETRATION



Insufficient Penetration

INCOMPLETE / EXCESS PENETRATION



Incomplete penetration



Excess penetration

INCOMPLETE ROOT FUSION



REASONS



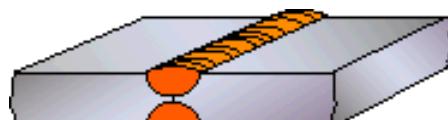
A



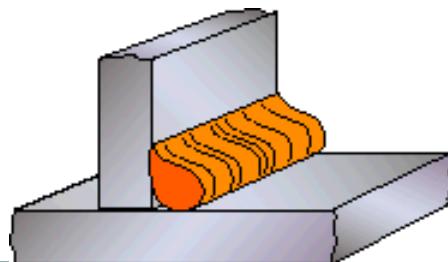
B



C



D



E

A - Excessively thick root face

B - Too small a root gap

C - Misplaced welds

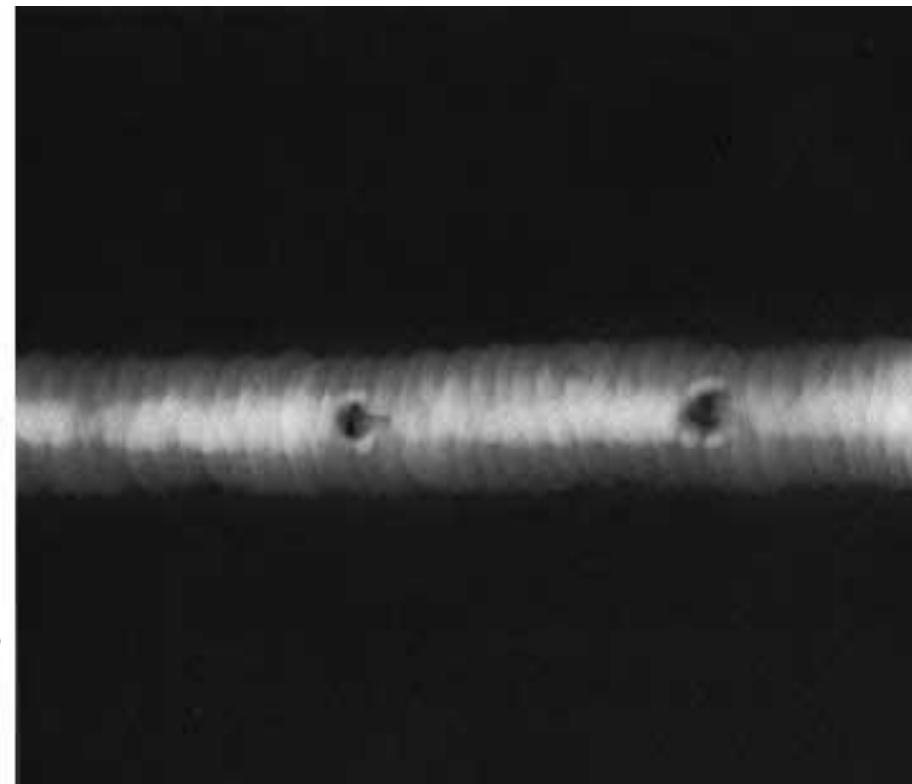
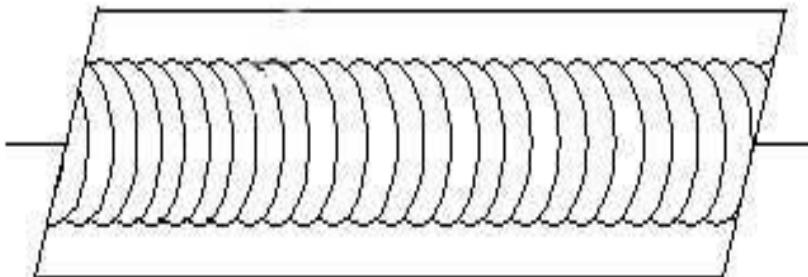
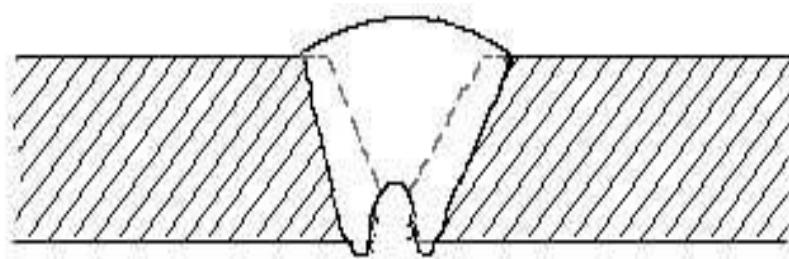
D - Power input too low

E - Arc (heat) input too low

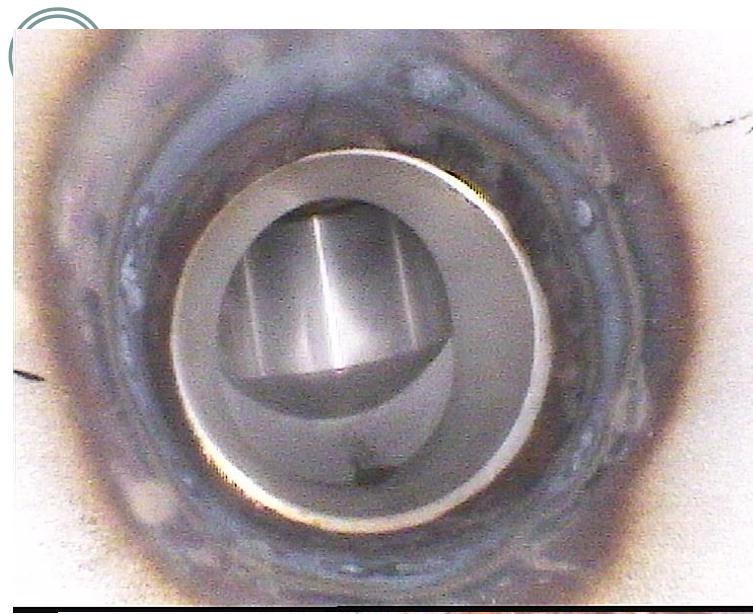
BURN THROUGH (NON STANDARD)

Definition: When an undesirable open hole has been completely melted through the base metal. The hole may or may not be open

