

Module 14

BASIC CONCEPTS OF QUALITY

**PART OF THE CERTIFICATE PROGRAM IN
WELDING TECHNOLOGY AND INSPECTION**



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MODULE 14

**BASIC CONCEPTS
OF
QUALITY ASSURANCE**

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MODULE 14

BASIC CONCEPTS OF QUALITY ASSURANCE

Introduction

The welding inspector's job can be varied and challenging. Today it is rarely limited to simply examining finished welds but more often comprises a series of defined tasks within the context of an overall quality assurance plan. The welding inspector may represent any one of several parties involved: the fabricator, the purchaser, the regulatory authority, an insurance company, and so forth.

In order to perform effectively, welding inspectors should have a clear understanding of what a quality assurance plan is and how they fit into one. It is the objective of this module to provide an introduction to the basic ideas of quality assurance to help welding inspectors understand their role, the functions, and the skills required.

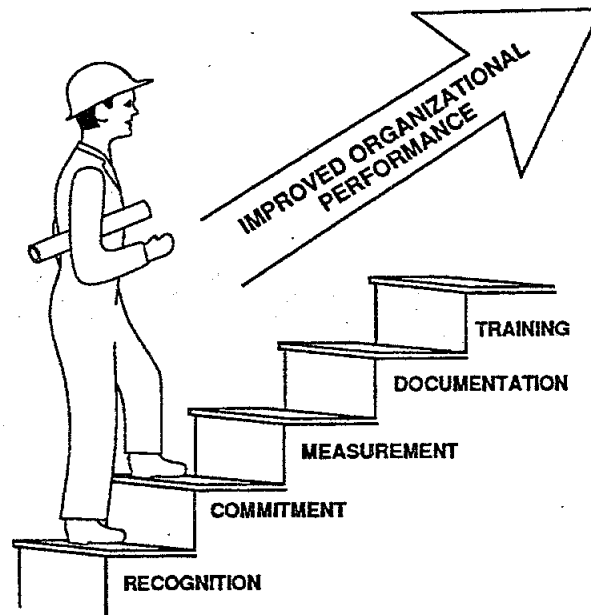
Objectives

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

- Define Quality, Quality Assurance and Quality Control
- Explain why a quality assurance manual is an essential part of a quality program
- List the principal program elements that require control under CSA Z299.1
- Explain the differences between the CSA Z299.1, .2, .3 and .4 programs
- Explain the contribution that inspection makes to the total quality program
- Describe the contents of an inspection and test plan for a product
- List the explicit and implicit responsibilities of the inspector
- List the attributes of a good inspector
- List the qualifications necessary to become a certified welding inspector.

Basic Concepts of Quality Assurance

Figure 1. The stairway to quality. Recognizing the importance of quality is the first step to improving organizational performance.



Background

In any manufacturing, fabrication or production business, the quality of the product or component produced is a key factor in the long term economic success of the business. Increasing awareness of the importance of product quality in every area of technology has resulted from sensitivity to growing pressure of international competition, more discriminating demands from the marketplace, and stricter consumer protection and product liability legislation.

Part of this awareness is that consistent product quality requires much more than product testing. The need to identify and correct inadequacies well before the final product is ready for shipping has become an economic priority in many industries. The purpose of a quality assurance program is not only to identify and correct problems with the product at an early stage, but also to identify the conditions that allowed the problem to occur, and by taking corrective action, to prevent recurrence of the problem. Recognizing the importance of quality in the performance of an organization is only the first step in achieving quality.

Definitions

While inspection of products has been around as long as manufacturing, and quality control since the early days of assembly lines, quality assurance started to develop in the seventies as nuclear power plant construction required more confidence in the product. In the eighties, many other industries adopted the quality assurance concept, while in the nineties the thrust of quality assurance has been broadened to focus on ensuring customer satisfaction.

Let us now define three related, but different, terms:

- quality
- quality assurance
- quality control.

Although almost all standards use these terms to mean generally the same thing, they all use slightly different definitions for these terms. The definitions used by the International Standards Organization in the ISO 9000 series are as follows:

Quality: the totality of features and characteristics of a product or service that bear on its ability to satisfy stated or implied needs;

Quality assurance: all those planned and systematic actions needed to provide adequate confidence that a product or service will satisfy given requirements for quality;

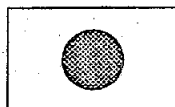
Quality control: the operational techniques that are used to fulfil requirements for quality.

Concept of quality

While the formal definition of quality is precise and meaningful, each of us has a personal impression of quality. For some, quality means well-made, while for others, it means made of an expensive material—a so-called “high quality product”. The perception of what constitutes quality also varies greatly from country to country. Fig. 2 shows a comparison of how consumers define quality in three countries, based on an American Society for Quality Assurance Gallup survey.

In manufacturing and in this module, however, the term quality is not used to express a degree of excellence in a comparative sense, but strictly as conformance to requirements, as stated in the definition. A quality product is one where all features and characteristics meet the customer's requirements. Products or services that do not meet the customer's requirements are *nonconforming*.

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United States	
Quality determined by	Decision to buy a product that will meet needs determined by
1. Well-known name 2. Word of mouth 3. Past experience 4. Performance 5. Durability 6. Workmanship 7. Price 8. Manufacturer's reputation	1. Price 2. Quality 3. Performance 4. Word of mouth 5. Well-known name
Germany	
Quality determined by	Buying decision influenced by
1. Price 2. Well-known name 3. Appearance 4. Durability 5. Past experience 6. Quality itself	1. Price 2. Quality itself 3. Appearance 4. Durability 5. Well-known name 6. Design and style 7. Performance
Japan	
Quality determined by	Buying decision influenced by
1. Well-known name 2. Performance 3. Easy to use 4. Durability 5. Price	1. Performance 2. Price 3. Easy to use 4. Design and style 5. Well-known name

(Quality Progress, American Society for Quality Control, Nov 1991)

Figure 2. How consumers in different countries define quality.

Nonconformance

At this point let us define *nonconformance*. As used in the Z299 series of standards, *nonconformance* means a deficiency in a characteristic, documentation or procedure which renders the quality of a product or service unacceptable or indeterminate or not according to specified requirements.

Fig. 3 gives an example. You take your car to the garage to have one of its bias ply tires replaced, and when you return you find that a radial tire was installed. This is a nonconformance. Although the tire itself is good (better than the agreed to bias ply), when mounted on your car with a bias ply on the other wheel of that axle, it is dangerous, and not what you had ordered. Methods of dispositioning this nonconformity would include replacing the radial with a bias ply tire, or leaving the radial and changing the other tire on that axle to a radial type tire.

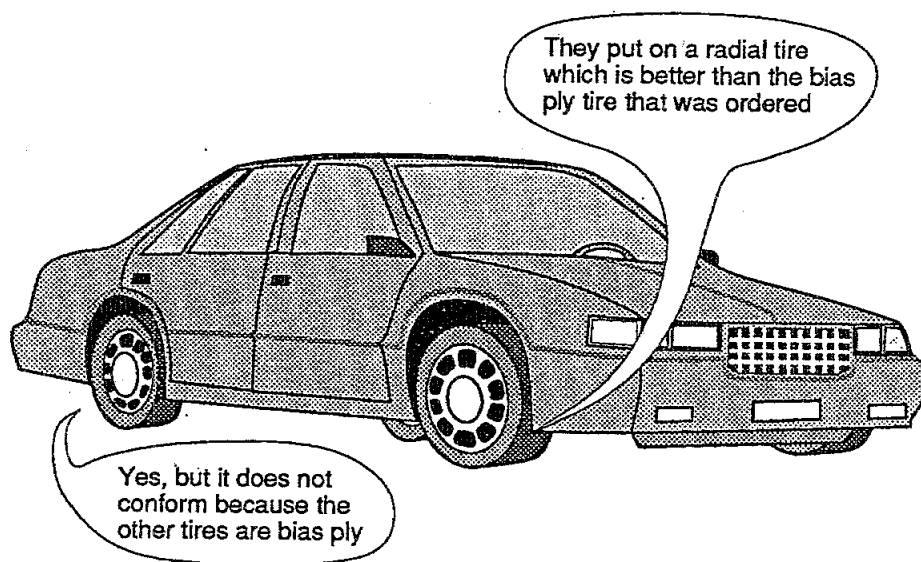


Figure 3. Example to illustrate the concept of conformance.

Quality assurance standards

Various standards describing quality assurance program requirements have been prepared in Canada (see Table 1). The most widely used in Canada is the CSA Z299 series, which describes four levels of assurance. The highest level of assurance is described in CAN3-Z299.1-85, used for complex safety related systems such as nuclear reactors. The lowest level of assurance is described in CAN3-Z299.4-85, a standard frequently used in the manufactured steel products industry for simple structures. The CAN3-Z299.3-85 standard is the minimum level of quality assurance that is appropriate for the fabrication of major steel structures. It also describes the level of quality assurance similar to that required for boilers and pressure vessels, but specific details as defined by CSA B51 and/or ASME are also required.

While each country has its own standards, some American and international standards are used quite extensively in Canada (Table 2). The ISO 9000 series of standards is the common European standard which is being specified more frequently for international trade. While the ISO 9000 standards are generally similar in requirements to the Z299 standards, there are only three levels of quality assurance, compared to the four in the Canadian standard.

