An Approach to Best Welding Practice Part – XIX.

S. K. Gupta, B.E., C.E., FIE., FIIW., MISNT., MAE., MITD.
E-mail : skg1938@gmail.com

ORCID: Samir Kumar Gupta: https://orcid.org/0000-0002-1504-8301

"AN APPROACH TO BEST WELDING PRACTICE. Part – XIX." is the Nineteenth Detail Part of "AN APPROACH TO BEST WELDING PRACTICE" which was written as a General and Overall approach to the subject matter.

AN APPROACH TO BEST WELDING PRACTICE. Part – XIX. is particularly focused on the Generation and Computer based Storage of Welding Data required as a Working Guideline for Planning Engineers, Welding Co-ordinators and Quality Managers working in an Engineering Fabrication Plant using welding as the main manufacturing process.

In fact, this is a lengthy process to develop and as each and every step is connected with each other for cross references, none can be eliminated.

In every Fabrication concern where Welding is the major manufacturing process preparation, recording and storage of welding processes must be done.

The Importance of Record Keeping

In earlier days we have seen that for technology implementation, production and productivity enhancement every manufacturing and fabrication industry was dependant on what is called a "Mistri Culture". Any past or present performance information about individual or group or machinery was also to be obtained from the Mistris of different work centers. Later on shop floor engineers replaced the Mistris but information regarding shop floor performances still remained under the custody of individuals and retrieval can not be done if the individual leave the organization.

Such situations are critical in case of Fabrication and Manufacturing concerns employing welding as the main manufacturing process, as because welding is a "Special Process" and the Product acceptance is dependent upon follow up of a number of Procedures, Codes and Standards. Documentation of all these proceedings are to be meticulously prepared and maintained – normally by the "Welding Engineer" or "Welding Coordinator." Again, apart from documentation so many data related to the Power Source, Electrodes, Gases used, Maintenance schedules etc are to be coordinated with variety of data converging for a product to be manufactured and to be accepted by the customer. Normally, most of these are paperwork and the tendency is either to destroy the past records of papers or to dump them somewhere beyond restoration. Even the large volume of information kept in mind of the Welding Engineer or the Welding Coordinator in course of work are irretrievable to any new incumbent or others.

It is an accepted fact now that data collection, storage and retrieval can not be done effectively with human individuals or even by groups and possibilities of distortion of retrievable data cannot be ruled out.

With the above background three basic questions come up :

I. What data are needed?
II. Who will use the data?
III. How to design, store and retrieve data ?

I. What Data are needed ?

It is understood and accepted that in Fabrication and manufacturing Industries where Welding is the main process, classification of Data used and needed is very difficult. We can at best identify the following as top three needs

I.1. General welding procedures and Procedure qualification records

I.2. Materials and Properties of materials

I.3. Welding Processes, Power Sources. Equipment and Consumables, Codes.

The above mentioned needs can be elaborated a little more as under :

1. Preparing and Maintaining Procedure and Personnel Qualification Records.
2. Welding Consumables and Power Sources with Ancillary Equipment
   a. Welding power sources type
   b. Electrodes and weld metal
   c. Shielding and flux material
   d. Electrical characteristics
3. Base-metal type and thickness;
4. Joint design weldment design and surface preparation

5. Weld location Welding position -
6. Welding process
7. Quality level (NDT); specifications and codes

II. Who will need the data for use in their professional work ?

It has already been stated in the beginning of this article that our target population as users of computerized data will be :

- Planning Engineers,
- Welding Engineers,
- Co-ordinators and
- Quality Managers.

In wider perspective the beneficieries of data users may be :

- Owners
- Designers
- Fabricators and manufacturers
- Code writers
- Researchers

III. How to store and retrieve data ?

A large number of computer softwares have been developed to store data, modify and to retrieve as and when required. This system will eliminate human error, can link and compare past performances with the present one instantly, may even point out optimum use of resources for increased efficiency, effectiveness of resources for ultimate gain of productivity and quality improvement.

An integrated system will include:

- Filler and base metals and their chemical and mechanical properties;
- Histories of welder qualification and the quality of welds by each welder;
- Welding-procedure information, including WPSs, PQRs, and pre- and post weld heat-treatment information;
- Design information, including joint design graphics and welding symbol information; Corrosion-resistant and wear-resistant material information, such as ferrite content and prediction for stainless steel welds.

The softwares art all designed to operate in the computing environment of the desktop computer, turning the computer into a welding engineering work station.

I.1 Maintaining Procedure and Personnel Qualification Records.