Cause: Excessive Heat Input

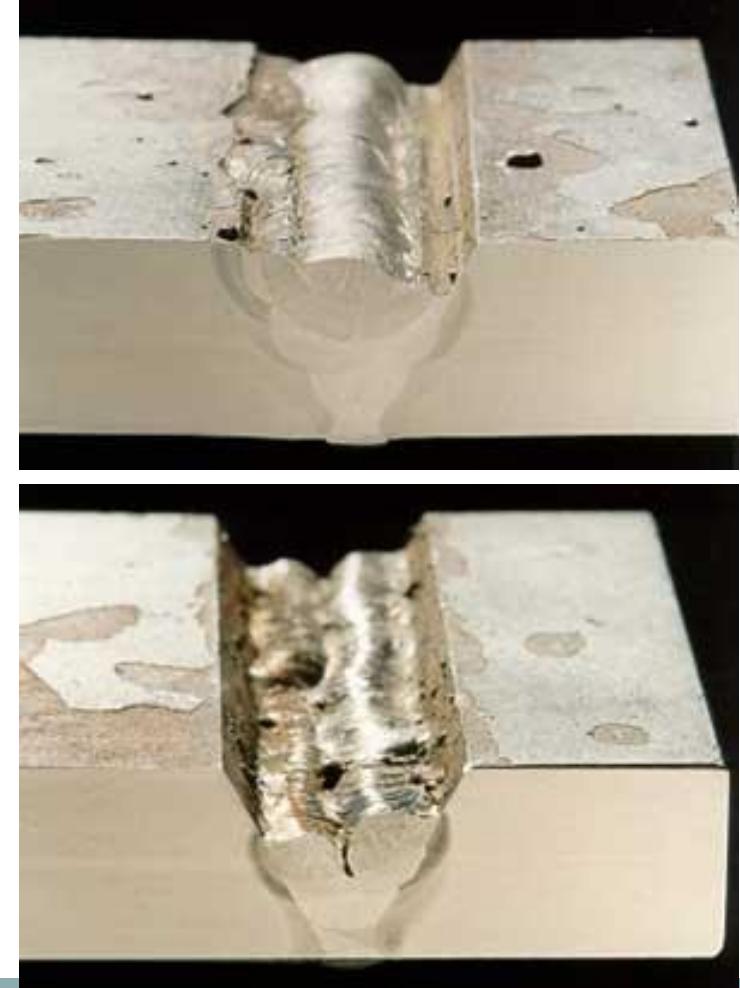
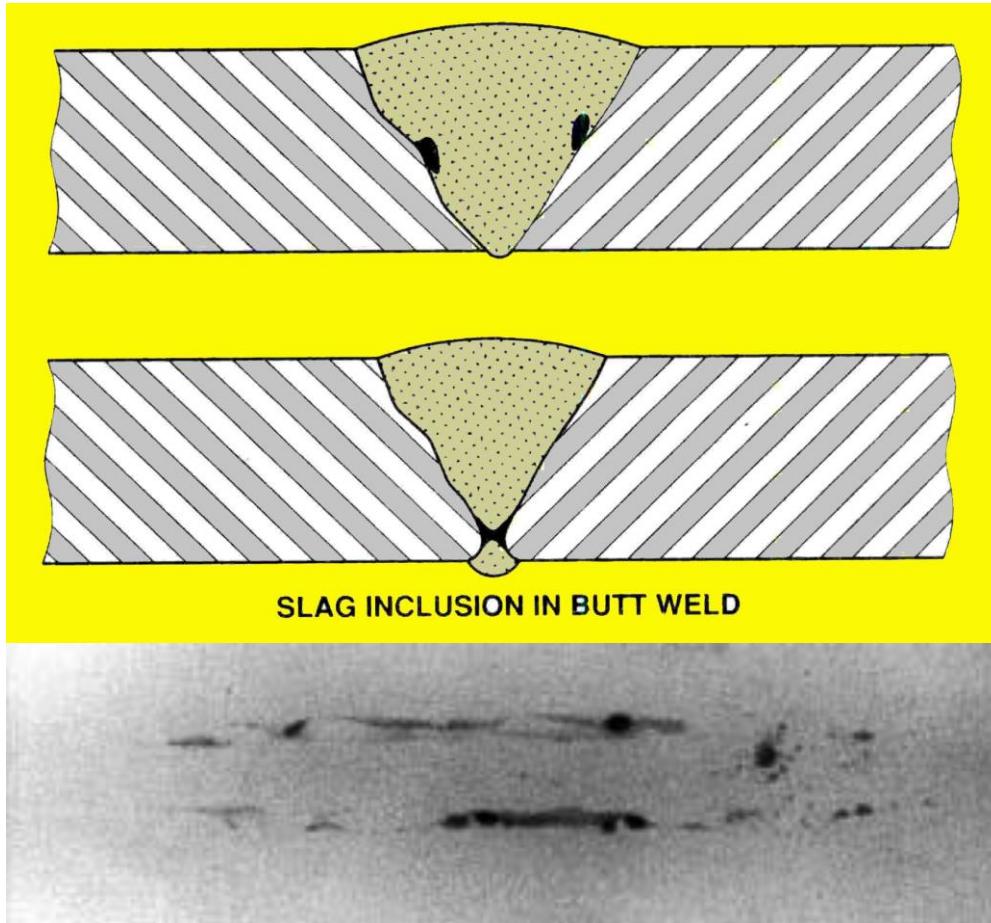


BURN THROUGH



Example of Burn through

Slag or other non-metallic foreign materials entrapped in a weld.

