

MODULE 15

ELEVATIONS

OF THE

INSPECTOR



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MODULE 15

**FUNCTIONS OF THE
INSPECTOR**

CONTENTS

Introduction and objectives	1
The inspector's role	2
Reports	4
Control of Materials	7
Purchase of materials	7
Mill test certificate	9
Welding materials	13
Verification of Welding Procedures	17
Welding procedure specification	17
Procedure qualification	25
Verification of Personnel Qualifications	29
Welder qualifications	29
Duration of validity	32
Welding Inspection Tasks	34
Inspection prior to welding	34
Inspection during welding	35
Inspection after welding	38
Nonconformances	40
Postweld heat treatment	42
Summary	44
Guides and exercises	45

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CONTENTS

Introduction and objectives	1
The inspector's role	2
Reports	4
Control of Materials	7
Purchase of materials	7
Mill test certificate	9
Welding materials	13
Verification of Welding Procedures	17
Welding procedure specification	17
Procedure qualification	25
Verification of Personnel Qualifications	29
Welder qualifications	29
Duration of validity	32
Welding Inspection Tasks	34
Inspection prior to welding	34
Inspection during welding	35
Inspection after welding	38
Nonconformances	40
Postweld heat treatment	42
Summary	44
Guides and exercises	45

MODULE 15

FUNCTIONS OF THE INSPECTOR

Introduction

The functions, responsibilities, and accountability of the inspector can be wide ranging. An inspector could be employed full-time by the contractor performing the work or could be employed by an inspection organization acting as a third party and reporting to the owner or designer. An inspector may just inspect and monitor welding operations or may be involved in many other aspects of inspection including

- material inspection
- measurement of shape
- machining inspection
- heat treating operations
- proof testing.

The inspector today, however, is very often in the latter category and is required to participate in a variety of activities. Nevertheless, the welding inspector, regardless of the reporting relationship or of other duties, does have some specifically defined functions which relate to the production of welds that meet the contracted performance criteria. In this module we will be covering in some detail these various functions, particularly as they relate to verification and the associated documentation. The details of the technology of weld inspection are covered in subsequent modules.

Objectives

After successfully completing this module, you will be able to:

- Describe and check the documentation required to control the ordering, delivery and issuing of production materials and welding consumables
- Verify a welding procedure specification and determine if it has been properly qualified

Functions of the Inspector

- Verify the qualifications of the welder or welding operator
- List the requirements to ensure the welding operation is executed correctly and in accordance with the approved welding procedure specification
- Verify that an adequate and approved inspection procedure is available
- Verify that heat treating equipment and procedures conform to specifications
- Prepare inspection records and reports.

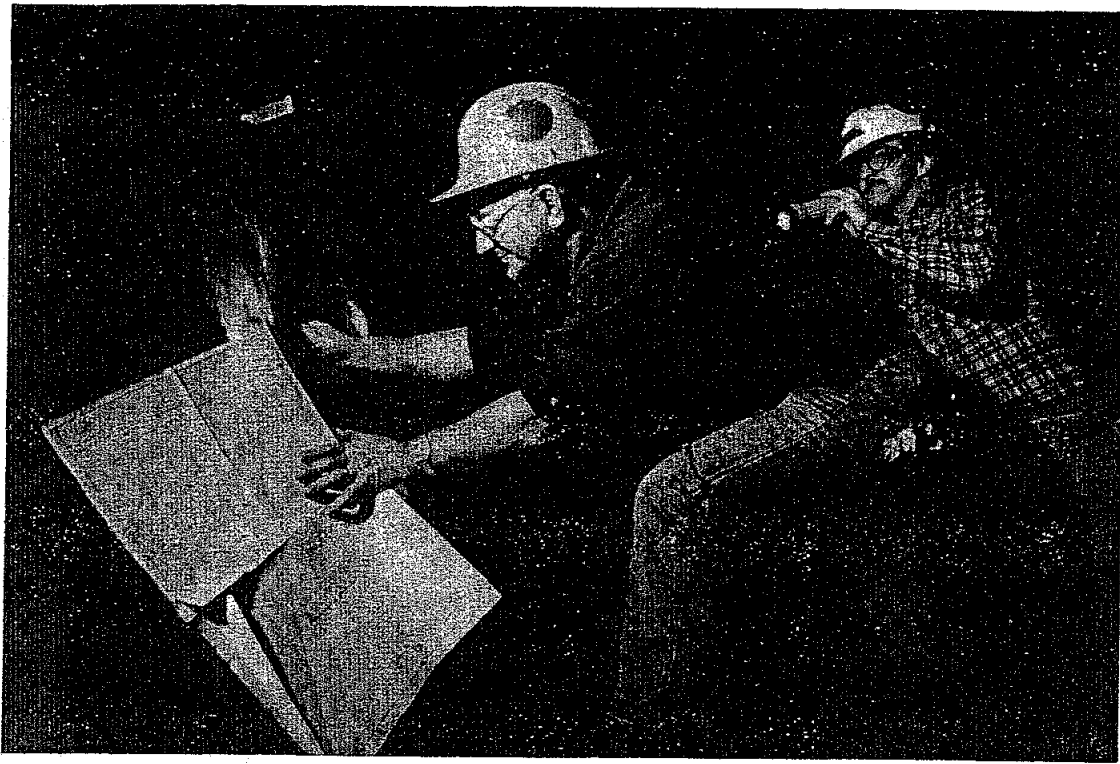


Figure 1. A welding inspector checks a fabricated item against the drawing.

The Inspector's role

T.R.

The inspector's role begins well before welding starts, continues during the welding operation, involves action after welding is completed, and is finished only when the results are properly reported (Fig. 1). As part of the quality system, inspection activities are defined in an inspection and test plan which clearly describes what is required. The inspector is frequently responsible for producing documents that ensure traceability of the components and related fabricating action.

Prior to welding, the inspector must be assured that the materials are correct and that the shop has approved welding procedures and appropriately qualified welders (Fig. 2). Written procedures and competent operators are important to the production of a quality welded product, but the actual execution of the weld is also a critical point for the inspector. Once the inspector is satisfied that all is in order for the welding to proceed, the task becomes one of witnessing and monitoring. There are three basic interests at this point: ensuring that the written procedures are being followed; ensuring that workmanship requirements are being followed; and, of course, watching for any physical signs of nonconformance of the final product.

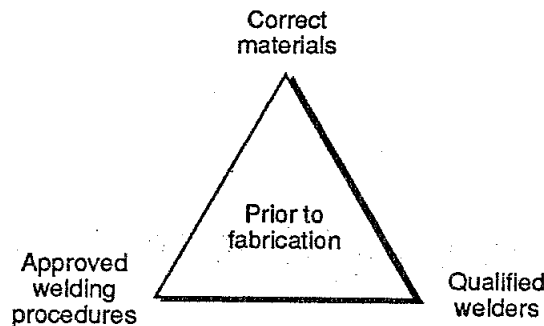


Figure 2. The "Quality Triangle" for welding showing three key items that would be verified by the welding inspector prior to beginning any welding.

The inspector's responsibilities are to verify base metals and welding consumables, observe the fit-up and preparation for the weld, and watch the welding operation itself. Once the welding is completed, a new series of inspection tasks begins, which starts with executing an inspection program according to an approved procedure, keeping track of the status of examination and testing and selecting specific welds for further NDE or mechanical testing.

Heat treatment (such as preheating, postheating and postweld heat treatment) can be a critical parameter in a welding operation and the inspector is often required to ensure that it has been done properly. Heat treatment must be carried out following an approved written procedure. The inspector must know enough about the technique, the equipment and the reports to have confidence in the results.

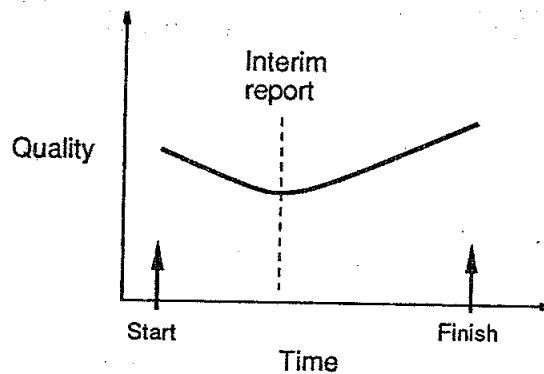
Functions of the Inspector

Reports

When preparation, production and inspection are over, the inspector must collate the observations, checklists, and results into a report which is structured to meet the needs of the client, a jurisdiction, or a code. This report is the document of reference which could allow the tracing of a production parameter which proves after years of service to be contributing to a failure. It allows the tracing of responsibility to a specific supplier or contractor.

One or more interim reports might well be necessary to show progress during a long or complicated construction project. Reports must detail the inspection stages, parameters, and results, including corrective action if required. It is important to recognize quality related problems as early into a contract as possible. Interim reports and observations are extremely valuable as they provide engineering and production personnel with information they might not otherwise be aware of. The inspector's observations might highlight quality problems that could, perhaps, be remedied by design or production changes if found early enough. The inspector should remember to quantify observations where possible.

Figure 3. Interim reports can be beneficial in alerting personnel to potential quality problems, allowing them to be rectified early.



Importance of documentation

Throughout this module we will emphasize the importance of proper documentation. Reports produced by the inspector should be:

- neat and accurate
- complete and timely.

As an example take a look at the Welding Record Sheet shown in Fig. 4. This card was used for weld monitoring and records what actually took place when a submerged arc weld was made in a pressure vessel. All entries are clearly legible and the card has been signed and

WELDING RECORD SHEET										PROC. NO. KC236/L
CONTRACT NAME		CONTRACT NO.		VESSEL NO.		REF. QCD 408				W.Q. NO. 814
ORDER NO.		MATERIAL		ISSUE DATE						
WESTERN		JOU 94		2 Sept 4		15/11/80				
B 421/1106/001		SS4360-500								
Name	Pressure No.	Weld Identification	Consumables	Type	Gauge	Batch No.	No. of Joints	Amps	Volts	Speed mm/min
WRIGHT, V.	41	SIDE 1	6485500	-	3-2	131260	1-2	120	-	-
			6485500	-	4	161021	3-4	170	-	-
SMITH, N.	Z10	SIDE 1	SD3	-	4	6491	5-19	420	30	400
			8X300	-		321/6				
SMITH, N.	Z10	SIDE 2	SD3	-	4	6491	1-	450	30	400
			8X300	-		321/6				
COMMENTS										SPECIAL REQUIREMENTS
SLAG TRAP AFTER RUN 12 - GROUND OUT.										TO BE SOWN AT 150°C FOR 2 HOURS ON COMPLETION.
DATE COMPLETED										AUTHORISED SIGNATURE

Figure 4. An example of a carefully completed report recording details of a weld. Reports should be legibly written and complete. Sketches are often useful.

Standard formats

dated. This card could be readily reviewed by someone else at any time and all relevant information pertaining to that weld would be found.

To minimize additional paperwork standard formats can be used wherever possible. Fig. 5 shows an example of a quality plan for the manufacture of a boiler drum. The format includes standard items and reference to existing quality documents by number. Items not required are deleted. The letter "R" is written in to indicate that a control check is required and the letter in the box above indicates the type of control. Such a format is easy to prepare, is unambiguous, and easy to follow. The format should be acceptable to the client and meet the requirements of the codes, standards, or regulations. Standard check lists may be used to identify the various documents required in the documentation package required at the end of a contract.

As we go through some of the functions in detail—control of materials, qualifications, welding operations, and so forth—we will discuss them more or less in the order of fabrication: prior to welding, during welding, and after welding.