The following documents are mandatory to be prepared, qualified and approved by the Purchaser before manufacturing starts.

- Welding Procedure Specifications
- Procedure Qualification Records
- Welders Performance Qualifications

Welding Procedure Specifications (WPS)

The WPSs are prepared to ensure repeatable acceptability of the weld, when the procedure is implemented by trained and qualified professional welders and tested as per qualification standards.

The advantage of computer-aided WPS is to make sure that essential, supplementary essential, and nonessential variables in Standard Codes like ASME's Boiler and Pressure Vessel Code Section IX, AWS D1.1, API 1104, or any other code being used are being followed to fulfill the requirements. The Fabricator / Manufacturer should have a standard Format of WPS in which relevant data / information / diagrams are incorporated and preparation will then take minimum time. Also past WPSs must be documented in the computer so that references can be made. It has been observed that ASME Section IX if followed meticulously, acceptance by the Client/ Customer will be easier. Every WPS must bear the Company Logo, Address and other details, Serial Number and a Code to identify Product wise WPS.

Procedure Qualification Records (PQR)

Every WPS is to be qualified by PQR, representing a record of the welding variables and the tests conducted to qualify the WPS. The PQR includes the non-destructive and destructive tests based on acceptance criteria as specified in a particular Code or Standard.

Just like WPS Format and details PQR should have the identical system and Markings to connect the related WPS. It must have the test results with certifying testing agency details and credentials. The data entry Engineer must understand the importance of this document for its intrinsic value.

With the emergence of computer software packages that create and manage the PQR and WPS documents, their capabilities have been extended into an area namely welder continuity and certification management. These advanced applications cover the analysis and storage of the welders, plus the WPQRs, which are the official records of a welder's ability to perform a weld according to a specific welding procedure specification.

Welders Performance Qualification (WPQ)

Any welder engaged in welding ferrous, nonferrous metals and alloys must pass the Qualification Tests as specified in the code for a particular product. Such tests involve use of the same welding process to be used in fabrication/welding to a specified

Position with Consumables and also following the pre weld and post weld heat treatment procedure. The test pieces will be subjected to non-destructive and destructive testing for qualifying the welder.

WPQs are to be prepared for each welder the organization intends to deploy for the products for which the WPS and PQR have been approved by a Client/Customer. Again a Standard Format is to be used incorporating all the details of the welder and the test details. Just like PQR all the test documentation has to be done thoroughly with cross references.

Every welder qualifying for particular process, engagement details etc. must be listed for any quick reference needed.

With the emergence of computer software packages that create and manage the PQR and WPS documents, their capabilities have been extended into an area namely welder continuity and certification management. These advanced applications cover the analysis and storage of the welders, plus the WPQRs, which are the official records of a welder's ability to perform a weld according to a specific welding procedure specification.

I.2. Materials and Properties of Materials

The wide use of various Ferrous and Non-ferrous Metals in Fabrication and Manufacturing industries with Welding as the main manufacturing process requires access to the properties of each of the metals or alloys.

The common metals and alloys in use are :

a. Carbon steel
b. Low-alloy steel
c. Stainless steel -P6, P7, P8
d. Nickel-base alloys -P41, P42, P43, P44
e. Aluminum
f. Copper-base alloys -P31, P32, P33, P34, P35
g. Reactive metals — titanium, zirconium

The essential and effective Properties of weld metal, HAZ, and base metal (including statistical spread) are :

1. Mechanical properties
   a. ultimate tensile strength
   b. yield strength
   c. ductility
   d. toughness (Kjc, CVN)
   e. hardness
   f. creep
   g. fatigue
   h. stress rupture (most lacking in HAZ data)
2. Corrosion rates and fatigue
3. Physical Properties of Material —
   a. modulus,
   b. conductivity,
   c. density
   d. formability
   e. machinability
   f. hardenability
   g. wear and abrasion characteristics
4. Additional metallurgical characteristics
   a. cleanliness
   b. composition
   c. prior history, including thermal treatment or deformation
5. Chemical properties
6. Weldability

I.3. Welding Processes, Power Sources Equipment and Consumables

This is an area in which the Welding Engineer will have proliferation of data from a large number of Manufacturers of Consumables, Power Sources, Ancillary Equipment and Spares. Data entry in this area to be made precisely on the Power Sources, Gas and Plasma Cutting equipment, Consumables used at the Plant mainly. There must be ways and means to enter Performances. Capacity, Duty Cycle, OCV, Compatibility with equipment, Calibration Records, Maintenance Schedule and Spares are the entries required. Consumables like Electrodes, Gases should have regular entries to compare with a prepared Standard recorded lists.