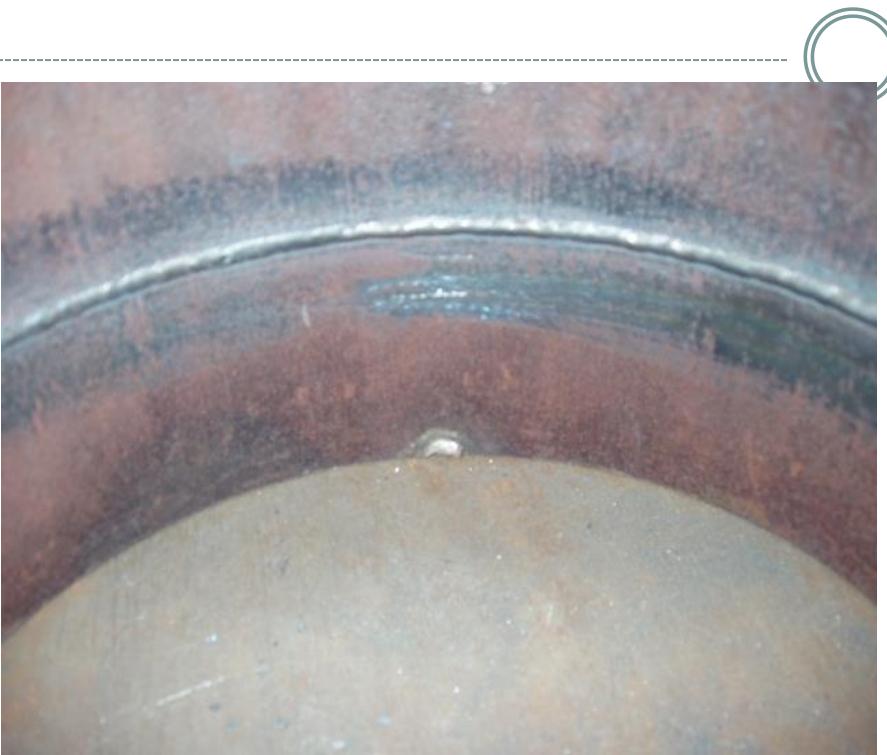


ARC STRIKE

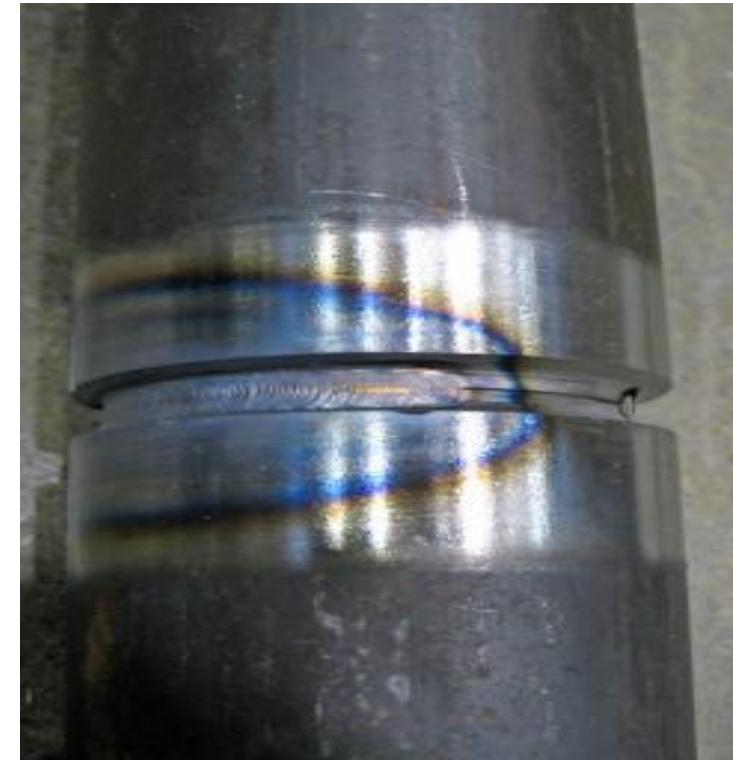


Example of an Arc Strike

GOOD ROOT RUN BY TIG

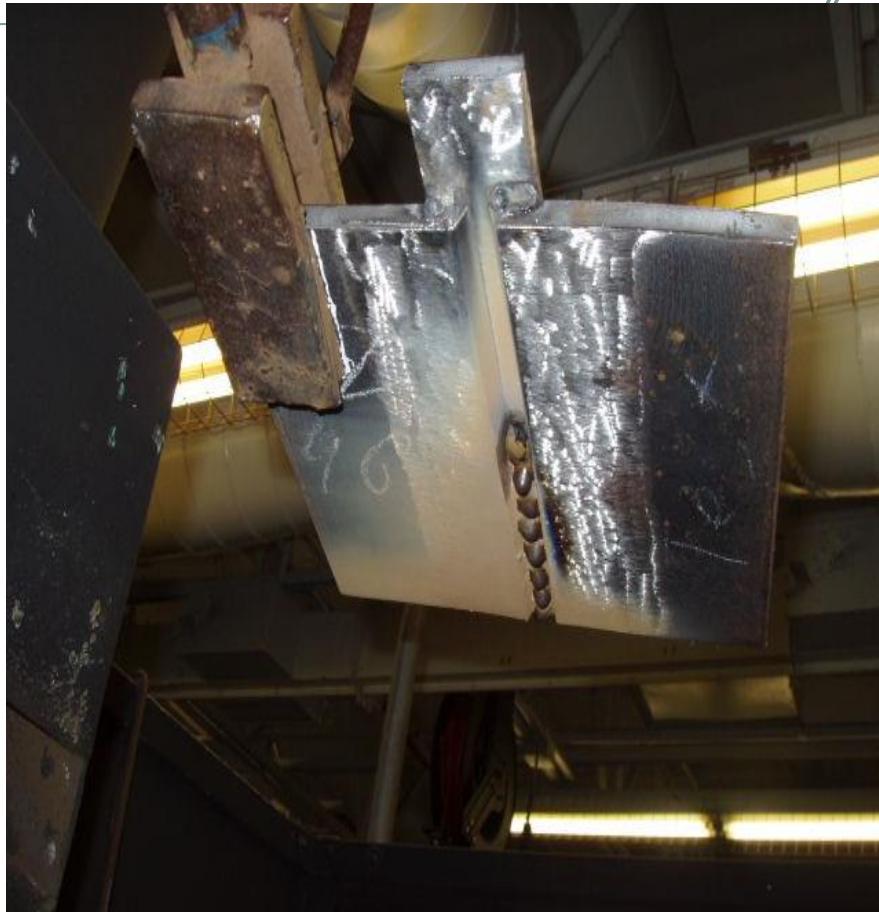


Proper TIG Root weld

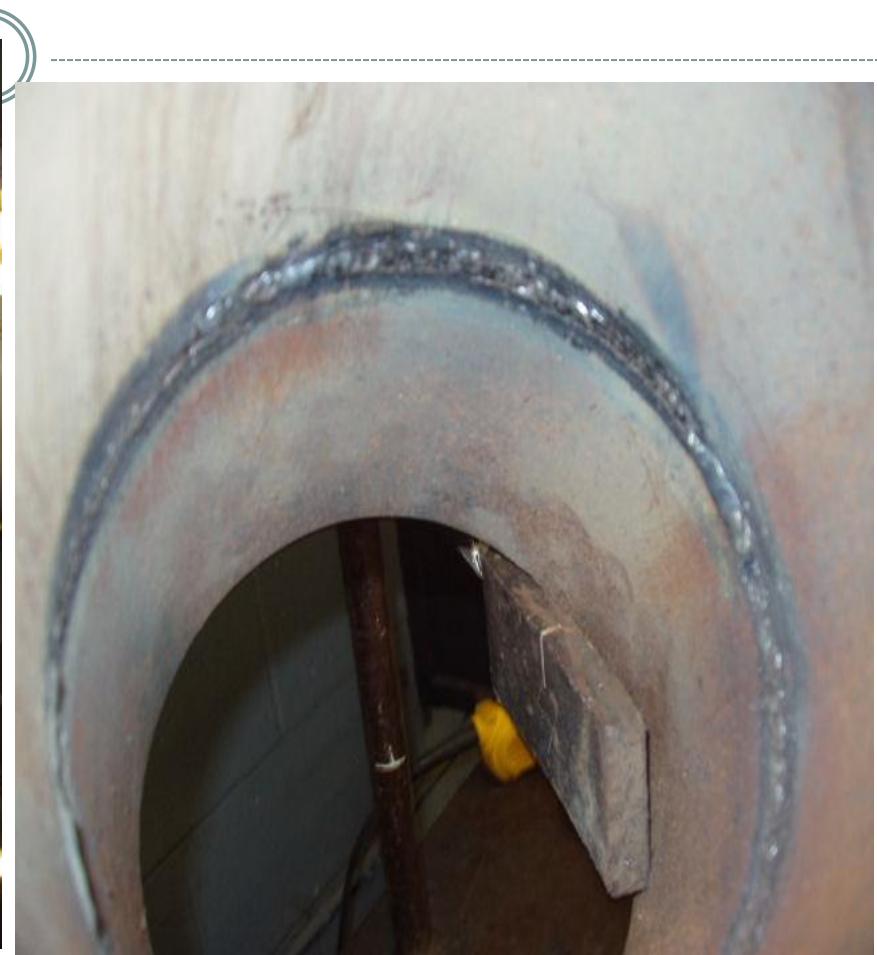