Basic Concepts of Quality Assurance

Table 1. Various Canadian quality assurance program standards.

-
- CAN3-Z299.0-86 "Guide for Selecting and Implementing the CAN3-Z299-85 Quality Assurance Program Standards"
 - CAN3-Z299.1-85 to CSA CAN3-Z299.4-85 "Quality Assurance Program - Category 1 to 4"
 - CAN3 - N286.0-82 "Quality Assurance Program Requirements for Nuclear Power Plants"
-

Table 2. Various international quality assurance program standards.

-
- ANSI Standard Z1.8-1971 "Specification of General Requirements for a Quality Program"
 - AQAP-1 "NATO Quality Control System Requirements for Industry"
 - ASME NQA-1-1989 "Quality Assurance Program Requirements for Nuclear Facilities"
 - ISO 9001:1987 "Quality Systems - Model for quality assurance in design/development, production, installation and servicing"
 - ISO 9002:1987 "Quality Systems - Model for quality assurance in production and installation"
 - ISO 9003:1987 "Quality Systems - Model for quality assurance in final inspection and test"
 - The ISO 9000 standards have been adopted by CSA and are issued as the CAN/CSA - Q9000 series.
-

Quality assurance program requirements

Two further terms from the ISO 9000 series are worth defining at this point:

- **Quality surveillance:** the continuing monitoring and verification of the status of procedures, methods, conditions, processes, products and services, and analysis of records in relation to stated references to ensure that specified requirements for quality are being met.
- **Quality audit:** a systematic and independent examination to determine whether quality activities and related results comply with planned arrangements and whether these arrangements are implemented effectively and are suitable to achieve objectives.

The CSA Z299 series of standards groups the requirements for quality assurance programs under three categories:

- Management responsibilities
- Quality Assurance Manual
- Procedures for controlling the program elements.

This section will examine these requirements for the four quality standards of the series. Let us consider the scope of the CSA Z299 series of standards:

Z299.4

This standard requires suppliers to plan and establish a program for *sorting* the good from the bad. The program need not be documented unless specified in the contract.

This standard is suitable for mass produced products or for high volume services designed to commercial technical standards or for simple processes such as custom machining, assembly, and installation.

Z299.3

This standard requires suppliers to plan and establish a program for *verifying* the conformance of products or services throughout the process. The program is documented but in a limited manner.

This standard is suitable for products or services requiring some complex processes. They may be high volume services or mass produced products. Failure in service could result in significant cost or some risk to health and safety, or both.

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Z299.2

This standard aims at *reacting* to nonconforming products or services to prevent their recurrence. This is achieved by specifying feedback control to correct causes of nonconformances.

This standard is suitable for relatively high technology products or services. They tend to require design verification and production planning, and have a significant number of complex processes. Failure in service could result in serious cost or significant risk to health and safety, or both.

Z299.1

This standard aims at *preventing* the occurrence of nonconforming products or services. This is achieved by thorough planning and controls which extend to identifying and correcting weaknesses in the program.

This standard is suitable for custom-designed, high technology products and services. They tend to require many complex processes and extensive design effort by either customers or suppliers, or both. Failure in service could result in extreme cost or undue risk to health and safety, or both.

These are the elements that the Z299 series of standards considers:

- Tender and Contract
- Documentation
- Measuring and Testing Equipment
- Procurement
- Inspection and Test Plan(s)
- Incoming Inspection
- In-Process Inspection
- Final Inspection
- Inspection Status
- Identification and Traceability
- Special Processes
- Packaging and Shipping

Elements of the quality
assurance program

Basic Concepts of Quality Assurance

- Quality Records
- Nonconformance
- Corrective Action
- Customer-Supplied Products and Services
- Statistical Techniques
- Quality Audits.

Whereas only eight of the above elements are required for a Z299.4 program, intermediate programs increase the number of elements required so that each program becomes more extensive, until all eighteen are required in a Z299.1 program. The elements already present also become more comprehensive as one goes towards Z299.1. Fig. 4 based on Table 1 from Z299.0 shows the main features of the standards as one goes from the simplest, Z299.4 at the left to the most stringent, Z299.1, at the right.

			Category 1
		Category 2	PREVENTING
Category 4 SORTING Management responsibilities Planned inspection Calibration Quality records Disposition	Category 3	REACTING	Management review Design planning Process review Internal audit
	VERIFYING Manual Inspection plan Program descriptions Document control Procurement	Design verification Production planning Program procedures Corrective action	
Z299.4	Z299.3	Z299.2	Z299.1

Refer to original for details and notes.

Figure 4. Comparison of the main features of the Z299 series of standards.

THE QUALITY ASSURANCE MANUAL

The most common method of documenting a quality assurance program is in a quality assurance manual (Fig. 5). The quality assurance manual has been adopted by many users and regulatory authorities as a key requirement when accrediting or qualifying manufacturers or suppliers. In the CSA Z299 series of standards, all except Z299.4 require the quality assurance program to be documented in a quality assurance manual.

Areas addressed

The following areas are required to be addressed in a CSA Z299 quality assurance manual:

- (i) Program Application: The manual identifies the organization, facility, and products or services covered by the program, as well as the quality standard that the program is intended to satisfy.
- (ii) Management Policies: The manual states in a formal manner management's policies, objectives and commitment to quality.
- (iii) Organization: The manual contains an organization chart showing the interrelationships of the positions in the organization, and defining the responsibility and authority of key positions.



Figure 5. The usual method of documenting a quality assurance program is in a quality assurance manual.

- (iv) **Manual Review:** The manual states how senior management will review the adequacy of the program, and how the manual will be updated and controlled.
- (v) **Independent Inspection:** The manual states that the inspectors assigned shall be other than those who performed the work, and that they shall not report to the immediate supervisor responsible for producing the work.
- (vi) **Programs Descriptions or Procedures:** The manual contains descriptions (in the case of CSA Z299.3) or procedures (in the case of CSA Z299.1 or .2) for planning and controlling the applicable program elements. Procedures document, for each applicable element, such things as its purpose and scope; who is responsible for what; how, when and where all steps are performed; what materials, equipment and documentation shall be used; and how it is all controlled. Descriptions document such things as its purpose and scope; who is responsible for what; and an outline of what shall be done.
- (vii) **Exhibits:** Samples of the forms to be used.

Sample quality assurance manual

In the following few pages we will go through the structure and contents of a typical quality assurance manual for a steel fabricator. This will enable you to obtain a good understanding of the type of information contained in a quality assurance manual. The Quality Assurance program chosen is one that meets the requirements of CSA Z299.1, so that we can briefly look at all the program elements that the Z299 series of standards considers.

Section # 1 — Assignment Sheet

The first sheet of a manual identifies the company and the company location or plant that it applies to, and assigns the manual to an individual within the company, or to a client. The revision of the manual is clearly shown, and the sheet is signed by the quality assurance manager.

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Section # 2 — Revision Record Sheet

This is a sheet that records any revisions to any section of the manual, and is signed by the Quality Assurance Manager. Fig. 6 shows a typical revision sheet.

REVISION RECORD SHEET						
Revision #	Section or Procedure	Revision on Page #	Date of Revision	Description of the Revision	Revision made by	Approval of the revision
0	All	All	1991-7-1	Original Issue	Name	Signature

Figure 6. Part of a typical revision sheet.

Section # 3 — Table of Contents

A typical table of contents for a steel fabricator's quality assurance program might look as shown in Fig. 7.

Section # 4 — Statement of Policy

The policy of the company with regard to quality is described in this section. This statement documents the responsibility of all company staff to comply with the requirements of the manual. This section is also the place where the highest authority in the company appoints the Quality Assurance Manager, and outlines his or her authority in quality matters. A typical statement of policy and authority for a manufacturing plant is shown in Fig. 8.

Section # 5 — Statement of Certification

Fig. 9 shows what the statement of certification might look like.

TABLE OF CONTENTS

Section # 1	Assignment Sheet
Section # 2	Revision Record Sheet
Section # 3	Table of Contents
Section # 4	Statement of Policy
Section # 5	Statement of Certification
Section # 6	Organization
Section # 7	Control of the Quality Assurance Manual

Procedure # 1	Contract Review and Design Control
Procedure # 2	Document Control
Procedure # 3	Measuring and Test Equipment
Procedure # 4	Procurement and Vendor Control
Procedure # 5	Customer Supplied Material
Procedure # 6	Planning
Procedure # 7	Receiving Inspection
Procedure # 8	Inprocess Inspection and Status
Procedure # 9	Final Inspection
Procedure # 10	Identification and Traceability
Procedure # 11	Material Handling and Cleanliness
Procedure # 12	Production
Procedure # 13	Special Processes
Procedure # 14	Welding
Procedure # 15	Nondestructive Examination
Procedure # 16	Preservation, Packaging and Shipping
Procedure # 17	Quality Records
Procedure # 18	Nonconforming Material Control
Procedure # 19	Corrective Action
Procedure # 20	Quality Audits
Appendix	Index of Exhibits
Exhibits	Samples of forms in use

Figure 7. Typical table of contents from a fabricator's quality assurance manual.