Functions of the Inspector

	CONTROL CHECK	REFERENCE DOCUMENT	CONTROL CATEGORY			
1	Design and Drawing approval	Client's approval required See Sheet	C	D	A	M
2	Vendor Control	Only NEI ICL approved Vendors shall be used	C	D	A	M
3	Materials and Related Purchase Orders	See Sheet 1	C	D	A	M
4			C	D	A	M
5	Goods Inwards Inspection	QCD 734	C	D	A	M
6	Receipt of Pin Bar	QCD 110	C	D	A	M
7	Receipt of Material in Bar Form	QCD 112	C	D	A	M
8	Receipt of Material in Tube Form	QCD 113	C	D	A	M
9	Receipt of Carbon Steel Pressure Plate	QCD 100	C	D	A	M
10	Receipt of Carbon Steel Non-Pressure Plate	QCD 111	C	D	A	M
11	Receipt of Stainless Steel Plate	QCD 110	C	D	A	M
12	Receipt of Header Shell Material	QCD 107	C	D	A	M
13	Inspection of Incoming Castings	QCD 723	C	D	A	M
14	Receipt of Free Issue Material	QCD 183	C	D	A	M
15			C	D	A	M
16	Production Test Plates	QCD 407 QCD 409 See Sheet 1	C	D	A	M
17	Weld Procedures	QCD 401 See Sheet 1	C	D	A	M
18	Weld Procedure Qualifications	QCD 403 See Sheet 1	C	D	A	M
19	Welder Qualifications	QCD 404 See Sheet	C	D	A	M
20	Welding Consumable Control	QCD 142 QCD 402 QCD 412 See Sheet	C	D	A	M
21	Reporting of Production Weld Defects	QCD 410	C	D	A	M
22	Flash Butt Welding	P & M 406	C	D	A	M

KEY TO CONTROL CATEGORY:

R : Control Check Applies D : Document Required By Client
C : Certificate Required A : Client's Approval Required
M : Mandatory Check Points beyond which Manufacturer cannot proceed without Q.A. Authorisation

Figure 5. Example of a quality plan for the manufacture of a boiler drum.

CONTROL OF MATERIALS

Purchase of materials

The starting point for the control of materials is the purchasing process. Company policy usually dictates whether material is purchased by requisition, local purchase order, or formal purchase order. Typically the project engineer or superintendent raises a *requisition*—probably on a standard form. This document should show enough detail to enable the supplier to provide the right material.

For example,

- quantity and dimensions
("three 20 foot lengths of 8 inch diameter schedule 80")
- material specification
("ASTM A335 Grade P22 Stainless Steel Tubing")
- any special requirements
(heat-treating, QA requirements, inspection - prior to delivery)
- requirements to supply mill test certificates.

The *requisition* typically is routed to *stores* or a *central purchasing department* where the information is transferred to a formal *purchase order* (perhaps a "local purchase order" for small items or quantities). An example is shown in Fig. 6 although purchase orders can take many forms. Many Quality Assurance systems require that a copy of the requisition and purchase order go to the inspection department at the time the order is placed. The inspector should review these to ensure that what is being purchased is in accordance with specified requirements.

Base materials

The inspector might be required to review documentation related to base materials including metallurgy (mill specification), proposed manufacturing plan, heat treatment history, and inspection history. Remember that the common CSA and ASTM steel specifications also call up general requirements. For example, steels meeting any of the CAN/CSA-G40.21-M87 series must also meet the general requirements on CAN/CSA-G40.20-M87. The latter includes such requirements as dimensional tolerances, marking, repairs, and so forth.

In construction, manufacturing and repairs, the responsibility of the constructor, manufacturer or owner is usually to meet the requirements of a *code of practice* which relates to the performance requirements of

Functions of the Inspector

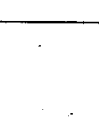
FORMAL PURCHASE ORDER				
		Ltd.		DATE SHIPPED AND ALL PAPERS PURCHASE ORDER NUMBER
P.O. BOX 5586, EDMONTON, ALBERTA T6C 4E9				
TO:		DATE TERMS F.O.B. SHIPMENT PROMISED SHIP VIA		
REQUISITION NUMBER	SHIP TO:	ACCOUNT NUMBER		
THE TERMS AND CONDITIONS SET OUT ON THE BACK HEREOF ARE A PART OF THIS ORDER AND HAVE THE SAME EFFECT AS IF SET OUT ON THIS SIDE.				
QUANTITY	UNIT	DESCRIPTION	UNIT PRICE	AMOUNT
☐ ORIGINAL NOTIFICATION		☐ CONFIRMATION		PLEASE RENDER INVOICES IN QUADRUPPLICATE
VENDOR WILL SIGN AND RETURN CARBON COPY OF THIS PURCHASE ORDER ACCEPTING ALL TERMS AND CONDITIONS UNDER WHICH IT IS ISSUED.				
ACCEPTED BY _____			BY _____	
TITLE _____ DATE _____			PURCHASING AGENT	

Figure 6. Typical purchase order.

Mill test certificate

the end product once in service. For materials, these requirements might include, for example, a specific alloy content for corrosion resistance, for notch toughness, or for strength at high temperatures.

The supplier, when requested, provides a *mill test certificate* which details the chemical analysis of the material, the mechanical test results, and, perhaps, a history of heat treatment and inspection. Fig. 7 shows a typical mill test certificate ("mill sheet"). There is no standard format; each steel mill uses its own design and conventions. Take careful note of the position of the decimal point in the chemical analysis figures. Sometimes these values are expressed as the weight percent multiplied by 1 000 to make it easier to read. Be careful of the units. Values should be expressed in the units of the specification. For example, check whether impact values are in ft lb or joules and what the acceptance values are. When the mill test certificates have been reviewed and found to comply with the specifications, they should be stamped and signed to signify acceptance.

Sometimes the figures reported on the mill sheet are from tests on a sample of the material that has undergone a further treatment and therefore does not represent the material as-delivered. For example, a pressure vessel steel may be normalized by the fabricator. The steel is therefore accepted on the basis of test results on a sample that has been normalized. But the as-delivered plate received from the mill would not be normalized. The inspector must be aware of who is doing the heat treatment and on what basis the material is accepted.

In another example, there have been cases where a normalized steel was ordered and delivered in the as-rolled condition with mill test certificate values from normalized test coupons. The mill assumed the fabricator would normalize the steel but the fabricator assumed the mill had done the normalizing. Special attention is required when part of the processing is the responsibility of the fabricator.

The inspector should review similar documentation supplied with fabricated components such as welded fittings or piping assemblies. When fabrication has been carried out by others and a component is to be incorporated into the structure or vessel which is the responsibility of the inspector, there must be assurance that it complies in every respect with the contract requirements. For example, Partial Data Reports are usually required for boiler and pressure vessel parts that have been welded by another fabricator. Such reports must be certified by the provincial boiler and pressure vessel inspector or other authorized inspector in the jurisdiction where the component is fabricated.

Functions of the Inspector

steel A division of **INCO**

55-7247-0000
ON WORKS
MILTON, ONTARIO, CANADA L9V 3T1

TALLY NO
19711

PAGE
1 OF 4

DATE
89/10/16

BILL OF LADING
CONNAISSANCE
582168

DIV OF CANADIAN
P.O. BOX
ST CATHARINES
ONT
L2R 6Y6

C/O STEEL SERVICE CENTRE
SMITH AND PETRIE STS
ST CATHARINES
ONT

1 ORDER PER T/R ONLYATTN T RAE

INSPECTION & T.R. TO / INSPE. ET RAPPORT D'ESSAI A

TO / A
SITE / LIEU

TRUCK - CALL 461-8111- NO TARP

FRIGHT / FRET
COL

INSPECTION PAR UN TIERS

TO A
CUST CLIENT

DEST
DIVER AUTRE

DESCRIPTION

HEAT NO.
N° DE COULEE

SLAB NO.
N° DE BRAME

PIECES
PIECES

THEO MASS
MASS THEORIQUE

THIRD PARTY INSP
INSPECTION PAR UN TIERS

5-23915
P-08755-002-00-0
PLATE C, CAN/CSA-G40.21-87 GRD 38WT CAT 5, CONL EA PLATE.35/
28 FT LB PLUS 4F
Ship Account - 012-06052
0.6790 X 103.50 In X 378.00 In

658541 809 1 7534 LB
1 7534 LB*

S.S. QUALITY CONTROL
This document has been reviewed for conformance of chemical and/or physical properties to the specifications or requirements as noted above.
O.C. *[Signature]* OCT 24 1989

REMARKS / REMARQUES

TOTAL
1 7534 LB

DUNNAGE / FARDAGE
sk

BILLED BY
ETABLI PAR
sk

HEAT NO N° DE COULEE	SLAB NO. N° DE BRAME	THICKNESS EPAISSEUR	C	Mn	P	S	SI	Cu	Ni	Cr	Mo	V	Co
1 658541	809		.15	1.34	.008	.006	.26						
2													
3													
4													

MPa / ksi MPa / ksi	YIELDING YIELDING	UTRA-SONIC ULTRA-SONIC	IMPACT TEST - J/M-IN ESSAI DE RESILIENCE - J/M-IN	HEAT TREATING CYCLE CYCLE DE TRAITEMENT THERMIQUE
1 45.8 70.7	28		245 256 245 249 FTS	
2				
3				
4				

* Unless otherwise indicated the soak time was one hour per 25 mm or 1 inch of thickness.
* Sauf indication contraire, le temps de réchauffage correspond à 1 heure par 25 mm ou pouce d'épaisseur.

st

Figure 7. Typical mill test certificate.

3.13.2 Required Documentation for Acceptance

The following certification of chemical analysis and mechanical tests are required for all piping and components on arrival at Plant for acceptance and use in the refinery.

These requirements apply for all piping materials requisitioned by the Company or contractors directly supervised by the Company or any engineering consultants and their contractors or subcontractors employed by the Company.

1. Carbon Steel Pipe

Mill Test Certificates are required for all carbon steel pipe. This will also include carbon steel pipe that is covered with any form of a manufacturer's applied protective coating.

2. Impact Tested Carbon Steel Materials

Mill Test reports are required for all material requiring impact testing.

3. Carbon Steel Fittings

Mill Test reports are not required for pressure parts such as fittings and flanges made in accordance with an accepted standard (such as ANSI) provided such parts are marked with the name or trademark of the manufacturer and such other markings as required by the Manufacturers Standardization Society, Standard MSS SP-25 and the mill heat number for the material used.

Mill Test Certificates are required if the material does not comply with the conditions outlined above or in the event that the material identification as per MSS SP-25 is not clearly marked.

4. Carbon Steel Valves

Mill test certificates are not required for carbon steel valves.

5. Alloy and Stainless Steel Pipe and Fittings

Mill Test certificates are required for all alloy pipe and fittings.

6. Alloy and Stainless Steel Valves

Mill test certificates are required for all alloy and stainless steel valves.

3.13.3 Unidentified Pipe and Fittings

Pipe and Fittings that have no material specifications or any other markings as required by MSS SP-25 are not acceptable and cannot be used in the refinery. This condition will continue to apply even if the material is accompanied with certification.

Figure 8. Example from a typical "Materials Receiving and Inspection Guidelines."

Functions of the Inspector

In Fig. 8 there is an example taken from the "Materials Receiving and Inspection Guidelines" of an operating plant, showing the type of documentation needed for materials to be used in the repair of pressure vessels.

When material is delivered several items must be verified against the order:

- Do the materials comply dimensionally?
- Are the materials properly identified?
- Do the chemical and mechanical properties as determined from the mill test certificate comply with specifications?
- Surface or edge defects resulting from material manufacturing.

Additional tests may be required if the inspector doubts the documentation or if the documentation or material identification is incomplete.

The material should be inspected upon receipt to verify its condition. Items to be checked include:

- weathering or transportation damage
- corrosion damage due to salt spray if the shipment has come by sea
- mechanical damage incurred during trans-shipment or during road transport—dents and scrapes, for example.