Proper TIG Root weld

ROOT WELD BY SMAW

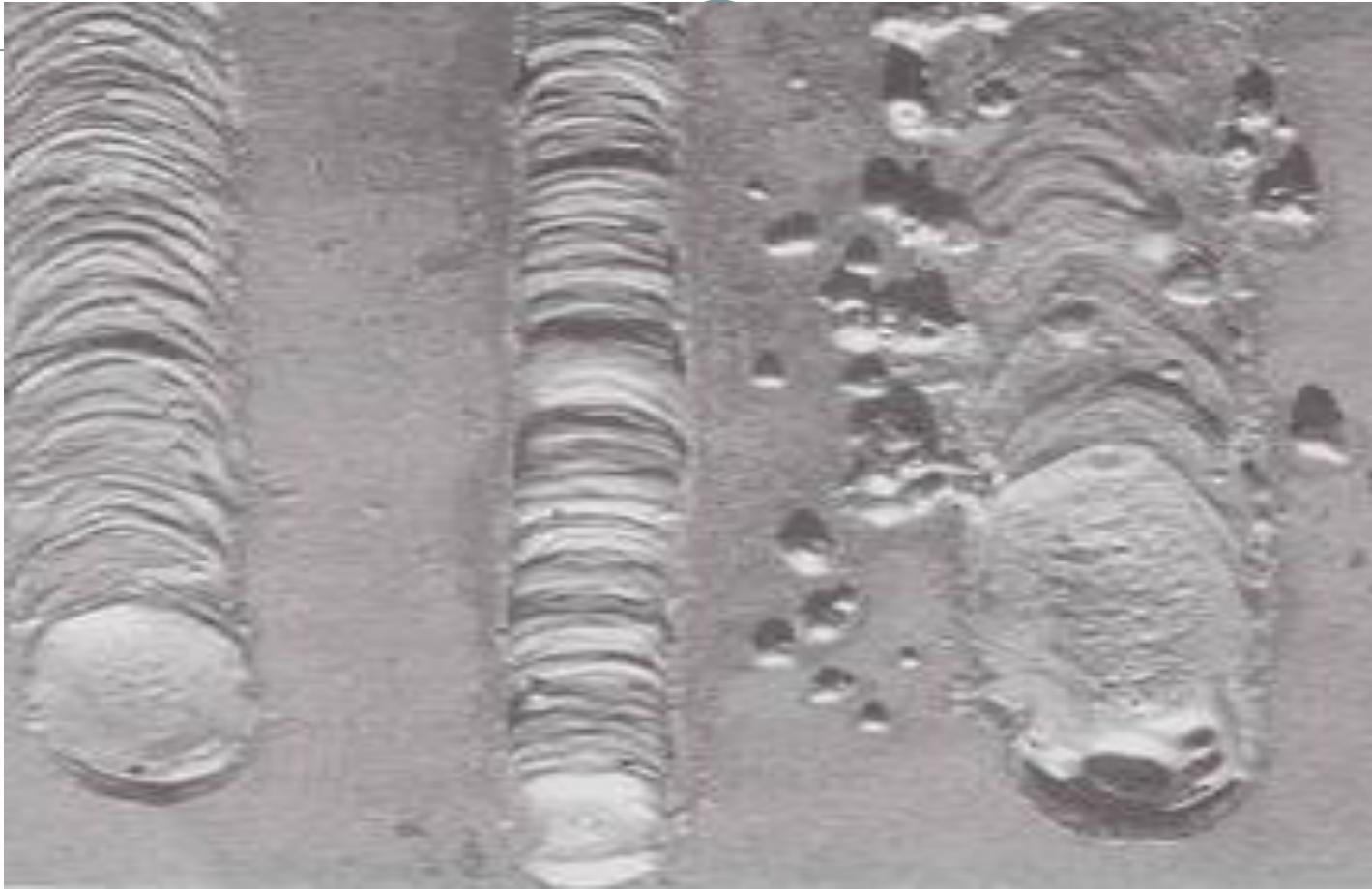


SMAW Root with slag



SMAW Root with E 6010

Comparison of weld beads



**The Good,
Ugly**

the Bad

and

the

VISUAL INSPECTION (NON-DESTRUCTIVE TEST)

REQUIREMENTS

Degree of undercut.