STATEMENT OF POLICY

It is the policy of ABC Company to fabricate to a high standard of workmanship and to furnish equipment, components and services that meet all customer specification requirements, as well as all requirements of any authorities having jurisdiction.

This manual, covering the company's Quality Assurance Program, describes the policies and procedures in effect at ABC Company, 123 Main Street, Smalltown, Canada, to ensure that the above is accomplished. For all customer orders, all employees of ABC Company are committed to adhere to all the requirements of the procedures in this manual.

The Quality Assurance Program as described in this manual has management's unqualified support. The Quality Assurance Manager is authorized to implement and maintain the program, to identify quality problems, and to initiate, recommend and implement solutions. The Quality Assurance Manager also shall be the final authority on quality related matters.

Mr. John Doe,
President, ABC Company
February 22, 1991

Figure 8. Typical statement of policy.

STATEMENT OF CERTIFICATION

We hereby certify that the Quality Assurance Program as documented in this manual accurately describes the policies, objectives and procedures in use at ABC Company to meet the requirements of:

- a) National Standard of Canada CAN3-Z299.1-85 Quality Assurance Program—Category 1.
- b) ISO Standard 9002-1987 Model for Quality Assurance in Production and Installation.

S. Smith
Quality Assurance Manager,
ABC Company,
February 22, 1991.

Figure 9. Example of a typical statement of certification.

Section # 6 — Organization

The purpose of the organization chart is to show the interrelationships of the positions in the organization, and define the responsibility and authority of key positions. The organization chart shows that the senior person responsible for the quality program has the support of the company's management.

In addition to the normal direct reporting relationship, individuals may be functionally responsible to another position (also known as administrative and technical reporting relationships). This is often shown on organization charts by a dotted line.

The type and complexity of the organization will be dictated by the size of the company and the type of product fabricated. While the organization chart must contain all positions referred to in the manual, not all the positions in the company need to be shown.

A sample organization chart is shown in Fig. 10 to illustrate the organization of a typical welded steel component fabricator.

Basic Concepts of Quality Assurance

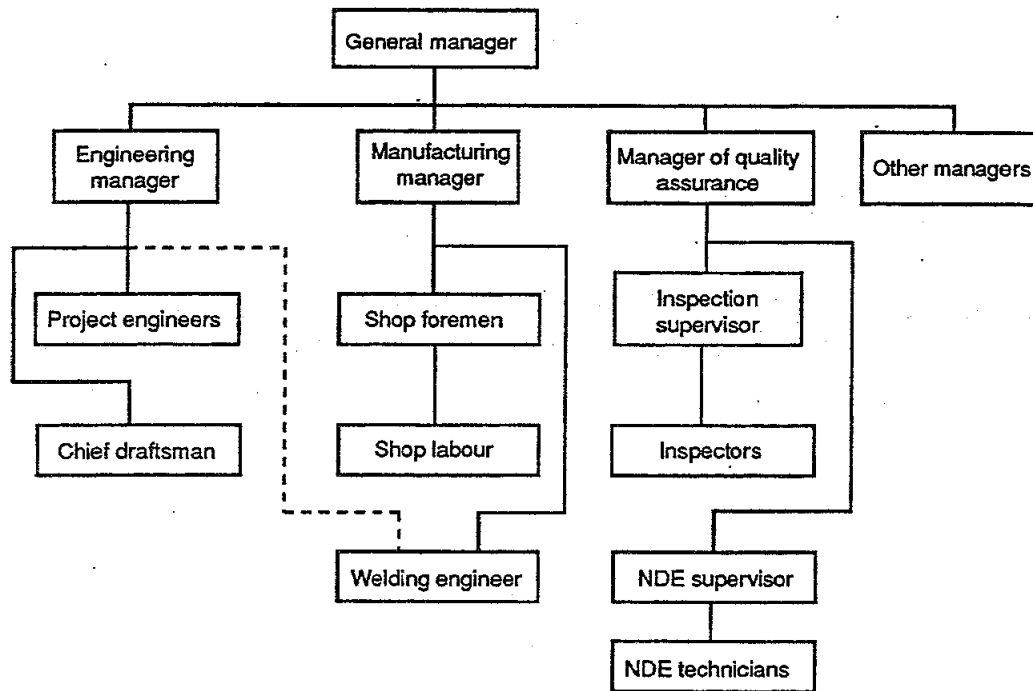


Figure 10. Typical organization chart for a fabricating company. Note the reporting relationship for inspectors which is independent of the shop.

Section # 7 — Control of Quality Assurance Program Manual

This section states the methods for controlling the quality assurance manual. A typical example is shown in Fig. 11.

Procedure # 1 — Contract Review and Design Control

This procedure defines how bids are reviewed to ensure that the company would be able to comply with tender requirements in the event of a contract. Contracts are to be reviewed prior to acceptance to ensure that any differences from the tender are detected and resolved.

The design shall be defined, controlled and verified. Design inputs shall be correctly translated into design documents, with design interfaces identified and controlled. Design adequacy shall be verified by persons other than those who designed the item. Changes to the design shall be controlled in the same manner as the original design.

CONTROL OF THE PROGRAM MANUAL

- 1 The Quality Assurance Manager shall control the distribution of this manual. Every copy issued shall be given a unique serial number on the assignment sheet. The Quality Assurance Manager shall maintain a record of the distribution.
- 2 The Quality Assurance Manager shall retain the master copy of the manual in his or her possession. Within the Company, the Quality Assurance Manager shall issue a copy to all supervisory staff engaged in Construction, Engineering, Manufacturing, Project Management, Procurement, Quality Assurance and Sales.
- 3 When a revision is made to a procedure or section of the manual, the front sheet of that procedure or section shall show the revision number, *and the revised text shall be in italics and shall have a revision mark in the left margin, as shown here.* The revision shall be approved on the front sheet of the procedure or section by the Quality Assurance Manager. A record of the revision shall be made in Section #2, 'Revision Record Sheet' of the manual, which shall be approved by the Quality Assurance Manager.
- 4 The manual for the Quality Assurance Program shall be reviewed annually to affirm its adequacy and general effectiveness in controlling quality. When, either during the annual review or as a result of the internal audits (see Procedure # 20, Quality Audits) areas are found not to be achieving adequate control, the Quality Assurance Manager shall arrange to have the program modified to ensure adequate control. Revisions shall be prepared as necessary, submitted for the required approvals, and issued when approved.
- 5 The Quality Assurance Manager shall report to senior management on the status of the quality program on an annual basis. This allows senior management to review the status and adequacy of the quality assurance program, and to determine its continuing suitability and effectiveness.
- 6 Revisions to the manual shall be sent to all holders of controlled copies of the manual with a transmittal form, which each recipient shall be required to sign and return to acknowledge receipt of the revision.

Figure 11. Typical requirements for the control of a quality assurance manual.

Procedure # 2 — Document Control

This procedure clearly defines the responsibility for preparing, reviewing, approving and distributing all contract documentation affecting quality. A method of distribution of documentation to ensure that only the latest revision of approved documents is used in manufacturing and assembly is also described.

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Procedure # 3 — Measuring and Test Equipment

This procedure describes the program for the calibration of measuring and test equipment required to ensure the validity of any measurements made. All equipment is marked with the date that the next calibration is due, and any equipment that is not recalibrated or is damaged is segregated in a 'Quarantine area.'

Procedure # 4 — Procurement and Vendor Control

In this procedure, a system is defined to control procurement to ensure that requisitioning documents include all of the elements required to describe the quality of the item to be purchased, and to ensure that these requirements are transferred to the Purchase Order. Procurement activities are organized around a strategy of prequalification by auditing of vendors based on the vendor's quality program.

Procedure # 5 — Customer Supplied Material

This procedure describes the methods used to ensure that customer supplied material is controlled to the same extent as material purchased by the company.

Procedure # 6 — Planning

This procedure describes the use of the 'Manufacturing Procedure and Inspection and Test Plan,' the document that is used to plan the production, examination, inspection, nondestructive examination and test activities. The signing off of activities by production, inspection and nondestructive examination personnel produces objective evidence that the required activities were successfully completed.

Procedure # 7 — Receiving Inspection

This procedure describes the methods for verifying and controlling purchased or customer supplied material or items. The system whereby items are quarantined until inspected and released by inspection is also described.

Procedure # 8 — Inprocess Inspection and Status

This procedure describes the methods for controlling and verifying product conformance to requirements, and the system for indicating the inspection status of material, items or components by the use of tags. All

inspection is carried out to inspection instructions prepared to suit the nature of the product.

Procedure # 9 — Final Inspection

The methods used to control the testing and final inspection of the product are described in this procedure. Following final inspection, the method of releasing the product for shipment is also outlined.

Procedure # 10 — Identification and Traceability

This procedure describes how material, whether purchased or customer supplied, is only released after the test report has been verified and accepted, and the identification on the material has been checked and matches the test report. Where traceability is specified, the methods of keeping a record of the location of each piece of material in the finished product is described.

Procedure # 11 — Material Handling and Cleanliness

This procedure describes the methods used in the handling and control of material, items and components without damage or loss of identity and the control of cleanliness. It describes the special care that is to be taken to avoid the contamination of materials.