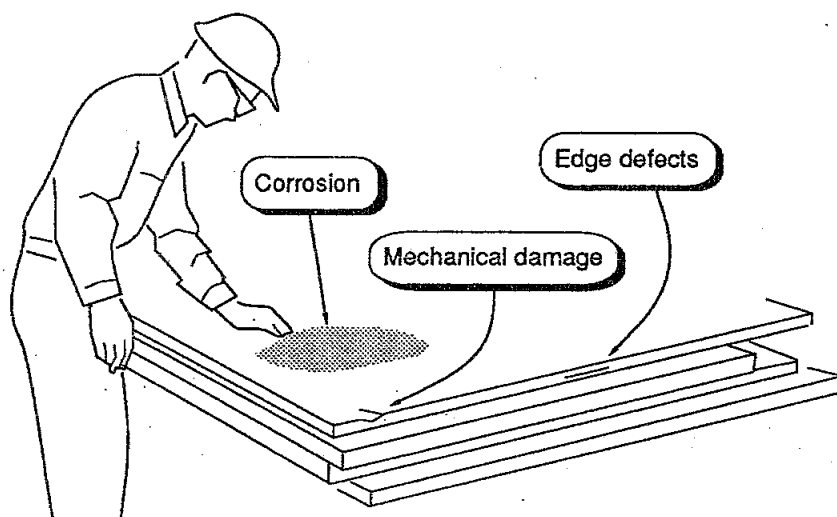


Figure 9. Typical items to be checked in a physical inspection of material.

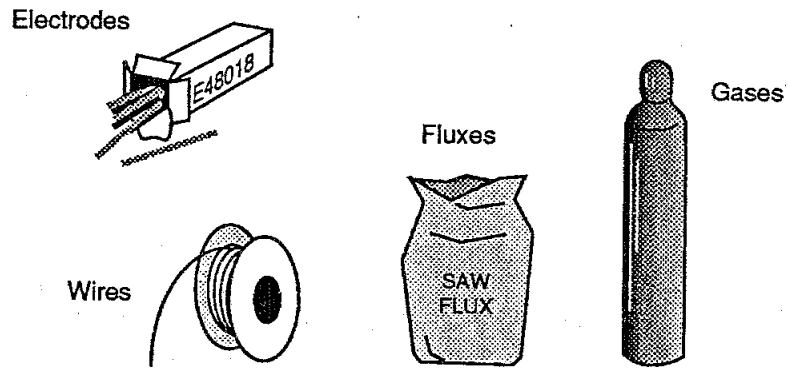


Figure 10. Several types of welding consumables may be used on the shop floor, and their control is critical.

Welding materials

The control of welding materials is particularly important since there may be many suppliers and several types in use on the shop floor (Fig. 10). Welding materials are usually governed by code requirements such as described in CSA or ASME codes.

Fabricators certified under CSA W47.1-1983 must use certified electrodes and consumables when this standard applies (Clause 8.2.2). Electrodes are certified by the Canadian Welding Bureau (CWB) to one of the CSA W48 Series Standards shown in Table 1. If there is a specific reason to use a noncertified consumable, W47 does provide a mechanism for qualifying the procedure. Similarly CSA W59-1989 requires that welding consumables conform to the requirements of the applicable W48 Series Standard. The inspector should verify that the consumables to be used are certified. The CWB publishes a yearly list of certified consumables for easy reference and updates and amendments are issued as they occur.

Table 1. CSA W48 series for electrodes.

Welding process	Electrode material	CSA Standard
SMAW	Carbon (mild) steel	W48.1-M1991
	Cr and Cr-Ni steel	W48.2-M1992
	Low alloy steel	W48.3-M1982
GMAW	Mild steel	W48.4-M1980
FCAW	Mild steel	W48.5-M1990
SAW	Mild steel	W48.6-M1980

Electrodes for ASME work

AWS specifications

For ASME pressure vessels constructed in accordance with the requirements of Section VIII for example, there is no agency to oversee the qualification of welding consumables. However, each electrode manufacturer must have performed tests in accordance with the requirements of the pertinent ASME SFA specification and state conformance of the product to the same standard. The inspector should verify that the label identification on the consumables to be used includes the conformances required by the welding procedure specification.

The AWS publishes a wide range of filler metal specifications covering most types of welding consumables which provides a comprehensive system for electrode classification. These specifications may contain both mandatory provisions such as chemical and mechanical properties, manufacture, and testing as well as nonmandatory provisions which provide more information for the user. AWS also publishes the following documents to aid users with the purchase of filler metals:

- *AWS A5.10, Filler Metal Procurement Guidelines* provides methods for identification of filler metal components, classification of lots of filler metals, and specification of the testing schedule in procurement documents.
- The *Filler Metal Comparison Charts*, provide lists of manufacturers that supply filler metals in accordance with the various AWS specifications and the brand names. Conversely, the AWS specification, classification, and manufacturer of a filler metal can be determined from the brand name.

ANSI has approved most AWS filler metal specifications as American National Standards and they have also been adopted by ASME. ASME in Section IX of the Boiler and Pressure Vessel Code groups electrodes according to an F number. Table 2 shows the F number classification and the corresponding ASME specification number and AWS classification number. When ASME adopts an AWS filler metal specification, either in its entirety or with revisions, it adds the letters "SF" to the AWS alphanumeric designation. Thus, ASME SFA-5.4 specification would be similar, if not identical, to the AWS A5.4 specification.

Table 2. F Number classification for electrodes (ASME).

QW-432 F-NUMBERS Grouping of electrodes and Welding Rods for Qualification			
QW	F-No.	ASME Specification No.	AWS Classification No.
Steel and Steel Alloys			
432.1	1	SFA-5.1 & 5.5	EXX 20, EXX 24, EXX 27, EXX 28
	2	SFA-5.1 & 5.5	EXX 12, EXX 13, EXX 14
	3	SFA-5.1 & 5.5	EXX 10, EXX 11
	4	SFA-5.1 & 5.5	EXX 15, EXX 16, EXX 18, EXX 48
	4	SFA-5.4 other than austenitic	EXX 15, EXX 16
	5	SFA-5.4 (austenitic)	EXX 15, EXX 16
	6	SFA-5.2	RX
	6	SFA-5.17	FX-EXX
	6	SFA-5.9	ERXX
	6	SFA-5.18	ERXXS-X
	6	SFA-5.20	EXXT-X
	6	SFA-5.22	EXXT-X
	6	SFA-5.23	FX-EXX-X, FX-ECXX-X, and FX-EXX-XN, FX-ECXX-XN
	6	SFA-5.25	FESXX-EXXX-EX
	6	SFA-5.26	EGXXTXX
	6	SFA-5.28	ER-XX-X AND E-XX-X
	6	SFA-5.29	EXXT-X
	6	SFA-5.30	IN XXX

Labels

The supplier should provide documentation such as a label on the package which shows that the materials meet the code requirements, classification and certification status. Typical labels from packages of welding materials are shown in Fig. 11.

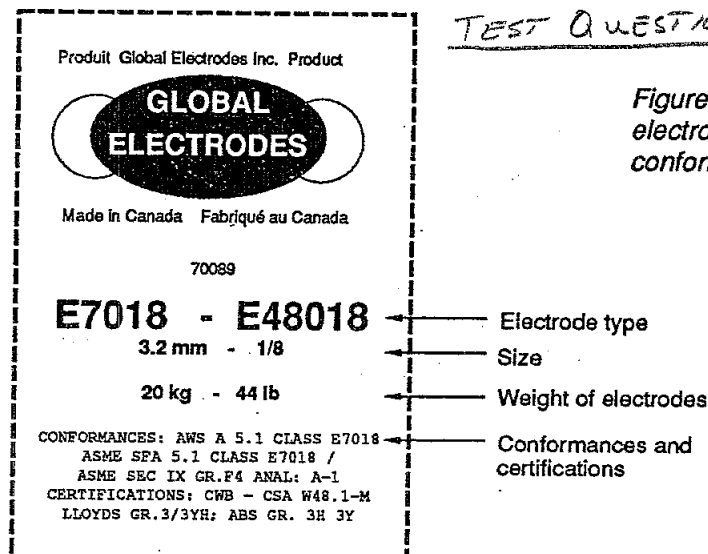
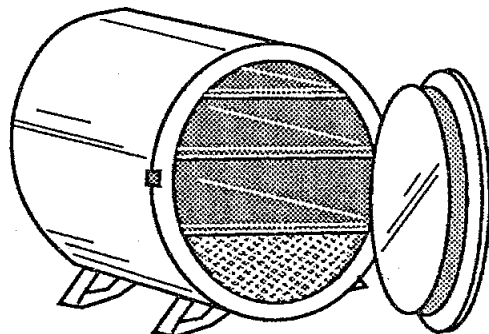


Figure 11. Typical part of a label on an electrode package. Note the list of conformances and certifications.

Figure 12. Typical holding oven for the storage of basic electrodes. Note that the maximum temperature at which these ovens operate, while suitable for holding (120°C minimum), may not be high enough for rebaking electrodes ($370 - 430^{\circ}\text{C}$). If rebaking is contemplated, suitable ovens must be available.



Electrode handling

In addition to this the packaging should be checked to ensure that the packages are intact and there is no damage from dropping or tearing. Some standards require damaged containers to be treated in a certain manner. CSA W59-1989, for example, requires that basic electrodes delivered in containers that show evidence of damage must be reconditioned by baking.

The inspector should check that the fabricator's storage and handling procedures comply with the applicable codes. Holding ovens must be available for basic electrodes to ensure they are dry and retain their low hydrogen properties (Fig. 12). There should be a procedure to control the issuing of electrodes to welders so that the wrong electrodes cannot be used in error.

The inspector should check on a regular basis that the holding ovens are operating properly and set at the correct temperature. A temperature indicating crayon is a useful tool for this. Electrode ovens should be clearly identified as to their contents and electrodes of different classifications should not be indiscriminately mixed together.

**Welding procedure
specifications**

VERIFICATION OF WELDING PROCEDURES

Fabrication and construction codes require that welding be carried out in accordance with written procedures, and most go on to formalize this requirement by specifying the content and recommending the format of such procedures.

Codes might also require that the "Welding Procedure Specifications" be *approved* by some appropriate body such as the "jurisdiction" or the Canadian Welding Bureau. The Ontario Boilers and Pressure Vessels Act, for example, requires approval "by the chief inspector."

The ASME Boiler Code (Section IX) requires that the fabricator has Welding Procedure Specifications (WPS) and Procedure Qualification Test Reports (PQR):

QW-200 General

QW-200.1 Each manufacturer and contractor shall prepare written Welding Procedure Specifications which are defined as follows.

(a) *Welding Procedure Specification (WPS)*. A WPS is a written qualified welding procedure prepared to provide direction for making production welds to Code requirements. The WPS or other documents [See (e) below] may be used to provide direction to the welder or welding operator to assure compliance with the Code requirements.

CSA Standard W47.1 requires WPS's approved by the Canadian Welding Bureau:

7.3 Welding Procedure Specifications

7.3.1

The fabricator shall prepare welding procedure specifications outlining the general welding procedure to be followed in the construction of weldments built in accordance with any governing design or manufacturing standard, or both. Each such specification shall include and define numerically where applicable all the variables listed as essential variables in Clause 8.2. A suggested form showing the typical information to be included in the welding procedures specification is given in Appendix A.

7.3.2

All welding procedure specifications shall be submitted to the Bureau for approval and when stamped as approved shall be registered with the Bureau.

7.3.3

Welding procedure specifications shall be designated primarily for use by shop and field supervisory personnel although on occasion they may be referred to by inspection and engineering personnel.

CSA W47.1 recommendations for the content of a WPS are shown in Fig. 13 on the following pages.