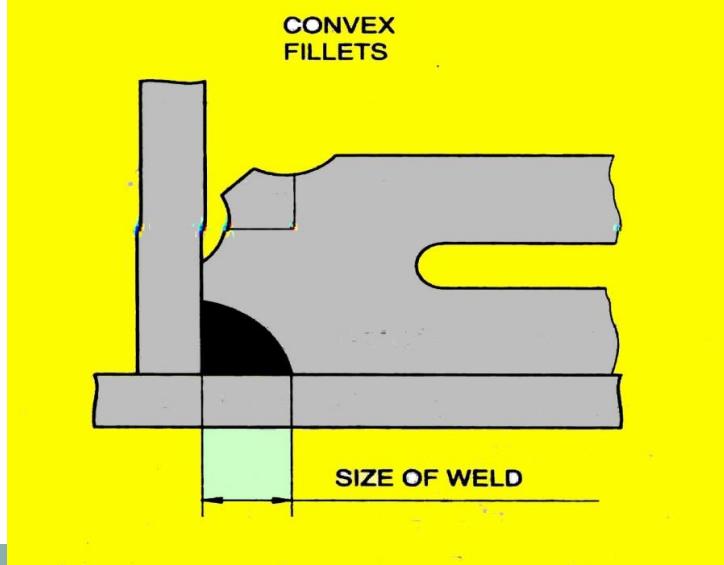
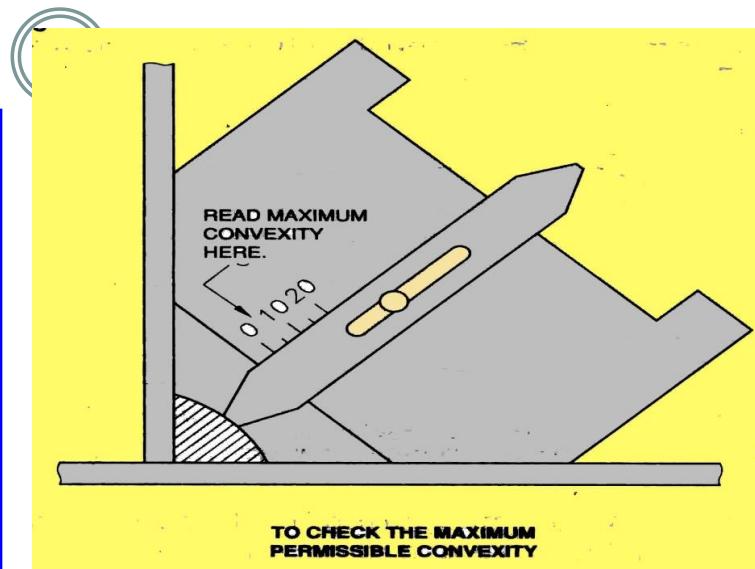
Smoothness of joint where welding is recommended.

Freedom from surface cavities, spatters, under cuts and trapped slag.

Deposition of runs, single or multiple.

Penetration bead in butt weld.

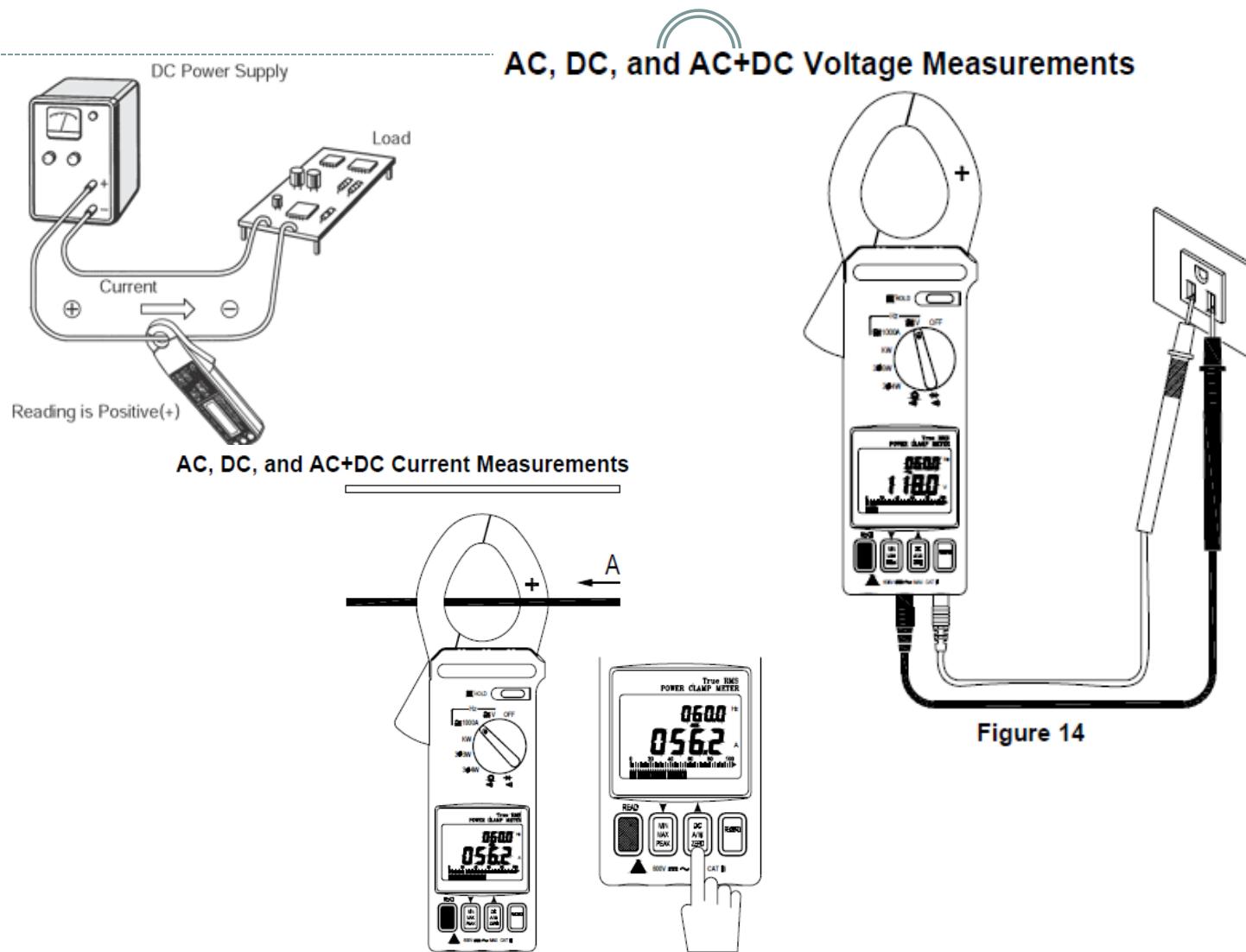
Quality of the weld metal.



MEASUREMENT OF CURRENT & VOLTAGE



MEASUREMENT OF CURRENT & VOLTAGE



MEASUREMENT OF TEMPERATURE



HOW TO WRITE A WPS FORMAT

Company Name ¹ CO INC. by ² (not required by rules of IX)
Welding Procedure Specification ³ #134 (no rules for numbering) Date ⁴ 01 August 87
Revision No. ⁵ 1 Date ⁶ 06 October 1998 Peat McSquinty, Welding Engineer by ⁷
Supporting PQR No.(s) ⁸ # Q134
Process ⁹ SMAW (Stick welding) Type ¹⁰ Manual
¹¹ For welding carbon steels with E6010 & E7018, without PWHT, (not qualified for notch toughness or impact tested applications)

- 1 The Code user should use the same name that the Code user has in the quality control manual
- 2 after the company name entitled “By:”. This was intended to be for the Code user's authorization or certification to use the WPS
- 3 There are no rules in Section IX for a WPS numbering system. A good quality program, however, should require a unique identification be assigned for each WPS.
- 4 The date that the WPS was certified or authorized in ² is normally used in this space.
- 5 QW-200.1(c) allows changes to be made to a WPS provided such changes are documented by revision or amendment. When a WPS is amended it should be documented including a revision level.
- 6 The revision or amendment should be dated on the WPS per QW-200.1(.c)
- 7 The revision or amendment should be certified or authorized as detailed in ². (Table 5.1, WPS # 134, listed the revision level at the top in the company identification block).