Procedure # 12 — Production

This procedure describes the methods used in the planning and control of manufacturing and assembly, so that the work is performed to meet specified requirements. It also describes the responsibilities and procedures involved in the preparation of company Quality Standards for use in production. These standards would contain data used for production, standard tolerances and other process procedures that are in use. Specific requirements on the contract drawings and documentation take precedence over the values in the quality standards.

Procedure # 13 — Special Processes

This procedure covers special processes (processes where conformance is established by evidence generated during the process) used in the production of company products, other than welding and nondestructive examination. One such process would be heat treatment.

Procedure # 14 — Welding

This procedure establishes methods to ensure that all welding is done to approved procedures using qualified welders. It goes on to stress that the most important control on welding is the inprocess checks to ensure that the parameters used actually fall within the range of the approved procedure. The methods used to control records of qualified welders, and welder qualification or requalification are all described.

Procedure # 15 — Nondestructive Examination

This procedure describes the training of Nondestructive Examination Technicians, their qualifications to CGSB or SNT-TC-1A standards, and the performance of nondestructive examination to verify the freedom from undesirable defects in welds. Preparation of nondestructive examination procedures, their approval and revision is also described.

Procedure # 16 — Preservation, Packaging and Shipping

This procedure describes the methods used for controlling the blasting, cleaning, painting or preservation operations carried out on the product. It stresses that only products that have been released for shipment by Inspection are to be shipped, and explains the way this is to be carried out.

Procedure # 17 — Quality Records

This procedure describes the methods used for generating and maintaining the quality related documentation that is required by this manual, the contract and the applicable codes. It requires the completed quality records to be forwarded to the central contract file. From these records, the "As Built" dossier or other customer required documentation package is compiled.

Procedure # 18 — Nonconforming Material Control

In this procedure a system is described to document nonconformances, and to tag the affected material to ensure it is not processed further.

Two terms need definition here: rework and repair. 'Rework' means processing a nonconforming item so that it meets the specified requirements by repeating methods or operations already in the 'Manufacturing Procedure and Inspection and Test Plan.' 'Repair'

means processing a nonconforming item by using methods that may or may not have been part of the original 'Manufacturing Procedure and Inspection and Test Plan.' Repairs do not make an item conform to the original requirements, but make it suitable for the intended purpose. As an example, if a shaft is machined too long, it can be reworked by taking an additional cut to make it to length. However, if a shaft is machined too short, it cannot be reworked, but must be repaired. Possible repairs could include replacing the material and machining a new piece, weld overlaying the end and remachining, or perhaps machining a hole in the end of the shaft and shrinking in a piece. All these repairs would require engineering instructions and revisions to the 'Manufacturing Procedure and Inspection and Test Plan' to be issued.

The engineer is the person who disposes nonconformities. When the instructions for rework or repair have been issued, the inspector verifies that the rectification has been carried out, and signs off the nonconformity report.

Procedure # 19 — Corrective Action

The procedure describes methods for implementing measures to prevent recurrence to avoid repetition of the nonconformity, as well as steps such as auditing the effectiveness of the program to try to prevent nonconformities from occurring.

Procedure # 20 — Quality Audits

This procedure describes how internal quality audits are to be carried out within the company at regular intervals to ensure that the program is implemented and is adequate to ensure that customer requirements are being met. The makeup of the audit teams, the auditor's qualifications and the planning of audits is all described in this procedure. How external audits are carried out on vendors is described in the procurement procedure.

Appendix — Index of Exhibits

Exhibits — Samples of Forms in Use

Included in this section of a manual are copies of the forms, tags, tickets, and stamps used in the control of the product. As forms are very dependant on the individual company we will not include any sample forms in this module.

WELDED STRUCTURES

Components, vehicles, vessels, and structures are fabricated using a variety of welding procedures and methods. Welding operations are a major part of manufacturing and thus welding needs to be given special attention within the quality assurance program. In addition, a large proportion of welding in the field and in the shop is carried out using manual or semiautomatic processes, where the operator's skill and consistent attention to detail are especially important variables that need to be monitored.

For successful operation, weldments should be:

- adequately designed to meet the intended service for the required life
- fabricated with specified materials and in accordance with the design requirements
- operated and maintained properly.

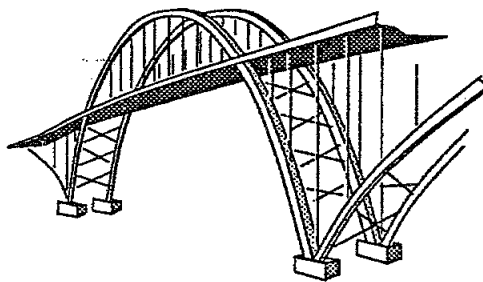
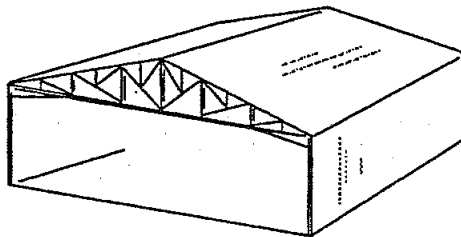


Figure 12. Companies fabricating steel structures such as bridges and buildings are required to be certified to CSA W47.1-1983.



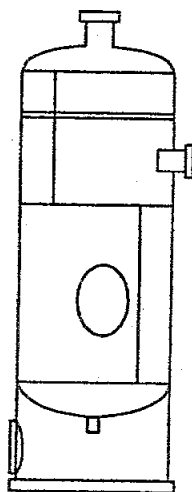


Figure 13. Provincial laws covering pressure vessels require them to be built to the provincial Boiler and Pressure Vessel Act which, in turn, references CSA and ASME codes.

Standards for companies using welding

In Canada, welded structural steel construction has been controlled for years through conformance to CSA Standard W47.1 "Certification of Companies for Fusion Welding of Steel Structures" and the system that the fabricator has to have in place to meet this standard (Fig. 12). A sister standard —W47.2—covers aluminum.

Similarly, boilers and pressure vessels (Fig. 13) have been required by the provincial "Boiler and Pressure Vessel Act" of each province to meet the requirements of CSA Standard B51 which, in turn, specifies applicable sections of the American Society of Mechanical Engineers "Boiler and Pressure Vessel Code", including the quality control system described in each section of that code.

The requirements of W47.1 or W47.2 or ASME Sect VIII Div 1 are specific to the type of product involved, and are the minimum that are considered acceptable. While each of these contributes to quality of production of the product in question, neither contains all the elements that are required in a formal quality assurance program. Such elements, as previously discussed, may include corrective action and quality audits.

Special requirements

Traditionally weld quality has been judged on physical features normally examined by inspectors, with surface and internal examination for most applications using a suitable nondestructive examination method. For surface examination, magnetic particle examination is typically used on magnetic materials, while dye penetrant examination is used on nonmagnetic materials. For internal (volumetric) examination,

radiographic examination or ultrasonic examination are the common choices. More details on these methods are given in modules 17 to 19.

For particularly critical service, such as might be encountered in an environment containing hydrogen sulphide, it is usual practice to sample the mechanical properties of the weld metal and/or heat affected zone using hardness tests. Certain other service conditions place limitations on the chemistry of the weld deposit, (maximum carbon, maximum silicon{for digesters}, or maximum iron in nonferrous material), requiring chemical checks to be carried out.

Engineering documentation

Prior to the advent of the engineering drawing the designer and builder were often one and the same person. Hence the transfer of technical information from idea to reality was relatively simple. As engineering became more complex and construction methods more complicated, design and construction became separate functions performed by different people or groups of people. Hence the engineering drawing became the method for expressing and transferring technical information. Although today the use of CNC technology can eliminate the need for drawings for some fabrication operations, the shop drawing still remains a necessary source of information for the inspector. In addition, because of the rigorous requirements of many industries, further documents are required to contain the total technical data. Fig. 14 describes how design information is changed into a form that can be applied on the shop floor. The inspector should understand how this process occurs, what the documents are, and how to verify that they are suitable for fabrication. Let us have a look at this in detail.

Design information

The design information will usually be contained within three documents:

- Design drawing
- Codes and standards
- Technical specification.

Design Drawing

In some industries the design drawing may be used for fabrication but generally it will not contain all the information necessary for the shop to execute the work. Hence changes are usually made and/or additional drawings are developed.