Power Sources introduced into the market at regular intervals advertise alround improved performances. A note with records of such items can be made so that during replacement of Power Sources and related equipment it comes handy as reference.

Catalogues, Manuals, Hand Books are regularly published by Consumable and Equipment Manufacturers. Lists can be compiled for performances of commonly used consumables and equipment.

Electrodes selected and used for a particular joint in a project may have so many alternative options, all technically appropriate. But there are factors like cost, bulk supply, daily supply, vendor approved, payment terms, welder friendly, safety are all to be considered for placement of order for a particular brand. The comparative study along with the test results must be recorded as a data base.

Shielding gases and a proper mix can also be done by various means – having cylinders with mixed gas supply, mixing two or three gases in pipeline supply from the liquid gas tanks for bulk supply to shops, cylinders with different gases mixed at the welding point. The Welding Engineer must collect data and enter into the computer as comparative choice with economic

and technical factors emphasized.

Specific characteristics of all the inert and active gases must be tabulated to identify particular gas or a mix for specific metal and productive welding.

Unlike earlier years of Welding application in fabrication and manufacturing there may be now a multi process production line in which a combination of Cutting processes for preparation and a combination of Welding processes for fabrication is used. Selection may be from SMAW, GMAW, GTAW, SAW, Resistance Welding, FCAW, PAW with variables associated with each process and for each material

1. Welding variables
   - process
   - joint design
   - post weld heat treatment
   - productivity data, deposition rate, . .
2. Process quality capability
   - inspection consideration and standards
   - selection of inspection process
3. Shrinkage and distortion— residual stresses
4. Flaw detection and sizing; nondestructive evaluation
5. Commercial considerations
   - suppliers and their location for filler and base metals
   - foreign equivalents for filler and base metiils
   - cost of filler and base metals
   - machinability of base and weld metals
6. Dissimilar materials
7. clad materials
8. Safety
9. Electrodes and welding machines
10. Electrical characteristics
    - phase (primary)
    - primary voltage
    - primary amperage
    - Characteristic curve
    - Pulse
    - Wave form and symmetry
11. Electrodes and filler metal
    - Initial composition — AISI, AWS, or foreign specification
    - All-weld-metal composition
    - Deposition efficiency and rate
12. Procedure guidelines
    - position
    - travel speed
    - heat input
    - hardenability
    - current range
    - filler-metal diameter
13. Position capabilities
14. Heating requirements
    - preheat
    - interpass temperature
    - postweld heating
15. Weld microstructure
16. Moisture pickup (content) and shelf life
17. Arc atmosphere

Welding Codes and Standards

There are Welding Codes and Standards to be followed in fabrication of structurals and Consumer Goods for which welding documentation has become an essential variable when code-level fabrication is involved. In most cases, the documents required for construction will remain with the structure for the entire existence in an operating production capacity. Codes are updated on a frequency from annually to every five years. This provides up-to-date rules and guidelines on a structured schedule.

- Indian Standard(BIS)
- German Standards (DIN and others)
- European Union (CEN) standards
- International Organization for Standardization (ISO) Standards
- British Standards (BS)
- Australian / New Zealand (AS/NZS) Standards
- American Petroleum Institute (API) Standards
- American Welding Society(AWS) Standards
- American Society of Mechanical Engineers (ASME) Code
- Canadian Standard Association(CSA) Standards

How to design, store and retrieve data ?

Database Design Considerations

Traditional and Nontraditional Data

Data base systems to be used by Engineers, Welding Co-ordinators, Quality Engineers and Inspection staff need to be designed to allow storage manipulation and retrieval of "traditional" data, which consist mainly of numerical information, character information, and text and associated items and must include several other kinds of information like: graphics, images, recorded speech, annotated speech, motion images, and knowledge.

Graphics illustrate trends and relationships between parameters. These data are generally stored in the form of an

image, but they also may require added software for manipulation of the information. Images may be explanatory drawings or photographs that are used to present information that often is difficult or impossible to represent in other ways.

Knowledge information is another important data consisting of formulae and other representations. This type of data is useful in describing relationships between objects or representing knowledge.

Computerization of Welding Information.

Database Design

At the beginning we must understand the Basic Definition of Data base Design as :

I. Database is a computerized collection of related data that can be used without knowledge of its storage details.

II. Data system is a collection of integrated databases.

Building a database includes four primary elements:

1. Planning the layers of data with priority,
2. Design of the layers of data,
3. Selecting appropriate software and hardware, and
4. Implementing the design, storage and retrieval system and procedure..