HOW TO WRITE A WPS FORMAT

8 QW-200.1(b) requires the WPS to reference its supporting PQRs. The supporting PQRs are normally noted in this identification block. (Note: It may take more than one PQR to support all the essential variable ranges specified in a WPS.)

9 The welding process is not listed as an essential variable in QW-253 , but is noted as an essential variable in QW-401.

10 QW-410.25 is a nonessential variable “type of process”, that must be described on the WPS. The type of welding is normally noted with the welding process,

<u>Comments</u>	<u>Welder or Operator</u>	<u>Process</u>	<u>Type</u>
	Welder	SMAW, GTAW	Manual
	Welder	GMAW, FCAW,	Semi-automatic
	Welding Operator	GMAW, FCAW,GTAW, SAW	Machine
adjustments can be made by welding operator	Welding Operator	GMAW, FCAW, GTAW,SAW	Automatic
No adjustment by operator			

11 There is no specified requirement for a description of what the WPS covers, but these descriptions are very helpful after the Code user has established a procedure qualification program with multiple WPSs. When a Code user has prepared dozens of WPSs, they all begin to look alike. A brief description may prove to be very beneficial when retrieving or assigning WPSs. (Table 5.1, WPS # 134 noted “For welding carbon steels with E6010 & E7018 without PWHT, (not qualified for notch-toughness or impact tested applications.”)

HOW TO WRITE A WPS FORMAT



JOINTS (QW-402)

Details

Joint Design _____

Root Spacing _____

Backing: Yes _____ No _____

Backing Material (Type) _____

(Refer to both backing and retainers)

Metal Nonfusing Metal

Nonmetallic Other

Sketches, Production Drawings, Weld Symbols, or Written Description should show the general arrangement of the parts to be welded. Where applicable, the details of weld groove may be specified.

[At the option of the manufacturer, sketches may be attached to illustrate joint design, weld layers, and bead sequence (e.g., for notch toughness procedures, for multiple process procedures, etc.)]

HOW TO WRITE A WPS FORMAT

QW-253 WELDING VARIABLES PROCEDURE SPECIFICATIONS (WPS) SHIELDED METAL-ARC WELDING (SMAW)

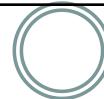
Paragraph		Brief of Variables	Essential	Non Essential
QW-402 . Joints	.1	φ Groove design		NE
	.4	- Backing		NE
	.10	φ Root spacing		NE
	.11	± Retainers		NE

When preparing the WPS, it does not matter if the variable is essential or nonessential. The WPS must address each variable listed for the process. QW-402.1 may be addressed by stating on the WPS which types of grooves may be used with the WPS.

HOW TO WRITE A WPS FORMAT

Joint Design (QW-402)

Weld Type: Groove and fillet welds



Joint Type	Backing	Root Opening	Groove Angle	Root Face	Groove Radius
Single-V groove	No backing	3/16" max	50 deg min	1/8" max	
Single bevel	No backing	3/16" max	45 deg min	1/8" max	
Single-V groove	Gouged & back welded	1/4" max	50 deg min	3/16" max	
Double bevel	Gouged & back welded	1/4" max	45 deg min	3/16" max	
Double-V groove	Gouged & back welded	1/4" max	45 deg min	3/16" max	
Square groove	T-joint	1/32" max			
Square groove	No backing	3/32" max			

Fillet Welds: All fillet sizes on all base metal thicknesses and all diameters. Retainers: None

WELD JOINT DESCRIPTIONS SHOWN ARE NOT INCLUSIVE OF ALL THOSE FOUND ON A JOB. WELD JOINT DESIGN REFERENCE IN AN ENGINEERING SPECIFICATION OR A DESIGN DRAWING SHALL TAKE PRECEDENCE OVER WELD JOINTS SHOWN IN THIS WPS.

HOW TO WRITE A WPS FORMAT



Example: Groove details may also be specified by reference on the WPS to:

- production drawings
- fabrication plans
- shop sketches

provided the joint design is available for reference by the:

- welder
- inspector (Code user's)
- supervisor
- Authorized Inspector (AI, NBCI, or API 510 Inspectors)

HOW TO WRITE A WPS FORMAT



*BASE METALS (QW-403)

P-No. _____ Group No. _____ to P-No. _____ Group No. _____

OR

Specification and type/grade or UNS Number _____

to Specification and type/grade or UNS Number _____

OR

Chem. Analysis and Mech. Prop. _____

to Chem. Analysis and Mech. Prop. _____

Thickness Range:

Base Metal: Groove _____ Fillet _____

Maximum Pass Thickness \leq $1/2$ in. (13 mm) (Yes) _____ (No) _____

Other _____

HOW TO WRITE A WPS FORMAT



QW-253 WELDING VARIABLES PROCEDURE SPECIFICATIONS (WPS) SHIELDED METAL-ARC WELDING (SMAW)

Paragraph	Brief of Variables	Essential	Non Essential
QW-403 . Joints	.7 T/t limits > 8 inch (203 mm)	E	
	.8 φ T Qualified	E	
	.9 t Pass > 1/2 inch (13 mm)	E	
	.11 φ P-No. qualified	E	
	.13 φ P-No. 5/9/10	E	

HOW TO WRITE A WPS FORMAT

The first rule for determining how each essential variable is to be applied, is to review the specific essential variable of QW-253, such as QW-403.8, φ T qualified. It is very difficult to understand and use the variable from the description noted in the “Brief of Variables” column. Read the actual variable, such as QW-403.8, “A change in base metal thickness beyond the range qualified in QW-451, except as otherwise permitted by QW-202.4(b).”

Base Metals (QW-403)

P-No. 1 Gr No: 1 & /or 2 Thickness Range: 0.1875 in. to 1.8120 in.

to P-No. 1 Gr No: 1 & /or 2 Thickness Range: 0.0625 in. to 0.1660 in.