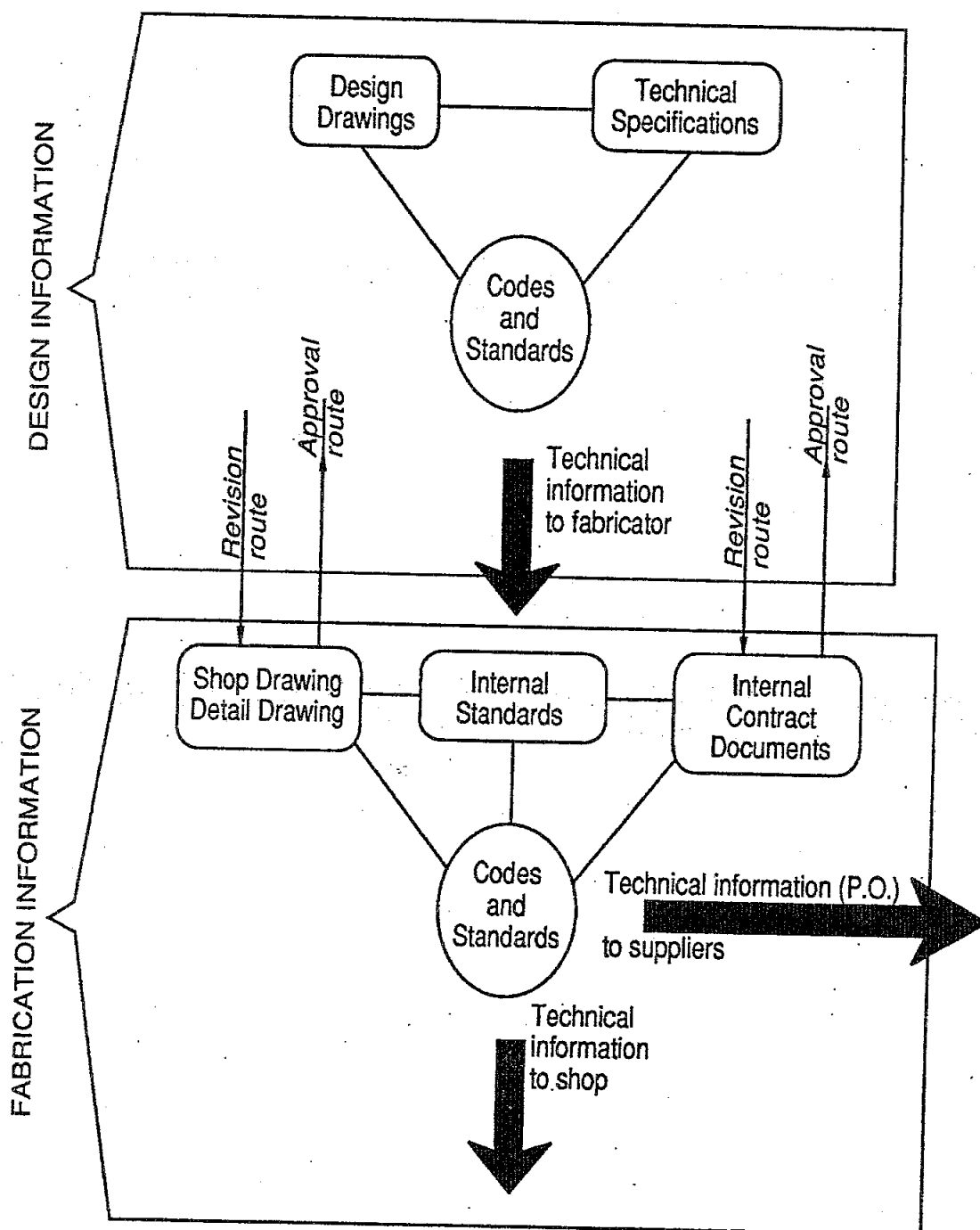


Figure 14. The flow of information between the designer and the fabricator.

Codes and Standards

As one would expect these are probably the only technical documents that are the same for both design and fabrication. The inspector should verify, however, that the shop is working to the latest revision or the revision specified. Module 13 covers most of the standards commonly used.

Technical Specification

The technical specification covers all the information that is *not* practical to include with the design drawings. For less demanding fabrication they may not be required, that is, the design drawing and codes would suffice. However, many designers and owners include a technical specification relevant to their particular requirements that would detail additional information such as:

- Material requirements
- Welding procedure requirement
- Welding consumable requirement
- Fabrication requirement
- Fabrication tolerances
- Coating requirements.

Inspectors employed by the fabricator performing the work would generally not be required to have access to design information. However, an inspector employed by an inspection organization acting as a third party inspector would use these documents as a reference.

Shop and Detail Drawing

As previously discussed the shop may not be able to work to design drawings. Hence shop drawings and detail drawings are developed to provide all necessary information in a format the shop is used to and comfortable with. The inspector should check that the shop is working to approved drawings, where required, and that both the inspector and the shop have the latest revision.

The fabrication information usually consists of

- Shop drawings and detail drawings
- Internal contract documents
- Codes and standards
- Internal standards.

**Fabrication
Information**

This is the information that the inspector works to for all inspection activities. The inspector must have access to all of these documents in order to perform the inspection function properly.

Internal Contract Documents

The fabricator may need to develop contract documents to cover many of the requirements of the technical specification. This could include the following:

- Welding procedures
- Manufacturing procedures
- Painting specification
- Inspection and test plan.

Again the inspector should check that these documents have been approved by the designer when required by the contract to do so and that the latest revision is being used. The Inspection and Test Plan or Manufacturing Procedure and Inspection Plan will, of course, detail many of the activities required of the inspector. Intimate knowledge of the other contract documents will also be required by the inspector in order to perform the inspection function satisfactorily.

Internal Standards

Internal standards are often used where detailed data or information is applied to many contracts. That is, rather than repeat the requirement in each contract document the company decides to make it a standard that can be called up. Internal standards may take the form of physical sample pieces (e.g., surface finish similar to sample SF1) or written data. Internal standards might pertain to:

- Welding consumable control on the shop floor
- Weld profile and surface finish
- Welding procedures for standard work not requiring approval by the designer.

Another use of internal standards is the translating of code requirements for use by production personnel. Some codes are not very user friendly, and internal documents can often do a better job of specifying and summarizing those requirements that apply to the product.

QUALITY CONTROL

Inspection, measuring, examining, testing, or gauging of one or more of the characteristics of a product or service is, along with nondestructive examination, the essence of quality control. Quality control, as we had seen earlier, comprises the operational techniques to verify compliance with requirements.

Definitions

Inspection may be defined (Burgess—refer to the section on additional resources) as the process of measuring, examining, testing, gauging, or otherwise comparing the unit with applicable requirements. An alternative definition (Davis, Troxell, Hauck) is the observation of the processes and products of manufacture or construction for the purpose of ensuring the presence of desired qualities. Welding Inspection is the monitoring and critical examination of welding prior to, during, and following completion of the weld.

Testing may be defined as the physical performance of operations (tests) to determine quantitative measures of certain properties. The term is also used as performance testing such as hydrostatically testing a vessel, or mechanically commissioning a machine.

Sampling inspection means the evaluation of a lot of product from the careful examination of a small number of units of product (the sample) drawn from that lot.

Nondestructive examination means methods of examination used to detect and locate relevant and nonrelevant indications in components and materials without incurring damage.

Applications

The extent of inspection may be a function of the design or service conditions of the component. This is reflected in the four categories of CSA Z299, where as the item gets more critical a more comprehensive category is required. The higher categories require more effort and cost more than the lower categories.

Nondestructive examination is used to evaluate materials and welds, generally to confirm absence of injurious defects. This includes surface defects too small to be seen by eye, or defects on a rough surface where surface features hide the defect, and subsurface defects.

Tests are used to evaluate such things as chemical or mechanical properties, usually related to specific service conditions.

Sampling inspection can evaluate whether each item in a selected sample meets a given criterion. In general, the greater the sample size, the greater the reliability that the sample is a true indicator of the entire batch. However, the makeup of the batch (number of operators, number of machines, different shifts) all affect whether a sample is representative of the whole batch. It is an economic decision whether the reliability of the sampling inspection is adequate, against the increasing cost of inspection as the sample size approaches 100%. For some applications, the need to have 100% freedom from defects and the costs associated with this higher level of reliability must be carefully considered.

Sampling inspection in welding usually applies to NDE such as radiography or ultrasonic inspection. Such inspection is termed spot or partial inspection. With appropriate sample selection even a relatively small sample size can have a significant effect on quality assurance. In the example* below, the process piping systems of different refineries were originally subjected to various levels of spot radiography and then re-evaluated later at 100% inspection for upgrading purposes. These were the results obtained:

*Ebert, H.W. "Repair
Welding of Refinery and
Chemical Plant Piping
Systems," *Welding Journal*,
February 1984.

Original RT %	Repair after 100 % inspection
100 %	0 %
5 %	10 %
0 %	70 %

The results demonstrate clearly the value of well planned and properly executed sampling inspection.

No amount of inspection can make a discrepant product nondiscrepant, so the main focus of production must be to 'DO IT RIGHT THE FIRST TIME.' Early detection of errors is vital, particularly for those that can be considered 'systematic' errors. For example, if the wrong electrode were ordered and issued to the shop, the error would be repeated in every weld. This clearly has more serious implications than, say, an error in the fit-up of one joint that affects only one weld which is a random error.

Every production worker has the responsibility to inspect the work being produced, to rework any items that are not complete, and to only offer conforming material for official inspection. In case of material believed by the production worker to be nonconforming, the inspector

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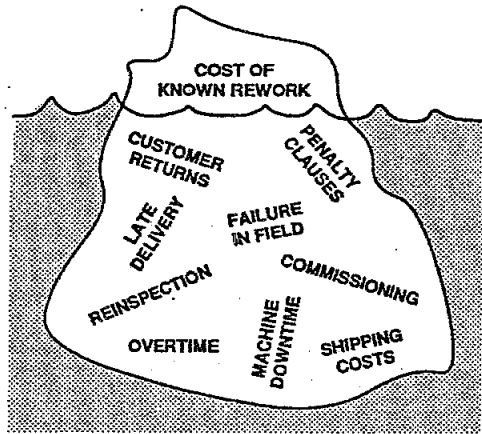


Figure 15. The "tip of the iceberg". The cost of known rework may only be a fraction of the total cost of quality problems.

will be requested to verify the worker's measurement and if the piece is nonconforming and cannot be reworked, the inspector will document the nonconformance. The engineer will disposition the nonconforming material.