Figure 13. Suggested form of a welding procedure specification according to CSA W47.1.

Appendix A

Welding Procedure Specification

Suggested General Form

Note: *This Appendix is not a mandatory part of this Standard.*

For.....(Process).....Welding
Welding Procedure
Specification No.....
Date.....

Scope

This welding procedure specification covers welding and related operations in accordance with.....(insert appropriate CSA Standard number and/or other code designation).

A change in any of the essential variables contained in succeeding paragraphs or detailed on an applicable welding procedure data sheet will require a new welding procedure specification and/or a new data sheet.

Welding Procedure

The welding shall be done.....(insert manually, semi-automatically, automatically, or other) using a.....(describe process, such as SAW, GMAW, etc., process).

The joints shall be made by.....(insert single pass, multipass, both sides, or from one side only.....describe).

Base Metal

The base metal conform to the specifications for.....(insert appropriate CSA material standard, other code designations, or chemical analysis and physical properties).

Base Metal Thickness

Base metal thicknesses from.....inch(es) to.....inch(es) inclusive may be welded under this specification.

Filler Metal

The filler metal shall conform to specifications for.....(insert appropriate CSA standard, other code designation, chemical composition, or proprietary designation).

Functions of the Inspector

Figure 13. cont.

Flux

The flux shall conform to specifications for.....(insert appropriate CSA standard, other code designation, chemical composition, or proprietary designation).

Shielding Gas

The shielding gas shall conform to the following nominal composition.....(insert the gas or gases by proportional parts).

Position

The welding shall be done in the.....position (insert classification in accordance with Clause 8.4.1).

Preheat

Description of the temperature of preheat, before welding, the control of temperature during welding, and the rate of temperature change.

Heat Treatment

Description of the heat treatment before or after welding that will include temperature, rate of temperature change, times of heating or holding, etc.

Stress Relieving

Description of stress relieving if not already included in the heat treatment.

Electrical Characteristics

Description of the type of welding current (AC or DC), voltage characteristic (CV or drooping), polarity (RP or SP), electrical stickout (if important for process) and the range of amperages and voltages recommended for the process and electrode diameters covered by the specification.

Welding Technique

Description of limiting factors of the welding technique such as the maximum tolerances on voltage and amperage, thickness of weld deposit layers for appropriate position, arc manipulation, maximum width of weave, etc. (Note: This could be considered as a part of Welding Procedure paragraph.)

Figure 13. cont.

Preparation of Base Material

The edges or surfaces of the parts to be joined by welding shall be prepared by.....(state whether sheared, ground, machined, gas-cut, etc.) and shall be cleaned of all oil or grease and excessive amounts of scale or rust.

Quality

Cracks or blow holes that appear on the surface of any pass shall be removed before depositing the next covering pass.

Undercutting shall be minimized by selecting the most suitable process and procedure, and applying the correct technique.

Weld Metal Cleaning

Slag or flux remaining after a pass, particularly in manual welding or in narrow grooves, shall be removed before applying the next covering pass.

Treatment of Underside of Welding Groove

Prior to depositing weld metal on the back side of a welded joint, the root shall be gouged, ground, or chipped to sound metal, unless otherwise specified on the applicable data sheet.

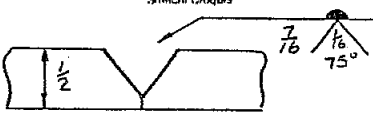
Data Sheets

The attached data sheets form part of this specification.

Functions of the Inspector

A typical WPS to ASME Section IX recommendations is shown in Fig. 14 below.

Figure 14. Typical welding procedure specification for ASME work.

 Ministry of Consumer and Commercial Relations Ministère de la Consommation et du Commerce		Pressure Vessels Safety Branch Direction des appareils sous pression		Welding Procedure Specification (WPS) Description de méthode de soudage (DMS)																
1 Company/Entreprise Name/Nom: Boiler Repair Co. Address/Adresse: _____ _____ _____ Postal Code/Code postal: _____		2 Provincial Registration Enregistrement provincial: WP MS K154.5		3 Procedure Identification/Désignation de la méthode WPS No. PI-M-104 Revision No. Rev. 0 Code section Sect. IX PQR No. SAW - 25																
4 Welding Process(es) Procédé(s) de soudage		<table border="1"> <tr> <td>1</td> <td>Shielded Metal Arc</td> <td>Manual/Manuel</td> <td>Semi-auto.</td> <td>Auto.</td> </tr> <tr> <td>2</td> <td></td> <td>Manual/Manuel</td> <td>Semi-auto.</td> <td>Auto.</td> </tr> <tr> <td>3</td> <td></td> <td>Manual/Manuel</td> <td>Semi-auto.</td> <td>Auto.</td> </tr> </table>				1	Shielded Metal Arc	Manual/Manuel	Semi-auto.	Auto.	2		Manual/Manuel	Semi-auto.	Auto.	3		Manual/Manuel	Semi-auto.	Auto.
1	Shielded Metal Arc	Manual/Manuel	Semi-auto.	Auto.																
2		Manual/Manuel	Semi-auto.	Auto.																
3		Manual/Manuel	Semi-auto.	Auto.																
5 Joints/Joins (QW-402) Design/Genre: Single Vee Backing/Soutien: Yes/Out No/Not NO Backing material/Matériau de soutien: Without Backing Other/Autre: _____		Sketch/Croquis 																		
6 Base Metals/Métaux de base (QW-403) or Specifications type and grade ou Spécifications type et grade: SA106 Grade B or Chemical Analysis and Mech. Prop. ou Analyse chimique et prop. méca.: _____ Thickness Range Qualified Gamme des épaisseurs qualifiées: Total 3/16" to 1" Other/Autre: _____		P N 1 Gr N° 1 Wt % 1 Gr N° 1 In % Same In % _____ 1 2 3																		
7 Filler Metals/Métaux d'apport (QW-404) 1 AWS No./N°: E6010 SFA 5.1 F.No. 3 A.No. 1 Dia. 1/8 2 AWS No./N°: E7018 SFA 5.1 F.No. 4 A.No. 1 Dia. 3/32 3 AWS No./N°: _____ SFA _____ F.No. _____ A.No. _____ Dia. _____ Flux Tradename Marque de commerce du flux: _____ Electrode-Flux Classification Classification du flux-electrode: _____ Consumable Insert Pièce insérée consommable: _____ Other/Autre: _____																				
8 Positions/Positions (QW-405) Position(s) of Groove Position(s) du chanfrein: 5 G Welding Progression Progression du soudage: E7018 Up Montant E6010 Down Descendant Position(s) of Fillet Position(s) de l'angle: _____ Other/Autre: _____		10 Postweld Heat Treatment/ Traitement thermique postsoudage (QW-407) Temperature Range Gamme de températures: NONE Time Range Gamme de durée: _____ Other/Autre: _____																		
9 Preheat/Préchauffage (QW-406) Preheat Temperature Température de préchauffage: Min. Interpass Temperature Température de l'interpasse: Max. Preheat Maintenance Maintien du préchauffage: _____ Other/Autre: Min Base Metal Temp. to be 50°F		11 Gas/Gaz (QW-408) Shielding Gas Composition Composition du gaz de protection: NONE Gas Flow Rate Débit du gaz: _____ Backing Gas Composition Composition du gaz de soutien: _____ Gas Flow Rate Débit du gaz: _____ Trailing Shielding Gas Composition Composition du gaz de protection traînant: _____																		

Welds
Joints

1 - SQUARE GROOVE

2 - SINGLE V-GROOVE

4 - SINGLE BEVEL GROOVE

M1-1

Effective Throat = T
 $T_{min} = 10$
 $T_{max} = 13$

B-L1a

M1-2

Effective Throat = T
 (for $T > 6$ up to $T \leq 13$
 (for $T \leq 6$ use B-L1c)
 $G = T/2$ to a max. of 5
 $T_{max} = 13$

B-L1b

M1-3

Effective Throat = T
 $T_{min} = 10$
 $T_{max} = 13$

B-L1c

M2-1

Effective Throat = T
 $R_f = 2$ or greater
 $G = 0-3$
 * Normally used when $R_f \geq 6$

B-U2a

M2-2

Effective Throat = T
 $R_f = 2$ or greater
 $G = 0-3$
 * Normally used when $R_f \geq 6$

B-U2b

M2-3

Effective Throat = T
 $R_f = 2$ or greater
 $G = 0-3$
 * Normally used when $R_f \geq 6$

C-U2a

M4-1

Effective Throat = T
 $R_f = 2$ or greater
 $G = 0-3$
 * Normally used when $R_f \geq 6$

B-U4a

M4-2

Effective Throat = T
 $R_f = 2$ or greater
 $G = 0-3$
 * Normally used when $R_f \geq 6$

B-U4b

M4-3

Effective Throat = T
 $R_f = 2$ or greater
 $G = 0-3$
 * Normally used when $R_f \geq 6$

B-U4c

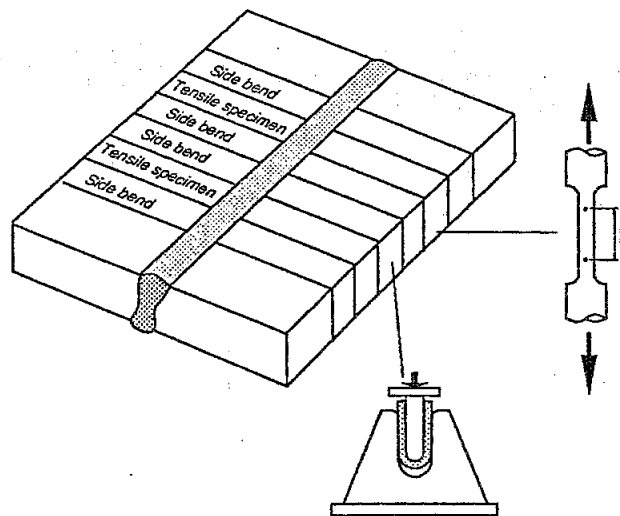
Figure 15. Example of prequalified joints for SMAW from CSA W59-M1989. Refer to the original for details and notes. For a welding procedure to be prequalified, the procedural restrictions in Clauses 10 and 5 also apply.

Procedure qualification

After establishing that appropriate welding procedure specifications exist, the inspector must verify that they have been properly qualified and approved. The method of qualification varies with the type of work and governing code. In some cases new tests are required. In other cases the results of previous tests can be used, and in most structural fabrication "prequalified" procedures can be used without the need for further testing. But whether or not testing is needed an approved written welding procedure specification is always required.

Let us first consider structural fabrication by a company certified to CSA W47.1 and welding to CSA W59-(M)1989. If the joint preparations selected follow those of Clause 10 of W59 and if the procedural restrictions of Clauses 5 and 10 of W59 are followed then the welding procedure is considered prequalified (Fig. 15). It must still be submitted to the Canadian Welding Bureau (CWB) for approval but testing is not required. At present prequalification in CSAW59-(M)1989 is only applicable for SMAW, SAW, and FCAW.

Figure 16. Procedures that do not comply with conditions for prequalification can be qualified by performing mechanical tests on a procedure qualification test weld (CSA W47.1).



If the procedure does not comply with the conditions for prequalification, or if there are additional requirements such as charpy impact properties then the procedure must be qualified by testing (Fig. 16). The results of tests are presented in a Procedure Qualification Test Report (PQR). Details for testing are given in W47.1. There are thus two main routes for qualifying procedures to W47.1 (Fig. 17). For actual production welding procedural information is given in the Welding Procedure Specification (WPS) and Welding Procedure Data Sheets (WPDS).