1. Planning.

The key to successful database planning is to keep in mind how the system will operate for users. The users of the system and their needs must be defined.

a. Details of data needed.
b. Sources to collect these data.
c. User details of such data.
d. Details of Use of the data.

2. Design.

Design is a technical activity that transforms the data content into three views:

- External, The external view is that seen by the user
- Logical, The logical view represents the data organization and structure, which can be network, hierarchical, or in the more advanced systems, relational and
- Physical. The physical view of the data is the structure of the data as it exists in the computer system. The result of the design process is an understanding of all data to be included and their relationship.

3. Selection of software and hardware.

Selection of software and hardware follows the design stage so that the chosen software and hardware will most closely meet the demands of the database and its user .

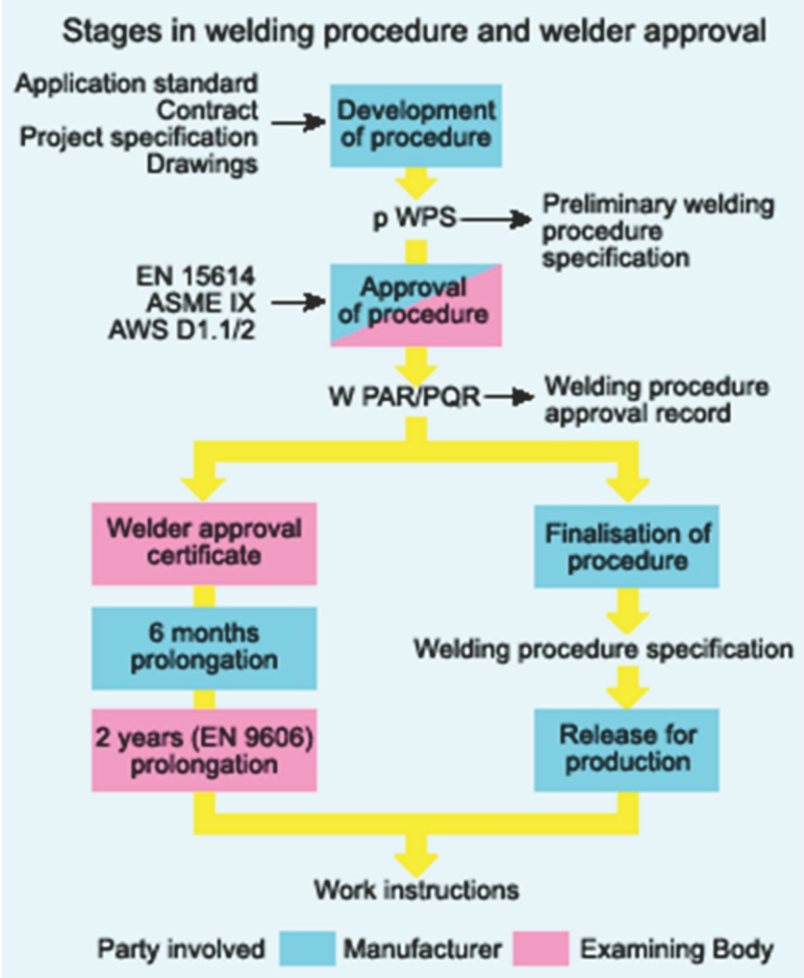
4. Implementation.

The first step in the Implementation Stage should include development of a prototype database so that it can be tested by the user of the database. Both the Designer and the User will check the desired applicability of the prototype and if required modify it. This prototype should be designed in such a way that if required it can be discarded for a replacement.

Once a design is accepted at this stage other activities of preparing manuals, training the user personnel must cover the intended users to be deeply involved. A significant effort expended during implementation is in the administration of the database. Follow-up activities — continuous re-planning and examination of changes that need to be implemented — are essential.

END OF PART – I

The subject being exhaustive the Basic Concept of only the essential items have been discussed and that too in a brief manner. Every Item will have to be elaborated with Diagrams, Charts and Tables. In this part only three illustrations of WPS, PQR and WPQ are enclosed. Other topics and items will be separately illustrated in the following Parts.