The inspector's specific duties will vary from plant to plant, from contract to contract, and from product to product. Shop Inspection is usually carried out on an ongoing basis by the manufacturer's own staff. Third-Party Inspection is the responsibility of the purchaser's Quality Assurance Representative, who may be an employee of the purchaser or a consultant or may be a classification society such as Lloyds, ABS or Veritas.

Fig. 15 shows how the known rework costs are only the 'tip of the iceberg' in that the nonconformances that are not detected can cost many times as much.

Weld monitoring

A quality assurance system for welded structures may incorporate the concept of weld monitoring. This involves measuring and recording details of each weld including the welding procedure parameters, the identity of the welder, conditions of fit-up and so forth. This creates a permanent record allowing an inspector to verify compliance with the welding procedure at any time after the weld was made. Some standards specifically require a weld monitoring program to be instigated. An example is the Steel Fixed Offshore Structures supplement to CSA W59-M1989.

One of the functions of a quality control system may be to document the work performed in a manner which allows the client to identify for each welded joint the procedure, welder, inspection results, and heat treatment records. This is often accomplished using a "weld map" which becomes part of the equipment/job record.

The Inspector's role

The inspector's role is documented in the Quality Assurance Manual which also spells out the inspector's authority to stop work if necessary. There might be several inspectors in a shop or on a construction site. While most have similar responsibilities and perhaps even the same terms of reference or qualifications, their roles differ according to their respective reporting relationships.

Welding inspectors concentrate on all welding and the operations which lead up to the welding. Their concern includes the welding operation and the completed weld, including the freedom from visual defects, the weld size and documentation of the weld. In some organizations the Nondestructive Examination Technician is also the welding inspector.

Shop inspectors, on the other hand, would be responsible for inspection of other operations such as machining, and for inspection of the finished product. They may overlap with the welding inspector on the inspection of welds, and the assignment of duties may vary with changing manpower availability.

Third-party inspectors (outside inspectors or Customer's Quality Assurance Representatives) may represent the purchaser but could also provide legislated inspection such as is used in boiler and pressure vessel acts. Their role is to ensure that the product conforms to the customer's specifications. They are interested only in the operations which are involved in production of the contract they were retained to inspect, and they may repeat some of the inspections of the welding inspector or the shop inspector. There is a tendency nowadays for customers to shift from inspection to surveillance. This means that the Customer's Quality Assurance Representative will verify the suppliers records, but witness only those critical measurements where a witness or hold point had been included in the supplier's 'Manufacturing Procedure and Inspection Plan.'

The Manufacturing Procedure and Inspection Plan

Quality in welded structures is achieved by thorough planning: using a documented sequence of operations which may be called the Manufacturing Procedure and Inspection Plan, the Inspection and Test Plan, the route sheets, the quality assurance sheets, or some similar name. We will use the term Manufacturing Procedure and Inspection Plan. One important objective of the Manufacturing Procedure and Inspection Plan is to indicate the extent and timing of inspection or nondestructive examination operations relative to the manufacturing

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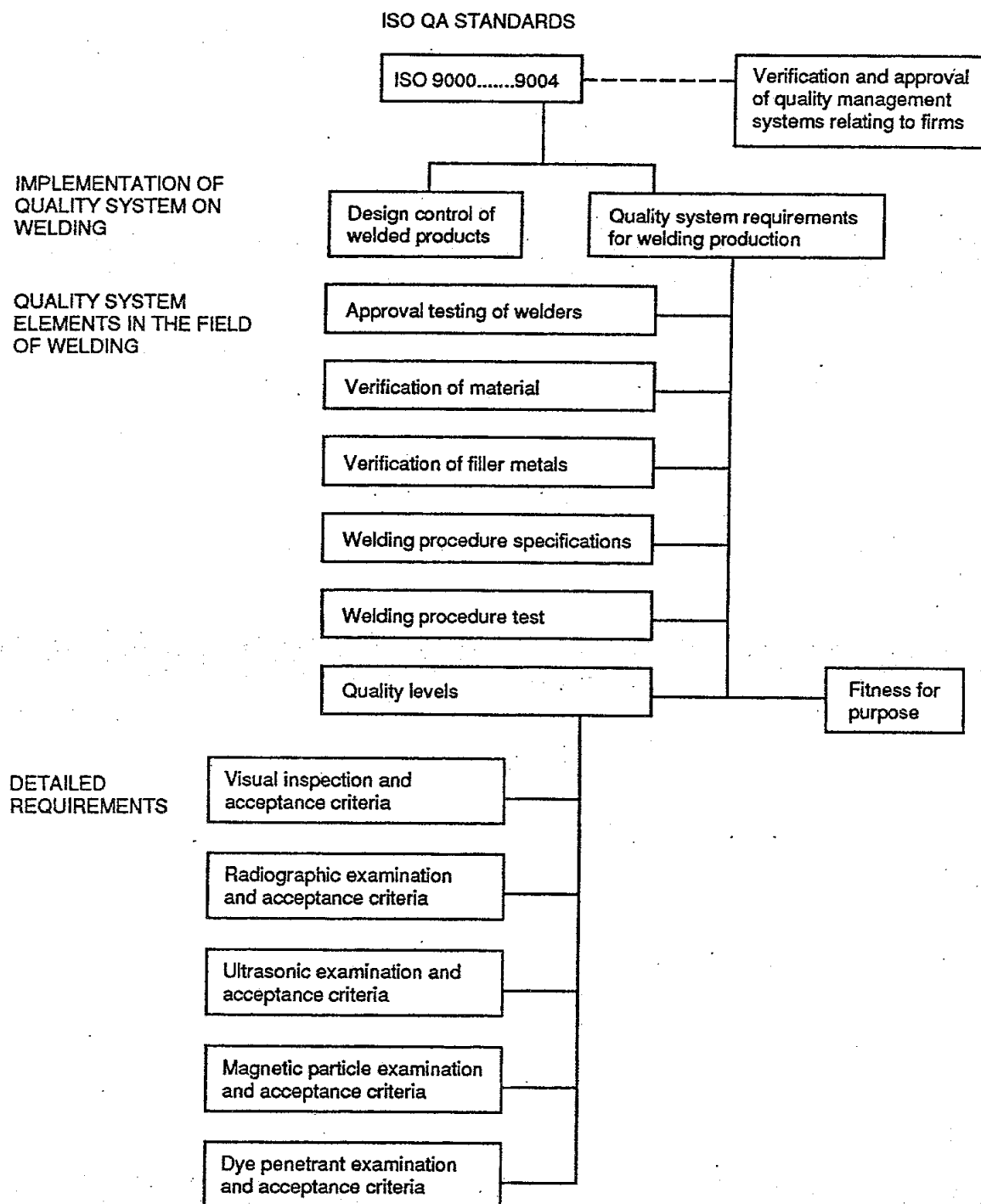


Figure 16. Quality factors to be considered in welding technology.

operations. It is important to ensure that production does not proceed before inspection is complete, as many operations cannot be performed later.

While there is no standard Manufacturing Procedure and Inspection Plan, most are designed to provide not only the sequence of operations for the guidance of production and inspection personnel but also to serve as documentary evidence that the various operations have been performed, by signing off each operation. Fig. 16 shows examples of factors which must be considered in establishing a Manufacturing Procedure and Inspection Plan for welded products.

Prior to utilization of the Manufacturing Procedure and Inspection Plan the inspector must start with action items that should occur long before welding begins. These should begin with a thorough review of the applicable engineering documents issued for the contract. Because inspection verifies conformance to requirements, it is important that the inspector is familiar with the requirements for each contract. Inspection of incoming materials is usually a part of the plan. Materials would be inspected for condition, and also for identification markings. The related documentation such as material test reports or certificates of compliance are checked against the specifications.

Observation of fit-up, weld preparation and cleaning are critical prior to the welding operation and these items should be included in the Manufacturing Procedure and Inspection Plan. Verification of qualifications of welding personnel should also be included. The inspector has a responsibility to verify that only appropriately qualified people are working on the job.

When weld monitoring is required by the contract the actual welding operation must be observed to ensure that the welding parameters comply with the ranges on the procedure and to ensure that the welder is familiar with the procedure. Most products will require examination after welding and before painting. The Manufacturing Procedure and Inspection Plan would detail the extent and timing of these operations.

For the production worker, the Manufacturing Procedure and Inspection Plan indicates the points beyond which production cannot proceed without having the inspector present. For example, in Fig. 17 the inspector is required to check the burned edges of the plate before welding commences.