Functions of the Inspector

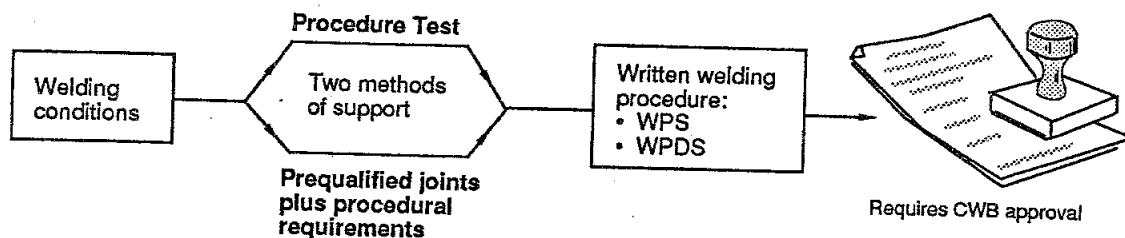


Figure 17. Summary of routes for welding procedure qualification following CSA W47.1-1983.

For work being done to ASME there is no system of prequalified procedures as such, but the results of qualification tests for previous jobs can be used. Fabricators, therefore, usually build up a file of approved PQRs that can be called upon as required.

The WPS properly supported by a PQR must be submitted to the appropriate jurisdiction for approval. For pressure vessels built to ASME in Canada this is a provincial government department such as the Ministry of Labour or, as in Ontario, the Ministry of Consumer and Commercial Relations (MCCR). A typical PQR registered with MCCR (Ontario) is shown in Fig. 18.

One of the most important features of the PQR is the range of conditions over which the qualification is valid. For example, under ASME, materials are grouped into "P" numbers. A qualification for one material in a particular "P" group is valid for any other material in that group. Similarly, tests on one thickness of material will be valid for a range of thicknesses (usually 3/16 in. to twice the thickness of the test coupon).

Parameters which are considered to have a significant effect on the properties of the resulting weld when varied outside a given range are termed essential variables. The essential variables and their allowable ranges are given in the standards. ASME also uses the term supplementary essential variables for those that are considered to affect the notch toughness of the weld. In addition ASME requires nonessential variables to be listed on the WPS although a change in them is not considered to affect the mechanical properties of the weld and does not require requalification.

Essential variables

Functions of the Inspector

Figure 18. Typical Procedure Qualification Test Report to ASME Section IX.



Ministry of
Consumer and
Commercial
Relations

Ministère de la
Consommation
et du
Commerce

Pressure Vessels
Direction
des appareils
Sûreté sous pression
Branch

Procedure Qualification Record (PQR) Résultat de méthode de soudage (RMS)

(Reference: ASME Section IX/Référence: ASME, Section IX)

1 Company/Entreprise Name/ Nom: Boiler Repair Co. Address/ Adresse: _____ Postal Code/Code postal: _____				2 Provincial Registration Enregistrement provincial: WP 45 KL54.5																																																					
3 Record Identification/Désignation du résultat PQR No. SMW - 25 WPS No. P1-M-104																																																									
4 Welding Process(es)/Procédé(s) de soudage 1 Shielded Metal Arc Type Manual 2 _____ Type _____ 3 _____ Type _____				5 Groove Design used/Croquis du joint utilisé																																																					
6 Base Metals/Métaux de base (QW-403) P. No. 1 Gr. No. 1 Alloy SA 106 Grade B P. No. 1 Gr. No. 1 Specification/Spécification 60 KSI																																																									
Thickness 1/2" Diameter/Diamètre 6" Ø Other/Autre: _____																																																									
7 Filler Metals/Métaux d'apport (QW-404) <table border="1"> <thead> <tr> <th>Classification (AWS)</th> <th>SFA No.</th> <th>F. No.</th> <th>A. No.</th> </tr> </thead> <tbody> <tr> <td>E6010-Root</td> <td>5.1</td> <td>F3</td> <td>1</td> </tr> <tr> <td>E7018-Fill</td> <td>5.1</td> <td>F4</td> <td>1</td> </tr> </tbody> </table>				Classification (AWS)	SFA No.	F. No.	A. No.	E6010-Root	5.1	F3	1	E7018-Fill	5.1	F4	1	10 Postweld Heat Treatment/Traitement thermique postsoudage (QW-407) Temperature NONE Time NONE Other NONE																																									
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9 Preheat/Préchauffage (QW-406) Preheat Temperature NONE Interpass Temperature 450° F MAX. Other/Autre: _____				12 Technique/Technique (QW-410) String or Weave Bead/Cordon droit ou oscillant: Root-String, Fill Weave Oscillation: Multipass or Single Pass (per side)/Passe unique ou multiple (par côté): Multipass Single or Multiple Electrode/Électrode unique ou multiple: Single Other/Autre: _____																																																					
13 Electrical Characteristics and Technique/Caractéristiques électriques et techniques (QW-409) (QW-410) <table border="1"> <thead> <tr> <th rowspan="2">Weld Layer(s) Craque(s) de soudure</th> <th rowspan="2">Process Procédé</th> <th colspan="2">Filler Metal Métal d'apport</th> <th rowspan="2">Type Type</th> <th colspan="3">Current Courant</th> <th rowspan="2">Travel Speed Vitesse</th> </tr> <tr> <th>Classification</th> <th>Diameter Diamètre</th> <th>Polarity Polarité</th> <th>Amp Ampérage</th> <th>Volt Voltage</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>SMW</td> <td>E6010</td> <td>1/8</td> <td></td> <td>Pos.</td> <td>120</td> <td>24</td> <td>6" /min</td> </tr> <tr> <td>2-5</td> <td>SMW</td> <td>E7018</td> <td>3/32</td> <td></td> <td>Pos.</td> <td>95</td> <td>22</td> <td>2-3" /min</td> </tr> <tr> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> </tr> </tbody> </table>								Weld Layer(s) Craque(s) de soudure	Process Procédé	Filler Metal Métal d'apport		Type Type	Current Courant			Travel Speed Vitesse	Classification	Diameter Diamètre	Polarity Polarité	Amp Ampérage	Volt Voltage	1	SMW	E6010	1/8		Pos.	120	24	6" /min	2-5	SMW	E7018	3/32		Pos.	95	22	2-3" /min																		
Weld Layer(s) Craque(s) de soudure	Process Procédé	Filler Metal Métal d'apport		Type Type	Current Courant					Travel Speed Vitesse																																															
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2-5	SMW	E7018	3/32		Pos.	95	22	2-3" /min																																																	

Functions of the Inspector

[illegible]

When welds are to be stress relieved, the heat treatment period that is qualified in the tests must make allowance for all the heat treatment times to be experienced by the product including those that may arise from repairs.

When procedures must be qualified by testing the inspector may play a role in monitoring the tests. The contract may require that the inspector witness the welding, preparation of test coupons and mechanical or NDT testing of specimens. One function might be to attest to the origin and control of the specimens.

VERIFICATION OF PERSONNEL QUALIFICATIONS

Welder qualifications

One of the most important tasks of the inspector is verification that the welding operators, welders, and the tackers are appropriately qualified for the work at hand. Welding personnel are qualified by undertaking welder performance tests as required by the relevant code. Evidence of qualification is in the form of an identification card ("ticket") which shows the classification, process, position, etc., for which the individual is qualified. An example of the CWB welder identification card is shown in Fig. 19.

		SAMPLE ONLY 40201 CANADIAN WELDING BUREAU BUREAU CANADIEN DE SOUDAGE		SAMPLE ONLY 40201 WELDER'S TEST RECORD RAPPORT DE QUALIFICATION DE SOUDEUR	
SOCIAL INS. NO. N° D'ASS. SOCIALE HOLDER'S NAME NOM DE DÉTENTEUR		123 456 789 A. Welder		STD. NORME	
TYPE/LEVEL TYPE/NIVEAU CLASSIFICATION CLASSIFICATION ORGANIZATION ORGANISATION		Transferable S FAB COMPANY		POSITION/CATEGORY POSITION/CATÉGORIE	
ISSUE DATE DATE D'ÉMISSION		04/12/88 MO. DAY/YR. YR./AN.		FLAT/HORIZ/VERT/OVER SMAW MODE MANUAL MODE	
EXPIRATION DATE DATE D'EXPIRATION		03/17/90 MO. DAY/YR. YR./AN.		ELECTRODE/FILLER METAL GROUP ÉLECTRODE/GROUP DE MÉTAL D'APPORT THICKNESS ÉPAISSEUR PROCEDURE NO. NO. DE PROCÉDURE	
				F4 ALL THICKNESSES OVER 1/8-in N/A	
				S. Paezue CWB SIGNATURE SIGNATURE DE CWB	
				A. Welder HOLDERS SIGNATURE SIGNATURE DE DÉTENTEUR	

Figure 19. Welder identification card (CSA W47.1-1983).

The CWB issues cards according to the requirements of CSA W47.1 (steel) and W47.2 (aluminum). Qualification is governed by:

- classification
- process
- mode of process application
- position.

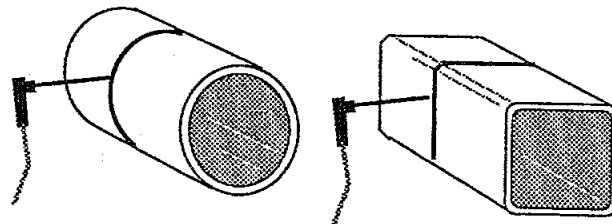
Two classifications are used: T for complete penetration welding of hollow sections from one side without backing (e.g., a pipe weld), and S for welding of plate, and rolled or hollow sections either from both sides or from one side with backing (Fig. 20).

Functions of the Inspector

T classification

Hollow sections welded from one side without backing.

KNOW DIFFERENCE
BETWEEN CLASSES.



S classification

Plates and rolled or hollow sections welded either from both sides or from one side with backing.

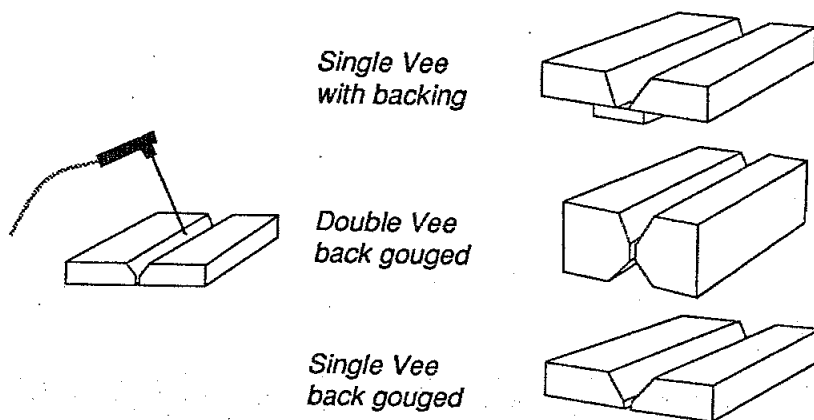


Figure 20. Classification of welders according to CSA W47.1-1983.

The valid positions of welding are determined by the class (Fig. 21):

- Class F: flat position and fillet welds in the horizontal position
- Class H: flat and horizontal position
- Class V: flat, horizontal, and vertical positions
- Class O: flat, horizontal, vertical, and overhead positions.

The class and the classification letters are used together to denote the qualification of the welder, e.g., FS. Qualification for "T" classification also qualifies for "S" in the same process, position, and mode, and "S" qualification is not a prerequisite for "T" classification.

For the purposes of performance qualification, electrodes are grouped such that a welder qualified with one electrode in a group is qualified to weld with other electrodes in the group and possibly with other groups (see Table 3). The grouping is intended to reflect the difficulty of handling the various electrodes.

Position Classes	Test plates required			
				
Class F	✓			
Class H	✓	✓		
Class V	✓	✓	✓	
Class O	✓	✓	✓	✓

Figure 21. Position classes for welder qualification according to CSA W47.1-1983.