BASE METAL (QW-403)

MATERIAL SPECIFICATION : -IS-2062 E250 (Fe 410W) to IS-2062 E250 (Fe 410W)

TYPE AND GRADE : Gr B to Gr. B

P NO. : P1 Gr 1 to P-1 Gr.1

THICKNESS OF TEST COUPON.: 8 MM to 8 mm

DIAMETER OF TEST COUPON.: - Not applicable

MAXIMUM PASS THICKNESS : Less than 13 mm Yes

HOW TO WRITE A WPS FORMAT



*FILLER METALS (QW-404)

1

2

Spec. No. (SFA) _____		
AWS No. (Class) _____		
F-No. _____		
A-No. _____		
Size of Filler Metals _____		
Filler Metal Product Form _____		
Supplemental Filler Metal _____		
Weld Metal		
Thickness Range:		
Groove _____		
Fillet _____		
Electrode-Flux (Class) _____		
Flux Type _____		
Flux Trade Name _____		
Consumable Insert _____		
Other _____		

*Each base metal-filler metal combination should be recorded individually.

HOW TO WRITE A WPS FORMAT

QW-404 Filler Metals	.3	ϕ Size			X
	.4	ϕ F-Number	X		
	.5	ϕ A-Number	X		
	.12	ϕ Classification		X	
	.14	\pm Filler	X		
	.22	\pm Consum. Insert			X
	.23	ϕ Filler metal product form	X		
	.30	ϕ t	X		
	.33	ϕ Classification			X
	.50	\pm Flux			X

SMAW	.4	ϕ F-Number	X		
	.5	ϕ A-Number	X		
	.6	ϕ Diameter			X
	.7	ϕ Diameter > $\frac{1}{4}$ In. (6 mm)		X	
	.12	ϕ Classification		X	
	.30	ϕ t	X		
	.33	ϕ Classification			X

HOW TO WRITE A WPS FORMAT

First Process:

GTAW

Type:

Manual

Filler Metal (QW-404)

Weld Deposit Limits: 0.2500 in. maximum

AWS Classification: ER70S-2

SFA Specification: 5.18

F-No.: 6

A-No. or Chemical Composition: 1

Filler Metal Product Form: Bare (Solid)

FILLER METALS (QW-404)

Weld Process	G.T.A.W	S.M.A.W
Spec. No. (SFA)	SFA 5.4
AWS No. (Class)	E-309Mo
F. No./ A No.	F6 - / A.8.	F-5 / A-8
Solid,Metal cored,OR Flux cored	Solid	Not Applicable
Size of Filler Metal	1.6 or 2 mm Ø	2.5,3.15 or 4.0 mm Ø
Trade Name	Avesta P-5	ESAB OK 67.70,DK-309 Mo, INOX D2-Mo or Equivalent
Consumable insert	NO	N.A
Process range in groove: in Fillet :	Upto 8 mm All size	Upto 8 mm All size
Others :	N.A	N.A

HOW TO WRITE A WPS FORMAT

POSITIONS (QW-405)

Position(s) of Groove _____

Welding Progression: Up _____ Down _____

Position(s) of Fillet _____

Other _____

GTAW / SMAW Positlons	.1	+ Position			X
	.2	ϕ Position		X	
	.3	ϕ ↑↓ Vertical welding			X

Position (QW-405)

Position of Joint: All Positions Weld Progression: Vertical up

POSITIONS (QW-405)
Position of groove : <u>All</u>
Welding Progression: <u>Uphill</u>
Position of FILlets: <u>All</u>
Other : <u>Not Applicable</u>

HOW TO WRITE A WPS FORMAT

PREHEAT (QW-406)

Preheat Temperature, Minimum _____

Interpass Temperature, Maximum _____

Preheat Maintenance _____

Other _____

(Continuous or special heating, where applicable, should be recorded)

SMAW

QW-406 Preheat	.1	Decrease > 100°F (55°C)	X		
	.2	ϕ Preheat maint.			X
	.3	Increase > 100°F (55°C) (IP)		X	

GTAW

QW-406 Preheat	.1	Decrease > 100°F (55°C)	X		
	.3	Increase > 100°F (55°C) (IP)		X	

HOW TO WRITE A WPS FORMAT

Preheat (QW-406)

Minimum Preheat Temperature:



55 ° F Maximum Inter pass

Temperature: 550 ° F

Preheat Maintenance: None

Preheat to 175 F if "T" > 1 and C > 0.30%

PREHEAT (QH-408)

Thickness Range (mm)	<=25	26 to 31	32 to 50	50 to 100	> 100
Preheat Temp. (Min.) °C	185 °C	165 °C	165 °C	165 °C	185 °C
Interpass Temp. (Max.) °C	250 °C	250 °C	250 °C	250 °C	250 °C

Preheat Maint: By Gas Burner or Electrical Resistance Heating. (300 °C)

PREHEAT (QW-408)

Thickness range (mm)	<= 25	26 to 31	32 to 50	51 to 100	> 100
Preheat Temp. (Min.) °C	15 °C	50 °C	100 °C	100 °C	100 °C
Interpass Temp. (Max.) °C	250 °C	280 °C	250 °C	250 °C	250 °C

HOW TO WRITE A WPS FORMAT

POSTWELD HEAT TREATMENT (QW-407)

Temperature Range _____

Time Range _____

Other _____

GTAW & SMAW

QW-407 PWHT	.1	ϕ PWHT	X	
	.2	ϕ PWHT (T & T range)		X
	.4	T LImits	X	

Postweld Heat Treatment (QW-407)

PWHT Type: PWHT below lower transformation temperature

PWHT Temperature : 11000 ° F

PWHT Holding Time: 1.0 hr./in., 0.25 hr. min.

HOW TO WRITE A WPS FORMAT

POSTWELD HEAT TREATMENT (QW-407)

Type of PWHT : Stress Relieving

Temp. Range : 610 °± 10 ° C

Time Range : 1Hr/Inch. (UCS 56*)

Heating Rate : 150 °C/ Hr. (max*)

Cooling Rate : 150 °C/ Hr. (max*)

* See equipment drg./spec. for
restriction within above range

POSTWELD HEAT TREATMENT (QW-407)

Temperature _____

Time Range NOT APPLICABLE

Others _____

HOW TO WRITE A WPS FORMAT

GAS (QW-408)

Percent Composition

	Gas(es)	(Mixture)	Flow Rate
Shielding	_____	_____	_____
Trailing	_____	_____	_____
Backing	_____	_____	_____
Other	_____	_____	_____

QW-408 Gas	.1	\pm Trall or ϕ comp.			X
	.2	ϕ Sngle, mixture, or %	X		
GTAW	.3	ϕ Flow rate			X
	.5	\pm or ϕ Backing flow			X
	.9	- Backing or ϕ comp.	X		
	.10	ϕ Shielding or tralling	X		

HOW TO WRITE A WPS FORMAT

Gas (QW-408)

Shielding: 100% Argon / CFH  14-21

Backing: None /
- CFH

Trailing: None /
- CFH

GAS (QW - 408)

* Composition

	Gas(es)	(Mixture)	Flow rate
Shielding Gas	Argon	Welding Quality	4 to 15 lpm
Backing Gas	Argon	Welding Quality	4 to 15 lpm
Trailing Gas	No.	----	-----
Others :	Backing gas for first two runs only.		