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DESCRIPTION : Rolod Shell			DATE 1992-2-22		REVISION # : 0	
PIECE MARK : AA			APPROVAL & DATE ENGINEERING:		Q.A. :	
Operation No	Depart.	C.C.	OPERATION	Customer	Author. Inspect.	Signed Date
1	QC	Receiving Inspector	Check material test certificates against the purchase order and CSA standards and stamp "Accepted"			
2	shop	Material Foreman	Deliver material on Material Bills 1 & 2 of Contract 1234 to preparation area.			
3	shop	Burner	Transfer identification and cut plates per drawing # 1	Witness Point		
4	QC	Inspector	Verify material identification and check cut edges of plates for defects, in accordance with the Standard Inspection Instruction	Witness point		
5	shop	Forming shop	Set the ends of the shell plates on press P1, and then form on rolls R7 to the drawing radius.			
6	shop	Burner	Trim excess length at plate ends, and burn weld preparation as shown on drawing # 2			
7	QC	Welding Inspector	Verify weld preparations to the Standard Inspection Instruction and Drawing # 2			
8	shop	Forming shop	Place can on rolls R7 and press ends together. Tack weld ends while in the rolls using CWB qualified welder			
9	QC	Inspector	Verify roundness, diameter and alignment at the weld per Welding Procedure # WP1234 and drawing # 2	Witness point		
10	shop	Welder	Manual weld root pass of longitudinal seam on shell, in accordance with Welding Procedure # WP1234			
11	QC	Welding Inspector	Inprocess inspection of welding; verify appearance of finished root pass.			
12	shop	Welder	Complete welding of longitudinal seam by Submerged arc using machine SA22; Grind starts and stops, and any areas not meeting the surface finish standard; drawing # 2 and Welding Procedure # WP1234			
13	QC	NDE Technician	Examine weld for size, surface finish and reinforcement. Radiograph full length of weld per NDE Procedure RAD1	Hold when radiographed		
14	QC	Inspector	Release for shipment to HEAT TREATERS INCORPORATED			
15	shop	Shipping	Ship to HEAT TREATERS INCORPORATED per subcontract # 1001			
16		HEAT TREATERS INC.	Heat treatment per the requirements of drawing # 4			
17	QC	Inspector	Verify heat treatment chart at HEAT TREATERS INCORPORATED, and verify roundness at ends in accordance with Drawing # 2			
ABC Co Inspection			All operations completed and accepted	Authorized Inspector	Customer	

Figure 17. Manufacturing Procedure and Inspection Plan using a written sequence format.

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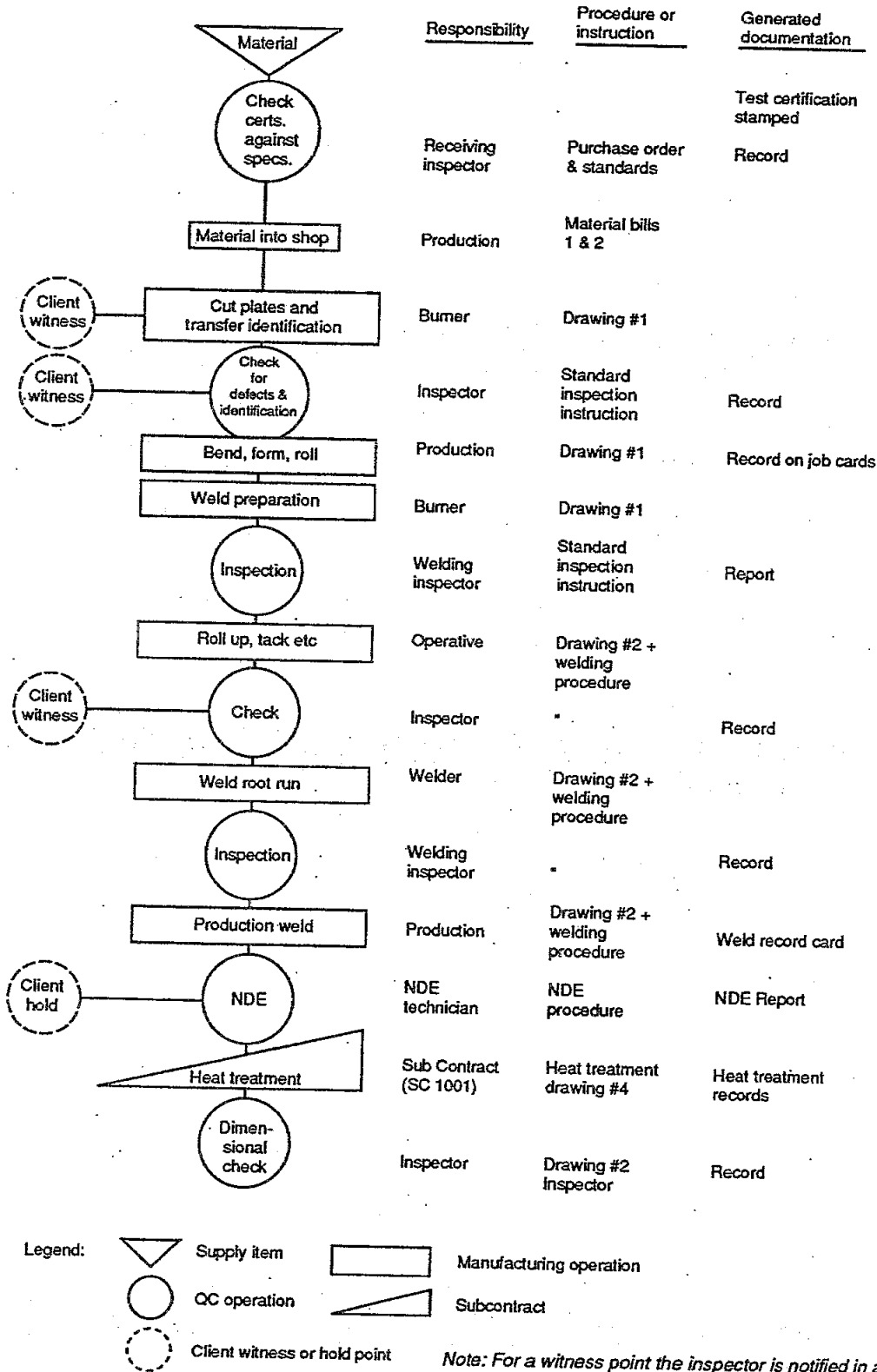


Figure 18. Manufacturing Procedure and Inspection Plan using a flow chart format.

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The Manufacturing Procedure and Inspection Plan will tell the inspector the level of inspection required. For example, whether the inspector is required to witness an operation or simply verify that the operation has been done and documented. A variety of styles of Manufacturing Procedure and Inspection Plans are used. We give two examples in Figs. 17 and 18. Fig. 17 is a written sequence type Manufacturing Procedure and Inspection Plan for a welding operation. Fig. 18 is a flow chart type Manufacturing Procedure and Inspection Plan for a welding operation.

Dispositioning of nonconforming items

A very important part of any quality assurance system is the way in which nonconformances are handled. At any point of inspection it may be determined that the item does not conform to requirements. If the item can be reworked by repeating the previous manufacturing step and this is done, and if the item conforms upon reinspection, the Manufacturing Procedure and Inspection Plan can be signed off. Otherwise, there must be a fully documented sequence of steps to be taken to hold further processing of the item until it has been dispositioned. The Quality Assurance Manual specifies who is responsible for dispositioning nonconforming items (Fig. 19). Frequently it is the product or design engineer. Some steps could be:

- further examination
- repair, rework and re-examination
- engineering critical assessment
- reject, scrap, or regrade.

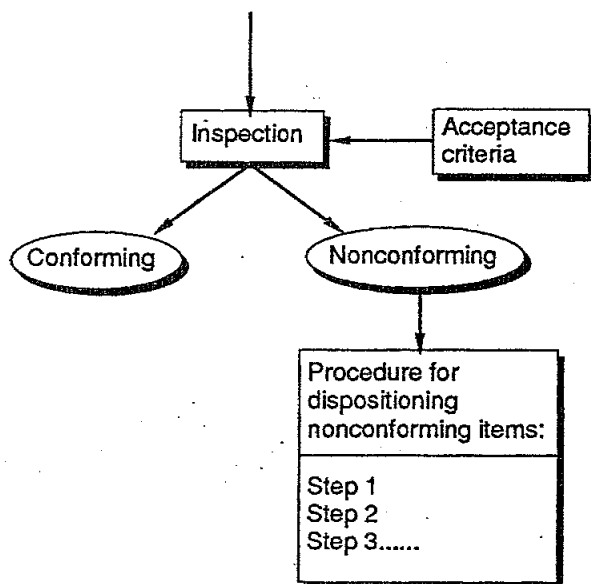


Figure 19. Proper procedures must exist for the dispositioning of nonconformances.

A weld, for example, may not meet the requirements because a crack-like indication was found during a magnetic particle inspection. Further examination might then be required with ultrasonics to try and identify the type of discontinuity, its exact location, depth, and length. This information could be valuable feed-back to the shop for preventing future occurrences as well as providing the data needed for an effective repair procedure.

It should be clearly stated in the engineering documentation whether repairs are permitted or not. CSA W59-1989, for example, clearly states that in lieu of rejection of an entire piece containing defective welds, corrective action may be taken. On the other hand according to CAN/CSA Z184-M86 a crack in a pipeline girth weld is not repairable, and a complete section of pipe containing the cracked weld must be replaced.