Table 3. Group designation of electrodes (CSA W47.1-1983).

Group designation		Electrode classification		
F4	EXXX15	EXXX16	EXXX18	
F3	EXXX00	EXXX10	EXXX11	
F2	EXXX12	EXXX13	EXXX14	
F1	EXXX22	EXXX24	EXXX27	EXXX28

F4 qualifies F4, F3, F2, and F1

F3 qualifies F3, F2, and F1

F2 qualifies F2, and F1

F1 qualifies F1

Functions of the Inspector

Duration of validity

The CWB standard qualification is transferrable among certified employers so welders retain their qualifications if they move to another certified employer. Identification cards have expiry dates and the inspector must verify that cards are current for the job in hand. It may be necessary to call for requalification of the welders and operators. Normally the CWB qualification is valid for two years. If the CWB qualification is based on an ASME qualification, for example, then the CWB ticket is only valid until the expiry of the ASME ticket. Fig. 22 shows an Ontario (MCCR) ticket for pressure vessel (ASME) work.

For other codes and jurisdictions the requirements for qualification of welders may be different and the specific codes should be studied for details. In some types of construction welder qualification is not required to be approved by the CWB or other jurisdiction but is directly approved by the company owning or operating the installation. Under these circumstances the welding inspector employed on behalf of the owner may be required to supervise the conduct of performance qualification tests as specified in the appropriate code.

Depending on the conditions of the qualification tests there are limitations on the position, type of weld, and thickness range qualified. Table 4 provides a summary of the ASME Section IX requirements.

 **IDENTIFICATION OF WELDER**
Pursuant to the Boilers & Pressure Vessels Act

Expiry Date: June 6-79 S.I.N. 425-393-923

Welder: M. T. WELDER Symbol: 13

Has passed the welding test required under section 36 of the Boilers and Pressure Vessels Act, and is hereby authorized to weld for:

FABRICATING CO LTD

subject to the limitations on this certificate

 P. Eng.
Chief Inspector

09397 (Rev. 5-77)

 Ministry of
Consumer and
Commercial Relations

Technical
Standards
Division

Pressure
Vessels
Branch

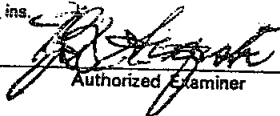
Process: G-M.A.W. Plate ☒ Pipe ☐

Filler Rod F. No. 6 A. No. 1 P. No. 1

Positions: 3G Progression:

Thickness Range Qualified 3/16 ins. to 1 1/2 ins.

Min. Diameter Qualified _____ ins.

Signature of Welder: _____ Authorized Examiner: 

This card is to be carried by the welder at all times and must be produced when requested by the inspector.

Figure 22. Welder qualification card for pressure vessel (ASME) application issued by the MCCR (Ontario).

Table 4.

SUMMARY OF PERFORMANCE QUALIFICATION - ASME SECT IX. (Refer to original document for details)

Qualification Test Specimen	Position of Test	Position and Type of Weld Qualified				Specimen Thickness Tested	Thickness Range Qualified (1)	Method of Test (2)		
		Groove		Fillet				Standard Coupon	Production Test	
		Plate & Pipe over 24" OD	Pipe < 24" OD	Plate and Pipe	Welder				Welding Operator	
PLATE - GROOVE	1G	F	F	F	F	Less than 3/4 " 3/4 " and over	2t Max to be welded	Radiography (6 ") or Perform Transverse Bends	Radiography (6 ")	Radiography (36 ")
	2G	F, H	F, H	F, H	F, H					
	3G	F, V	F	F, H, V	F, H, V					
	4G	F, O	F	F, H, O	F, H, O					
	3G + 4G	F, V, O	F	All	All					
	2G, 3G, +4G	All	F, H	All	All					
PLATE - FILLET	1F	Not Qualified	Not Qual	F	F	3/16" to 3/8"	All thickness to be welded	1-Macro 1-Fracture		
	2F	" "	" "	F, H	F, H					
	3F	" "	" "	F, H, V	F, H, V					
	4F	" "	" "	F, H, O	F, H, O					
	3F + 4F	" "	" "	All	All					
PIPE - GROOVE	1G	F	F	F	F	Less than 3/4 " 3/4 " and over	2t Max to be welded	Radiography (Full Weld Circumference) or Perform Transverse Bends		
	2G	F, H	F, H	F, H	F, H					
	5G	F, V, O	F, V, O	All	All					
	6G	All	All	All	All					
	2G + 5G	All	All	All	All					
PIPE - FILLET	1F	Not Qualified	Not Qual	F	F	O. D. (in) <1 1 to < 2 7/8 2 7/8 and over	All thickness to be welded	1-Macro 1-Fracture		
	2F	" "	" "	F, H	F, H					
	2FR	" "	" "	F, H	F, H					
	4F	" "	" "	F, H, O	F, H, O					
	5F	" "	" "	All	All					

(1) t = thickness of weld deposit for each process. (2) Radiography is not permitted for some specific materials and processes e.g., GMAW short circuiting.

WELDING INSPECTION TASKS

Prior to fabrication much of the inspector's job, as defined in the inspection and testing plan, is confined to examining the paperwork, verifying that procedures and qualifications are in place. When fabrication begins the job changes to one of observing and checking to ensure that things are done according to the documented procedures. Before welding starts duties may include checking of equipment, materials, and consumables to ensure they are as specified in the WPS. In addition to welding equipment this might include other equipment required during fabrication. For example, if welding with basic electrodes to W59 suitable electrode holding ovens must be available and operating at the correct temperature.

Inspection prior to welding

After preparation of the material but before welding starts, the weld preparations must be checked to ensure they comply with the requirements. In verifying the weld preparation and fit-up dimensions it is important to note the difference between the workmanship tolerances and the range of values for which the welding procedure is valid. For example, a prequalified joint from W59 Clause 10 may be valid for all groove angles down to some minimum value. If this minimum value were specified in the procedure it would still be subject to the -5° workmanship tolerance given in Clause 5.4.5 of W59. The measurement of these dimensions is discussed in detail in Module 16.

In addition to the dimensions of the joint, the condition of the edge preparation and cleanliness of the material must be checked. The requirements for these are normally given in the governing standard (e.g., CSA W59-1989) or the contract specification. For example, the quality of a flame cut edge is specified in W59. This same standard also requires that surfaces to be welded be free of scale, slag, loose rust, paint, grease, and so forth. Some typical items that require checking prior to welding are shown in Fig. 23.

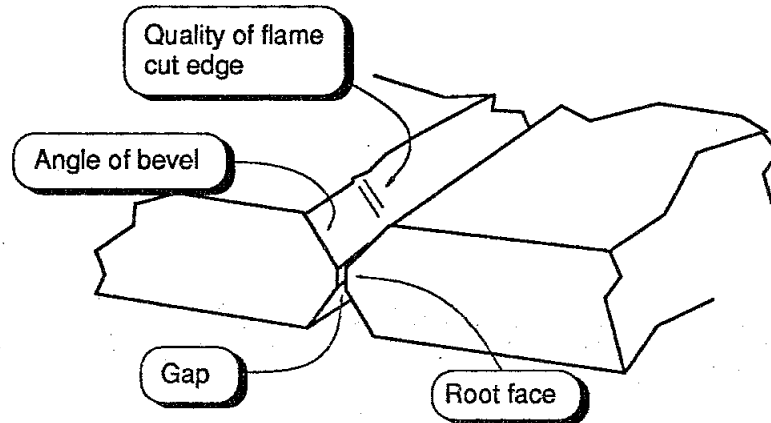


Figure 23. Typical items that require checking prior to welding.

Inspection during welding

When welding commences many of the items previously checked by the inspector must be verified again during welding. For example, although the inspector will have checked that qualified welders were available for the job, it must also be verified that they were actually used for welding. Again at this stage the inspector's task involves direct observation of the welding operations. Some of the items that the inspection and test plan might require the inspector to check are:

- Ensure that only the approved Welding Procedure Specifications are used
- Review welder, welding operator and tacker qualifications to ensure that they are current and appropriate to the task and the specification
- Check that welders only weld for the process, consumable, position, and other conditions for which they are qualified
- Verify that only compatible materials are used and that they conform to the welding procedure specification
- Verify that the welding parameters conform to the approved Welding Procedure Specification
- Ensure that the welding consumables have been properly stored, that they are in good condition and that they are being properly handled by the welders
- Ensure that clamping and fit-up has been done in accordance with good practice
- Ensure that tack welds have been suitably prepared for inclusion in the final weld
- Monitor the method of application and the measurement of preheat if required by the welding procedure specification.

Inspection after welding

Although checking the welds after completion is traditionally thought of as the main role in "weld inspection," this module has emphasized the continuous monitoring of all steps that affect the ability of the welds to meet the specified requirements. This starts well before production begins and runs through until after fabrication is complete. Nevertheless, the same systematic approach is required for operations after completion of the welds, including weld inspection.

One of the first items is to check that all the required welds have been made. This duty requires the inspector to be able to read drawings and interpret weld symbols. Inspecting for missing welds requires some system for recording completed welds, for example by checking them off on a drawing.

Inspection of completed welds is carried out according to a documented inspection and test plan. An example of a written inspection and test plan is given in Fig. 24 starting on page 37. Read through this and note the kinds of items that are included. Remember this is just one example and inspection procedures for other applications could look quite different.

To ensure smooth implementation of the inspection plan the inspector should establish a system of tracking the status of the inspection by marking work and by maintaining detailed records. If the construction code calls for sampling inspection (e.g., 10% radiography) the inspector may have to define the sample by selecting and marking the inspection sites (see Clause 4.1 of the example). In some jobs production welds may need to be selected and flagged for mechanical testing. These would usually have run-off plates added which can be removed after welding to provide the mechanical test samples.

When nondestructive examination is specified it should be integrated with visual inspection in the plan and not used in isolation. Good visual inspection is often needed to complement NDE and to assist in the interpretation of NDE results. Various NDE methods may be specified and each has advantages in specific applications. Some of the relative merits of NDE methods are summarized in Fig. 25.

Where nondestructive examination is called for this must be closely monitored. Equipment must be checked to ensure that it is suitable for the job, in good working condition, and properly calibrated. Although not normally qualified to interpret the results of NDE, the inspector must review the qualifications of NDE operators (radiographers, ultrasonic technicians, etc.) to verify they are appropriate for the product and

Figure 24. Example of part of an inspection plan.

PROCEDURE

INSPECTION PROCEDURE FOR CAUSTIC PIPELINE WELDED JOINTS

1. Reference codes:

- 1.1 CSA standard Z 184 - Gas Pipeline Systems
- 1.2 ANSI, B31.3 - Chemical Plant and Petroleum Refinery Piping
- 1.3 ASME, section V - Nondestructive Examination
- 1.4 ASME, section IX - Welding and Brazing Qualifications

2. Fabricator and Erector (Forge Shop, Pool Force or Contractor) are fully responsible for quality of welded joints.

Prior to starting the welding operation the supervisor (foreman) shall make the following examination:

- 2.1 Check if material of pipe, flanges, pipe attachments correspond to the drawing.
- 2.2 Is preparation of the joints: bevel, root opening, electrode in accordance with specification and drawing?
- 2.3 Are welders qualified under section IX of ASME code, and do they have the knowledge of approved welding procedure?
- 2.4 Welder is directly responsible for the quality of welded joints and he has the right to report to his supervisor any deviation from the procedure in joint preparation. Each joint shall be marked by identification stamp.

3. Welding inspector, project leader or his delegate has the right to check as per paragraphs 2.1, 2.2, 2.3 and on a random basis during welding operation.