ASME SECTION - IX

A list of general parameters observed for such qualifications are listed below

1.0. Scope of work and code by which the work is covered,

2.0. Welding process employed,

3.0. Base metals and applicable specifications,

4.0. Type, classification and composition of filler rods and weldments,

5.0. Type of current and current range,

6.0. Welder qualification requirements,

7.0. Joint design and tolerance,

8.0. Joint preparation and cleaning of surface for welding,

9.0. Tack welding,

10.0. Joint welding details,

11.0. Position of welding involved at factory or at site,

12.0. Preheat, interpass and post heat temperatures,

13.0. Peening,

14.0. Heat input Electrode run length,

15.0. Post weld heat treatment,

16.0. Repair of weldments,

17.0. Inspection - quantum and stages - acceptable levels,

18.0. Records - WPS, PQR, Welders Performance Qualification.

Annexure – I

METRODE WELDING CONSUMABLES

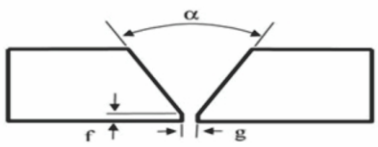
Welding Procedure Specification (WPS)

Welding Procedure No: CH9MVN-01

Consumables		Base Material	
Welding process (root):	TIG (GTAW)	Parent Material:	A335 P91
- Consumable:	**9CrMoV-N**		ASME IX P-Number 5B
- Specification:	BS EN: W CrMo 91 AWS: ER90S-B9		
Welding process (fill):	MMA (SMAW)		
- Consumable:	**Chromet 9MV-N**	Thickness:	15-60mm
- Specification:	BS EN, E CrMo 91 B	Outside Diameter:	16″ NB (406mm OD)
Joint Details		**Joint Position**	
Joint Type:	Butt single sided	Welding Position:	ASME: 5G
Manual/Mechanised:	Manual		BS EN: PF

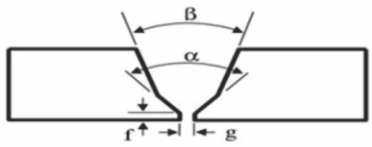
Joint Sketch

Joint for thickness < 20mm



f = 1-3mm; g = 2-4mm; α = 70°

Joint for thickness > 20mm



f = 1-3mm; g = 2-4mm; α = 70°; β = 20°

Welding Details

Run	Process	Consumable	Diameter mm	Current A	Voltage V	Type of current / Polarity	Wire Feed Speed m/min	Heat Input kJ/mm
1	TIG	**9CrMoV-N**	2.4	70-110	~12	DC-	NA	~1.2
2-3	TIG	**9CrMoV-N**	2.4	80-140	~12	DC-	NA	~ 1.2
4-7	MMA	**Chromet 9MV-N**	3.2	90-130	~24	DC+	NA	~ 1.0
Rem	MMA	**Chromet 9MV-N**	4.0	120-170	~25	DC+	NA	~ 1.2

Electrode Baking or Drying:	300-350°C/1-2h
Gas – root (TIG) shielding:	Pure Ar
purge:	Pure Ar (note 1)
Gas Flow Rate (TIG) – Shielding:	8-15 l/min
Purge:	4-10 l/min
Tungsten Electrode Type/Size:	2% Th/2.4mm
Details of Back Gouging/Backing:	NA

Preheat Temperature:	200°C min (note 2)
Interpass Temperature:	300°C max

Post-Weld Heat Treatment:	Note 3.
Temperature:	760°C ± 10°C
Time:	1h/25mm (2 hours min)
	Note 4.

Notes:

1. Maintain purge for runs 1-3.
2. Preheat 150°C min for TIG.
3. Cool to ~100°C before PWHT.
4. Heating & cooling rate <100°C/h (above 300°C).
5. Stringer beads, maximum weave 3 x ø.

c:\my documents\technical\welding procedure specifications\9mv wps.doc

Annexure – II

ANNEX N AWS D1.1/D1.1M:2010

PROCEDURE QUALIFICATION RECORD (PQR)

Company Name:
Welding Process Submerged Arc Welding
Supporting PQR No. MPS-PQR-6

Identification #
Revision 00 Date: 1/30/2013 By
Authorized by Date: 30/01/2013
Type- Manual ☐ Semiautomatic ☐
Mechanized ☐ Automatic ☑

JOINT DESIGN USED

Type: But ☐ Tee ☑ Corner ☐ Lap ☐ Edge ☐
Single ☑ Double Weld ☐
Backing: YES ☐ NO ☑
Backing Material NA
Root Opening 1 mm
Root Face Dimension NA
Groove Angle: NA Radius (J-U) NA
Back Gouging: Yes ☐ NO ☑ Method NA