HOW TO WRITE A WPS FORMAT

ELECTRICAL CHARACTERISTICS (QW-409)

Weld Pass(es)	Process	Filler Metal		Current Type and Polarity	Amps (Range)	Wire Feed Speed (Range)	Energy or Power (Range)	Volts (Range)	Travel Speed (Range)	Other (e.g., Remarks, Comments, Hot Wire Addition, Technique, Torch Angle, etc.)
		Classification	Diameter							

Amps and volts, or power or energy range, should be recorded for each electrode size, position, and thickness, etc.

Pulsing Current _____

Heat Input (max.) _____

Tungsten Electrode Size and Type _____

(Pure Tungsten, 2% Thoriated, etc.)

Mode of Metal Transfer for GMAW (FCAW) _____

(Spray Arc, Short Circuiting Arc, etc.)

Other _____

HOW TO WRITE A WPS FORMAT

SMAW



QW-409 Electrical Characteristics	.1	> Heat Input		X	
	.4	ϕ Current or polarity		X	X
	.8	ϕ I & E range			X

GTAW

QW-409 Electrical Characteristics	.1	> Heat Input		X	
	.3	± Pulsing I			X
	.4	ϕ Current or polarity		X	X
	.8	ϕ I & E range			X
	.12	ϕ Tungsten electrode			X

HOW TO WRITE A WPS FORMAT



Electrical Characteristics (QW-409)

Current Type and Polarity: DCEN (straight)

Pulsed Current: None

Tungsten Type: EWTh-2 Size: 3/32"

Max. Heat Input (J/in): None

First Process Welding Parameters

Layer(s) and/or Pass(es)	Filler Metal		Current		Voltage Range	Travel Speed Range (in/min)
	AWS Classification	Size (in.)	Type and Polarity	Amperage Range		
Any	ER70S-2	1/16	DCEN (straight)	70-150	n/r	Var.
Any	ER70S-2	3/32	DCEN (straight)	80-180	n/r	Var.
Any	ER70S-2	1/8	DCEN (straight)	130-275	n/r	Var.
Any	ER70S-2	3/16	DCEN (straight)	200-375	n/r	Var.

HOW TO WRITE A WPS FORMAT



Electrical Characteristics (QW-409)

Current Type and Polarity: DCEP (reverse)

Max. Heat Input (J/in): None

Second Process Welding Parameters

Layer(s) and/or Pass(es)	Filler Metal		Current		Voltage Range	Travel Speed Range (in/min)
	AWS Classification	Size (in.)	Type and Polarity	Amperage Range		
Any	E7018	3/32	DCEP (reverse)	70-110	n/r	Var.
Any	E7018	1/8	DCEP (reverse)	90-160	n/r	Var.
Any	E7018	5/32	DCEP (reverse)	130-220	n/r	Var.
Any	E7018	3/16	DCEP (reverse)	200-300	n/r	Var.
Any	E7018	7/32	DCEP (reverse)	250-350	n/r	Var.

HOW TO WRITE A WPS FORMAT

ELECTRICAL CHARACTERISTICS (QW-409)

Current AC or DC:Direct Current Polarity: GTAW-DCSP, SMAW- DCRP

Amps (Range):50 to 175 A(Ref.Table) Volts:(Range) 08-30 V (Ref.Table)

Tungsten Electrode Size & Type: 1.6,2.4 or 3.0 ø; EW Th.2

Pulsing Current : GTAW - NO. , SMAW - N.A

Electrode wire feed / speed range: Not Applicable

Maximum Heat Input (KJ / mm): Not applicable

HOW TO WRITE A WPS FORMAT

Weld Layers	Process	Filler Metal		Current		Volt Range	Gas Flow Rate lpm
		Class	Dia.	Type	Amp.		
Any	GTAW	ER-316L	1.6 mm	DCSP	60-150	08-18	4 to 15
			2.0 mm	DCSP	80-200	08-20	4 to 15
Any	SMAW	E316L-16	2.5 mm	DCRP	50-90	16-24	N.A
Any	SMAW	- do -	3.15 mm	DCRP	75-125	16-28	N.A
Filler	SMAW	- do -	4.0 mm	DCRP	80-175	20-30	N.A

HOW TO WRITE A WPS FORMAT



TECHNIQUE (QW-410)

String or Weave Bead _____

Orifice, Nozzle, or Gas Cup Size _____

Initial and Interpass Cleaning (Brushing, Grinding, etc.) _____

Method of Back Gouging _____

Oscillation _____

Contact Tube to Work Distance _____

Multiple or Single Pass (Per Side) _____

Multiple or Single Electrodes _____

Electrode Spacing _____

Peening _____

Other _____

HOW TO WRITE A WPS FORMAT

GTAW

**QW-410
Technique**

.1	∅ String/weave			X
.3	∅ Orifice, cup, or nozzle size			X
.5	∅ Method cleaning			X
.6	∅ Method back gouge			X
.7	∅ Oscillation			X
.9	∅ Multi to single pass/side		X	X
.10	∅ Single to multi electrodes		X	X
.11	∅ Closed to out chamber	X		
.15	∅ Electrode spacing			X
.25	∅ Manual or automatic			X
.26	± Peening			X
.64	Use of thermal processes	X		

SMAW

**QW-410
Technique**

.1	∅ String/weave			X
.5	∅ Method cleaning			X
.6	∅ Method back gouge			X
.9	∅ Multiple to single pass/side		X	X
.25	∅ Manual or automatic			X
.26	± Peening			X
.64	Use of thermal processes	X		

HOW TO WRITE A WPS FORMAT



Technique (QW-410) (For First Process GTAW)

Stringer or Weave Bead: Weave bead

Nozzle / Gas Cup Size: _____ #5 to #10

Peening: None

Multiple / Single Pass (per side): Multipass

Technique (QW-410) (For Second Process SMAW)

Stringer or Weave Bead: Stringer and weave bead

Peening: None

Multiple / Single Pass (per side): Multipass

HOW TO WRITE A WPS FORMAT

TECHNIQUE (QW-410)

String or Weave Bead String &/or Weave (Deposited Thk. per layer ≤ 12mm)

Orifice or Gas Cup Size: 6 or 9 mm

Closed or open chamber Open Chamber

Initial or interpass cleaning: By Brushing, Chipping &/or Grinding

Method of Back Gouging: Not Applicable

Multiple or Single Pass (per side) Multiple Pass

Multiple or Single Electrode Single Electrode

Oscillation : Not Applicable Peening : NO

Electrode Spacing: Not Applicable

Manual, Automatic, Semi Automatic etc. : GTAW & SMAW - Manual welding

Travel speed (Range): Variable



THANK YOU