- 3.1 Visually inspect quality of joint for undercut, reinforcement etc., as per Table # 325.4.1 & 327.4.1A (attached).
- 3.2 Inspect visually for Root Penetration, Root Reinforcement etc., at branch joints using mirrors.
- 3.3 For girth joints, a minimum of one cut-out 8" wide sample on 15 joints, shall be taken at random for visual, metallurgical and mechanical examinations.
- 3.4 Any deviation from established norms shall be reported to welding supervisor (foreman) and to project leader.

Functions of the Inspector

Figure 24. cont.

4. After welding is finished the following inspection shall take place:

- 4.1 Project leader or his delegate shall call outside specialized firm to take spot radiography photos as per Table I in places indicated by welding inspector.
- 4.2 In addition to radiography, cut-out samples as per Table I shall be taken for visual, metallographic and mechanical test by metallography dept.

Table 1

No. of weld joints	Min. no. of spot radiog. test	Min. no. of cut-out samples
To 10	3	1
11 - 30	4 - 6	2
31 - 100	7 - 10	3
101 -	11 -	4

5. If results of final examination are unsatisfactory (do not correspond to acceptable standards, tables, etc.) project leader shall call a meeting of: design engineer, welding inspector and fabricator to re-examine the results and to decide upon one of the following:

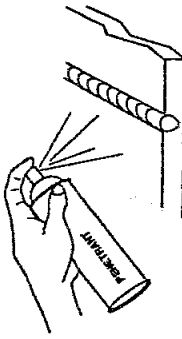
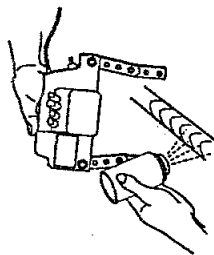
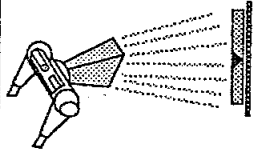
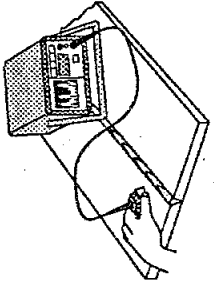
- 5.1 Conditional acceptance of the work.
- 5.2 Call for 100% radiography to indicate spots to be repaired.

6. After acceptance of welded joints (after repair of poor joints or rewelding of parts taken for sampling).

- 6.1 Postweld heat treatment of all welded joints is required as per procedure No.....
- 6.2 Hydrostatic test to 200% of maximum operating pressure, but not less than 200 psi for complete caustic pipeline is required.*

KNOW THIS PAGE.

Figure 25. Comparison of various nondestructive examination methods.

Inspection method	Advantages	Disadvantages	Typical applications
 Liquid penetrant. PT	Simple, inexpensive Suitable for ferrous and nonferrous metals Rapid results No electrical power required	Only detects discontinuities open to the surface Defects easily hidden Cannot be used on hot or cold parts	Quick, spot checks on welds Detection of surface defects such as fatigue cracks
 Magnetic particle. MT	Simple, inexpensive Limited depth capability Rapid results <i>D.C. has better penetrating power.</i>	Only detects surface or near surface discontinuities Only suitable for ferromagnetic materials Electrical power required	Detection of surface defects such as cracks in steel welds Useful for testing partially completed welds in thick sections
 Radiography. RT	Volumetric method Provides permanent record Large areas (e.g., complete pipe weld) can often be inspected with one shot Gamma ray requires no electrical power, portable	Potential safety hazard Disrupts other work Results not immediately available Some defects may be missed depending on beam angle Expensive, bulky equipment needed for X-ray Highly skilled operators required	Inspection of main load carrying butt joints to verify general weld soundness through thickness
 Ultrasonics. UT	Volumetric method Immediate results Portable Suitable for wide range of thicknesses Sensitive	Slow if applied manually to long weld lengths Skilled operators required Thin material and region close to surface difficult to inspect	Detailed inspection of critical welds Detailed measurement and characterization of defects Very thick sections not suitable for radiography

Functions of the Inspector

Nonconformances

the procedures to be used. Approved written NDE procedures must be available and followed by the operators. All NDE examination must be properly documented in accordance with the applicable codes, standards, and specifications.

Note in Clause 5 of the inspection procedure example that there is a procedure spelled out for dealing with nonconformances. In this case a meeting is required to decide the disposition. The inspector must be completely familiar with the conditions for conformance, i.e., the acceptance criteria and the procedure to be followed in the event of a nonconformance.

In summary, there must be a system for:

- reporting nonconformance, corrective and repair action
- authorizing, monitoring and inspecting repairs
- documenting repairs and other rectification action
- reviewing records for recurring problems and initiating corrective action.

After the completion of all welding, corrections, and repairs the inspection and test plan would typically call for the inspector to check that all required activities have been completed such as:

- Confirm all stated prior inspections were carried out satisfactorily
- Confirm all necessary monitoring was carried out
- Carry out any necessary final inspections, e.g., finish, appearance, straightness
- Confirm all mechanical testing sampling and NDE has been completed
- Confirm all repairs and corrections have been carried out to meet original specifications
- Check all nonconformances have been closed out satisfactorily
- Confirm all specified tests required by the customer have been carried out.

A typical nonconformity report is shown in Figure 26.

NONCONFORMITY REPORT (NCR)

PROJECT TITLE			JOB NO.		
LOCATION	SUPERVISOR		NCR NO.		
EQUIPMENT NO.	LINE NO.	JOB NO.	CRN.	OIN.	
DESCRIPTION OF NONCONFORMANCE			STANDARDS VIOLATED (state paragraph no.)		
A.I. Advised of Nonconformity		QC Supervisor:			
		Date:			
PROPOSED CORRECTIVE ACTION			PROPOSED BY:		
			CONCURRENCE QC SUPERVISOR		
			A.I.		
			M & C SUPERVISOR		
CORRECTIVE ACTION COMPLETE			M & C SUPERVISOR		
			DATE:		
CORRECTIVE ACTION CHECKED			QC INSPECTOR		
			DATE:		
NCR ACTIVITIES COMPLETE AND NCR TO DEAD FILE			QC SUPERVISOR		
			DATE:		

Figure 26. Typical nonconformity report.

Functions of the Inspector

Other operations

Several other operations, such as proof testing (e.g., hydrostatic testing of a pressure vessel) and postweld heat treatment, although not strictly welding activities, may require monitoring by the welding inspector when specified. As with the welding operations these tasks involve verifying that suitable procedures are available, checking the suitability and availability of equipment, and monitoring the execution of the test or postweld heat treatment to ensure they are done in accordance with the procedure.

Postweld heat treatment

The most common type of postweld heat treatment is thermal stress relief which usually involves soaking the product at a temperature of typically 625°C for a period of time then slow cooling. Other heat treatments, however, might be called for and the inspector should understand completely what is specified. Because the control of temperature, temperature gradients, and cooling rate are critical in postweld heat treatments many parameters must be specified in the procedure. The items that the inspector may be required to monitor could include:

- the number and placement of thermocouples
- area to be heated or placement of the product in the furnace
- heating and cooling rates
- holding temperatures and times and permissible variations
- maximum allowable temperature difference among thermocouples
- calibration of temperature recording equipment.

Following postweld heat treatment the inspector should carefully review the temperature records to verify compliance with requirements. A sketch of a heat treatment chart is shown in Fig. 27 which also explains some of the checks that typically would be made to verify compliance. Fig. 28 shows part of an actual heat treatment chart showing temperature records from several numbered thermocouples. When many thermocouples are used, the charts can become quite complex, and great care is needed in reading them. Records, of course, must be properly identified and dated so that they can be traced to the work to which they apply.

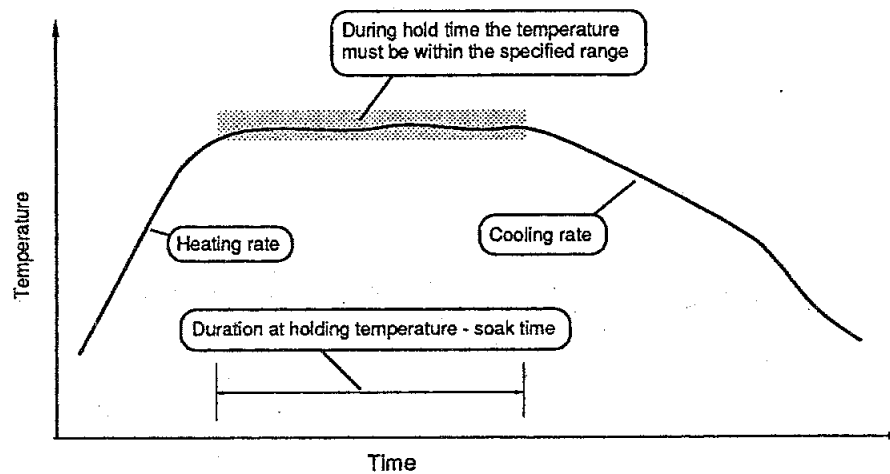


Figure 27. Some items that might require checking on a heat treatment chart.

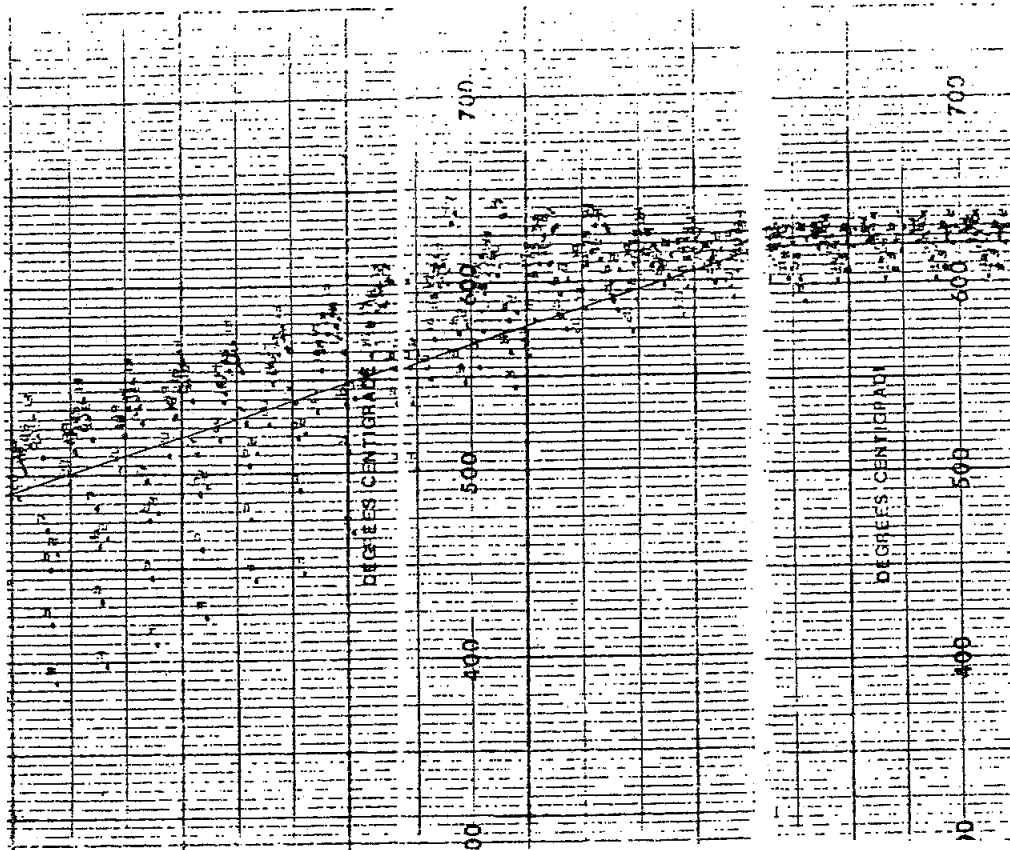


Figure 28. Part of a typical postweld heat treatment chart showing data from several numbered thermocouples.