POSITION

Position of Groove: NA Fillet: 2F
Vertical Progression: Up ☐ Down ☐

Electrical Characteristics

Transfer Mode (GMAW) Short-Circuiting ☐
Globular ☐ Spray ☐
Current: AC ☐ DCEP ☑ DCEN ☐ PULSED ☐
Other
Tungsten Electrode (GTAW)
Size: NA
Type: NA

BASE METALS

Material Spec. IS 2062/EQ to IS 2062
Type of grade Grade B*
Thickness: Groove NA Fillet 8mm
Diameter (Pipe) NA

TECHNIQUE

Stringer or Weave Bead: WEAVE
Multi -Pass or Single Pass (per side) SINGLE PASS
Number of Electrodes One
Electrode Spacing Longitudinal NA
Lateral NA
Angle NA
Contact Tube to work Distance 30mm
Peening NA
Interpass Cleaning: NA

FILLER METALS

AWS Specification AWS A 5.17
AWS Classification F-7AZ-EL8

SHIELDING

Flux
Gas NA
Composition NA
Electrode-Flux (Class) F-7A4EL-8 / 7P4EL-8
Flow Rate NA
Gas Cup Size NA

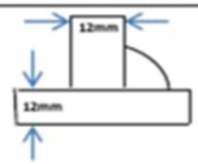
POST WELD HEAT TREATMENT

Temp. NA
Time NA

Preheat

Preheat Temp. Min 10º C
Interpass Temp. Min. 10º C Max. NA

WELDING PROCEDURE

Pass or Weld Larer(s)	Process	Filler Metals Class	Filler Metals Diam.	Current Type & Polarity	Current Amps or Wire Feed Speed	Volts	Travel Speed (IPM)	Joint Details
1	SAW	EL-8	3.15mm	DCEP	325-335	25-28	25-27	

* Material chemical composition is (C%= 0.22max, Mn%= 1.50max, P%= 0.045 max, S%=0.045, Si%= 0.03-0.4max), CE%= 0.41max

Annexure – III

WELDER and WELDING OPERATOR PERFORMANCE QUALIFICATION RECORD

Welder's Name:		**ATF No:** **Test No.**
Welder's SS No. XXX-XX-	**Date:**	**Reference WPS No:**

VARIABLE	QUALIFICATION TEST DETAIL	QUALIFICATION RANGE*
Code or Specification Used:		
Welding Process and Type:	☐ Manual ☐ Semiautomatic ☐ Mechanized ☐ Automatic	☐ Manual ☐ Semiautomatic ☐ Mechanized ☐ Automatic
Backing:	☐ Used ☐ Not Used	Required if used
Base Metal **Spec/P or M-Number**		
Plate/Pipe Thickness – Groove	Plate ☐ Pipe ☐ Thick.	
Plate/Pipe Thickness – Fillet	Plate ☐ Pipe ☐ Thick.	
Pipe/Tubular Outside Diameter – Groove		
Pipe/Tubular Outside Diameter – Fillet		
Filler Metal **Specification No.**		
Classification No.		
F No.		
Diameter		
Consumable Insert	☐ Yes ☐ No	
Penetration Enhancing Flux	☐ Yes ☐ No	
Deposited Weld Metal Thickness		
Current/Polarity & Current Range	Type/Polarity: Range: Amperes	
Metal Transfer Mode (GMAW or FCAW)		
Torch Shielding Gas	Type: Flow:	
Root Shielding Gas	☐ NA Type: Flow:	
Position(s)	Test Position(s) (1G, 2G, etc.):	Qualified Position(s) (F, H, V, O, or All)
Vertical Progression	☐ Uphill ☐ Downhill	☐ Uphill ☐ Downhill

* NOTE: Insert NA for Variables that are identified as Non-essential in the Code or Specification used for the Performance Qualification Test

MECHANICAL TEST RESULTS			
Type And Figure No.	**Results**	**Type And Figure No.**	**Results**
Guided mechanical Testing Conducted By:		**Date:**	

NONDESTRUCTIVE EXAMINATION RESULTS	
Radiographic Results:	**Report No.**
Radiographic Testing Conducted By:	
Welding Witnessed By:	**Visual Inspection:** ☐ Pass ☐ Fail (reason)
We certify that the statements in this record are correct and the test welds were prepared, welded and tested in accordance with the requirements of: AWS D1.1- , AWS B2.1- Other:	
Date Qualified:	**ATF Name and Number:** **Signed By:** **CWI No.**

ATF WPQR Blank Form 2010-04-15 1