Summary

Among many duties, the welding inspector has some specifically defined functions related to the production of welds. These include not only inspection of the finished weld but verification of compliance with specified requirements at each stage of the process. In this module we have discussed many of these functions and related tasks, although an inspector may not be required to carry out all of them.

In discussing the functions and tasks we have emphasized the importance of good reporting and documentation. We discuss the documentation associated with the purchase and delivery of materials and indicate some of the items that an inspector may be required to check. We cover the important topic of certification of welding consumables.

Welding must be carried out in accordance with a formal procedure which must be documented. The methods of qualifying and approving these procedures under various codes are discussed. Similarly, we cover qualification of welders and welding operators. We mention some typical tasks during welding operations from checking joint fit-up and preparation, checking that welding parameters are in accordance with the procedure, to inspection of a completed weld. It is emphasized that specific tasks would be listed in a formal inspection and test plan. Following welding, there may be further activities that the welding inspector is involved in such as postweld heat treatment and proof testing.

The specific functions and duties of an inspector should be planned and documented and they would depend on the particular industry and product. This module has provided an introduction to examples of what these might be.

GUIDES AND EXERCISES

MODULE 15

FUNCTIONS OF THE INSPECTOR

FUNCTIONS OF THE INSPECTOR

MODULE 15

Guides & Exercises

To obtain maximum benefit from this module we suggest that you follow this guide and complete the exercises as indicated. It is important that you work through the text methodically, studying each section thoroughly before moving on. The exercises are designed to give you an indication of whether you have learned the material and can move on or whether you need to go back and study the section again.

Do the exercises honestly. They will not help you unless you take them seriously. If you get a question wrong go back through the text until you understand where you have gone wrong and know the correct answer.

The length of time required to complete the module will vary from student to student. Find your own pace. Do not rush. Remember you are trying to learn something, not win a race.

Some people like to underline sections when they read a text. We suggest that you use caution if you do this. What you think is important first time you read it may be different after reading it three times. We suggest you read a section three times thoroughly before highlighting anything.

The last exercise is designed to give you an indication of whether you are ready to take the WIC closed-book exams. The exercise questions are of a similar standard to the official exams. Do not take the exam until you feel you are ready and you may wish to study several Modules before taking the exams on each. The details of the examination procedures are on a separate sheet.

If you have any difficulties with this Module do not hesitate to ask for help. You may find you learn more by attending seminars which are given periodically, and you should also contact your local WIC Chapter to see if they can be of assistance. Remember, if you fail the examination you can always try again later.

After working through each guide, check your answers (on page 51) for accuracy. If any of your answers are wrong, restudy the guide subject matter in the text until you understand it before moving on to the next guide.

Guide 1

Read carefully pages 1 to 6 and answer the following questions:

1. True or false?

"The inspector's role begins immediately after welding with visual inspection of the completed weld."

2. What three key items form the "Quality Triangle for Welding" and are required prior to fabrication?
3. What benefit may interim reports have?
- a) No benefit, they are just more paperwork
 - b) They avoid the need for a final report
 - c) They can alert people to potential quality problems allowing them to be rectified early.
4. According to the welding record sheet example shown in Fig. 4, was the same batch of SAW wire used for welding both sides of the joint?
5. According to the quality plan example given in Fig. 5, do welding procedures require the client's approval?

Functions of the Inspector

Guide 2

Read carefully pages 7 to 16 and answer the following questions:

1. For steels meeting CAN/CSA-G40.21-M87 the general requirements are covered by CAN/CSA-G40.20-M87. Which of the following are general requirements?
 - a) chemical composition
 - b) dimensional tolerances
 - c) marking
 - d) tensile strength
2. Refer to the mill test certificate shown in Fig. 7. If the minimum average CVN (impact test) specified had been 50 ft lb instead of 35 ft lb, would the steel have still met the requirements?
3. True or false?

"The samples used for mechanical testing reported on a mill sheet are taken directly from the plate and therefore always represent the condition of the plate as-delivered."
4. Which organization certifies welding consumables to the CSA W48 series standards?
5. How could you check whether an electrode was certified to the CSA W48 standard?
6. Why must holding ovens be available when using basic electrodes?

Guide 3

Read carefully pages 17 to 28 and answer the following questions:

1. What do the letters WPS stand for?
2. For companies certified to CSA W47.1, who must approve the WPS's?
3. In the suggested form of a WPS in CSA W47.1, does the method of joint preparation have to be specified?

4. True or false?

"One advantage of using prequalified joints is that a written welding procedure is not required."

5. What is a PQR?

6. True or false?

"An essential variable is one for which any change outside a specified range requires requalification of the procedure."

Guide 4

Read carefully pages 29 to 33 and answer the following questions:

1. How would you check that a welder is qualified under CSA W47.1?
2. In what positions is a class V welder permitted to weld under CSA W47.1?
3. What are the classifications for welders under CSA W47.1?
4. True or false?
"A CWB welder qualification is good for life."
5. Is a CWB welder qualification normally transferable among employers?
6. According to the example of a welder qualification card shown in Fig. 22, is this welder qualified to make horizontal groove welds in 1 in. thick plate?

Functions of the Inspector

Guide 5

Read carefully pages 34 to 44 and answer the following questions:

1. If you are checking a joint preparation according to CSA W59-M1989, are you allowed to consider the workmanship tolerances?
2. True or false?
"When checking a joint before welding, the quality of the flame-cut edge is not important since the edge is all melted in when welded."
3. True or false?
"If ultrasonic examination is specified there is no need for a visual inspection."
4. According to the inspection procedure example shown on pages 37 and 38, what is the next step in the event that radiographs fail to meet the acceptance standard?
5. According to the same example, is the welding inspector permitted to do random spot checks of the electrode type being used during welding?
6. List at least three items that might need to be checked during a postweld heat treatment.

ANSWERS

Guide 1

1. False
2. Correct materials, approved welding procedures, and qualified welders
3. c)
4. Yes
5. Yes

Guide 2

1. b) and c)
2. Yes
3. False
4. Canadian Welding Bureau (CWB)
5. It is marked on the package label and the CWB issues a list of certified consumables
6. To keep them dry and retain their low hydrogen properties

Guide 3

1. Welding Procedure Specification
2. CWB
3. Yes
4. False
5. Procedure Qualification Test Report
6. True

Guide 4

1. Qualified welders are issued with identification cards (tickets)
2. Flat, horizontal, and vertical
3. S and T
4. False
5. Yes
6. No

Guide 5

1. Yes
2. False, CSA W59-M1989 specifies edge quality
3. False
4. Project leader to call a meeting of the design engineer, welding inspector, and fabricator
5. Yes
6. Six items are mentioned on page 42

MODULE 15

TEST

This test is designed to determine whether you are ready to attempt the formal examination.

Complete the ANSWER SHEET and compare the results with the TEST KEY. If you score less than 70% we suggest you restudy the material.

1. Which of the following best describes the role of the welding inspector?
 - a) the welding inspector's role is strictly to perform visual inspection of the completed weld
 - b) the welding inspector's role begins well before welding starts, continues during and after the welding operation, and is finished only when results are properly reported
 - c) the welding inspector's role is primarily one of checking the qualification of welders
 - d) the welding inspector's role is mainly to check during welding that the procedure is followed
 - e) the welding inspector's role is mainly using NDE methods to inspect completed welds
2. Which of the following is specified in the "General Requirements" (CAN/CSA-G40.20-M87) rather than in the standard "Structural Quality Steels" (CAN/CSA-G40.21-M87)?
 - a) grade
 - b) chemical composition (heat analysis)
 - c) minimum yield point
 - d) dimensional tolerances
 - e) minimum elongation
3. To what standard are welding consumables certified by the Canadian Welding Bureau?
 - a) CAN/CSA G40.21-M87
 - b) one of the CSA W48 series
 - c) the Canadian Welding Bureau does not certify welding consumables
 - d) CSA W47.1 or CSA W47.2
 - e) CSA W59-M1989

4. Why are holding ovens used for basic electrodes?
- a) to keep them dry and retain their low hydrogen properties
 - b) to keep them warm to facilitate striking an arc
 - c) basic electrodes should not be kept in holding ovens because it damages the coating
 - d) holding ovens are only used to dry a basic electrode if it gets wet
 - e) to improve the impact properties of the deposited weld metal
5. Which of the following statements is true with regard to CSA W47.1?
- a) prequalified joint welding procedures require testing but do not need a written procedure
 - b) prequalified joint welding procedures require testing and also need a written procedure
 - c) prequalified joint welding procedures do not have to be approved by the CWB because they are prequalified
 - d) prequalified joint welding procedures do not require CWB approval if they are tested
 - e) prequalified joint welding procedures do not require testing but require a written procedure approved by the CWB
6. Which of the following statements best describes an essential variable?
- a) any variable that affects the toughness of the weld
 - b) any variable that can be changed $\pm 10\%$ without requalifying the procedure
 - c) a variable that may affect the weld properties and for which a change outside a specified range requires requalification of the procedure
 - d) a variable that may affect the weld properties and for which any variation from the specified value requires requalification of the procedure
 - e) any variable that need not be specified in the procedure
7. For work done to ASME codes, when must a Procedure Qualification Test Report (PQR) be submitted with the Welding Procedure Specification (WPS) for approval?
- a) PQR's need not be submitted
 - b) PQR's need not be submitted for prequalified joint welding procedures
 - c) PQR's must be submitted to support the WPS
 - d) PQR's must be submitted and they must be from new tests done for each job
 - e) there is no approval system for ASME work

Functions of the Inspector

8. In what positions is a class V welder permitted to weld under CSA W47.1?
- a) vertical only
 - b) flat, horizontal, and vertical
 - c) all five positions
 - d) flat and horizontal
 - e) vertical and flat
9. What is the normal length of time a CWB welder's qualification remains valid according to CSA W47.1?
- a) for life
 - b) 1 year
 - c) until the welder changes employer
 - d) for the duration of the contract
 - e) 2 years
10. Which of the following statements best describes the use of visual inspection?
- a) visual inspection is often the most effective method and should not be omitted when radiography is called for
 - b) visual inspection should only be used if the material is too thick for radiography
 - c) visual inspection is not required when either radiography or ultrasonics is specified
 - d) if a good visual inspection is carried out, any specified ultrasonic examination can usually be omitted
 - e) visual inspection is not effective and either radiography or ultrasonics should always be specified

**Welding Institute of Canada
Answer Sheet
Module 15**

Complete the "Answer Sheet" and compare your answers with those in the "Test Key." If you score less than 70% we suggest you restudy the material.

Please circle only ONE letter corresponding to the answer you think is most correct.

QUESTION	ANSWER				
1	a	b	c	d	e
2	a	b	c	d	e
3	a	b	c	d	e
4	a	b	c	d	e
5	a	b	c	d	e
6	a	b	c	d	e
7	a	b	c	d	e
8	a	b	c	d	e
9	a	b	c	d	e
10	a	b	c	d	e

The answer sheet below is provided in the event you wish to retest yourself.

QUESTION	ANSWER				
1	a	b	c	d	e
2	a	b	c	d	e
3	a	b	c	d	e
4	a	b	c	d	e
5	a	b	c	d	e
6	a	b	c	d	e
7	a	b	c	d	e
8	a	b	c	d	e
9	a	b	c	d	e
10	a	b	c	d	e

**Welding Institute of Canada
Test Key
Module 15**

Compare your answer sheet to this key.

QUESTION	ANSWER				
1	a	(b)	c	d	e
2	a	b	c	(d)	e
3	a	(b)	c	d	e
4	(a)	b	c	d	e
5	a	b	c	d	(e)
6	a	b	(c)	d	e
7	a	b	(c)	d	e
8	a	(b)	c	d	e
9	a	b	c	d	(e)
10	(a)	b	c	d	e