Where repairs or corrective action is undertaken appropriate procedures are required. The inspector then has the double task of ensuring that not only the weld meets the original requirements but also that the repairs were carried out according to the specified repair procedure.

Engineering critical assessment

Not in all cases does a nonconformance result in a correction or rejection. Sometimes it is permitted to carry out a detailed engineering analysis to determine whether the nonconforming piece would meet the performance requirements for the end application and therefore whether it could be accepted. This is usually termed an "engineering critical assessment" (ECA) or "fitness-for-purpose analysis." As an example, CAN/CSA Z184-M86 "Gas Pipeline Systems" Appendix J specifically allows, under certain conditions, the use of the ECA approach for determining whether non-conforming welds require repair or not.

It is most important to remember that an ECA, if permitted, is usually a complex, detailed analysis performed by an engineering specialist. Even if an Engineering Critical Assessment establishes that a defect could be permitted to remain in a weld, the customer would in most cases also have to approve this. As a result, the length of time required for this process often makes it impractical, and it is not something done at the discretion of the inspector. An inspector cannot change an acceptance standard on the basis of personal opinion.

Requirements for inspectors

THE INSPECTOR

The welding inspector's job is challenging. To be effective there must be the right mix of skills in addition to personal characteristics to be described later (Fig. 20). The skills required can be summarized as follows:

1. Essential Requirements

- Physical condition
- Vision (with glasses if necessary)
- Attitude
- Knowledge of welding
- Knowledge of drawings and specifications
- Knowledge of testing methods
- Ability to maintain records

2. Desirable Characteristics

- Welding experience
- Education and training
- Inspection experience.

Technical qualifications of inspectors

The technical knowledge of inspectors is important not only for their ability to make the appropriate decisions regarding acceptance or rejection but also to ensure their credibility with those whose work they are inspecting. A welder, supervisor, or production worker will soon determine whether an inspector has the technical knowledge required for the position. If not, the opportunity for shortcuts always exists. The relationship between the production worker and the inspector should never become a cat and mouse game. Yet a noticeably ignorant or bluffing inspector invites such action.

On the other hand, it must be recognized that inspectors are sometimes faced with responsibilities that make them stretch technically. These should be treated as opportunities to learn while observing closely. Trained inspectors can be just as effective, if not more so, in this situation if they are honest with themselves. Because of the importance of welding inspection and the skills, training and experience demanded of a welding inspector, standards have been written documenting these.

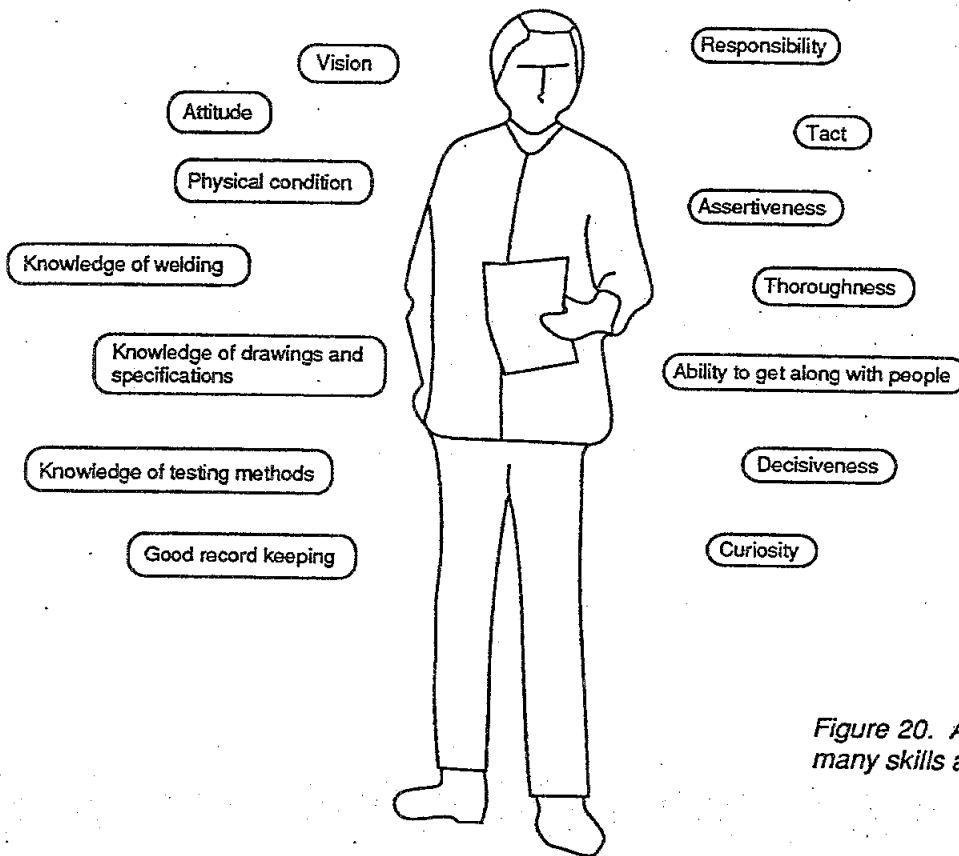


Figure 20. A good inspector has a mix of many skills and personality.

Canadian Standards Association Standard W178.2-1990 covers the certification of welding inspectors. (The companion Standard, W178.1, covers inspection organizations.) Under W178.2 there are three levels of certification for welding inspectors according to the level of responsibility.

Level I welding inspectors perform inspection under the direction of a Level II or Level III welding inspector.

Level II welding inspectors may be assigned the responsibility for verifying that work inspected and records maintained conforms to the applicable codes, standards, drawings, and specifications. This responsibility is only for the product categories in which they are certified.

Level III welding inspectors perform inspections or verifications as above and the responsibilities may extend to the exercising of a complete quality control function over the welding aspects of an inspection project or contract.

Certification levels

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5. Competency Requirements of the Welding Inspector

5.1 General. Welding Inspectors at any level shall be capable of:

- (a) Reviewing welding inspection procedures in conjunction with the related standards, codes, and drawings to a degree consistent with the welding inspector level held;
- (b) Monitoring and examining the work performed by tackers, welding operators, or welders;
- (c) Recording inspection results to the degree that the work personally inspected may be identified;
- (d) Preparing clear and adequate reports.

5.2 Level I Welding inspector. Level I inspectors shall be capable of:

- (a) Verifying that the specified base metal and welding materials are used and are maintained in proper condition for use as specified;
- (b) Verifying that the joint preparation and fit-up meet the requirements of the welding procedure and drawings;
- (c) Verifying that only specified and accepted welding procedures are used for the work;
- (d) Examining and evaluating welds according to a prescribed inspection procedure.

5.3 Level II Welding inspector. In addition to the capabilities listed in Clause 5.2 for Level I welding inspector the Level II welding inspector shall be capable of:

- (a) Confirming that the welding equipment to be used for the work is appropriate for the process specified in the welding procedure and has the capacity to produce the specified welds and that the welding equipment is in good working order;
- (b) Confirming that the tackers, welding operators, and welders have been properly qualified in accordance with the applicable codes and standards and that their qualifications are current and permit them to use the welding procedures specified for the work;
- (c) Identifying substandard workmanship during fabrication;
- (d) Examining the finished work for conformance to the requirements of the applicable codes, standard, specifications and drawings.

5.4 Level III Welding Inspector. In addition to the capabilities listed in Clauses 5.2 and 5.3 for Level I and Level II welding inspectors, the Level III welding inspector shall be capable of:

- (a) Interpreting specifications and codes, preparing welding inspection procedures, and implementing welding inspection aspects of quality programs;
- (b) Assuring that nondestructive and other examinations have been performed to the degree specified by contract documents, using qualified personnel, and that results have been duly recorded.

Figure 21. Competency requirements for welding inspectors according to CSA W178.2 - 1990.

Fig. 21 lists the specific competencies required of welding inspectors in the various levels taken from CSA W178.2.

Personal characteristics of inspectors

The most important characteristic of effective inspectors is their capacity to observe and to "see." In addition to the required technical skills, they should also have:

- an understanding of the processes involved
- an orderly approach to their duties
- attention to detail
- powers of observation
- broad technical knowledge
- justified self-confidence.

A good inspector would have the following personal characteristics:

- Sense of responsibility
- Tactfulness
- Assertiveness
- Thoroughness
- Ability to get along with people of all levels of organization
- Decisiveness
- Intellectual curiosity and willingness to learn.

Welding inspectors should be hired or selected for their specific skills and capabilities in these areas. If a production worker who has suffered an injury or is in ill health is transferred into the inspection department it should be on the basis of a rational evaluation of capabilities versus needs. Such workers may indeed make a valuable contribution to the inspection department, but should be properly retrained for the new assignment.

Responsibilities and reporting relationships

Inspectors must have a clear understanding of to whom they are responsible in performing their duties and to whom they report. When an inspector employed by an inspection organization works at the fabricator's facilities, the contact person in the fabricator's organization must be identified. Such an inspector should not normally give instructions to shop floor workers. The inspector must take care to develop a good working relationship with the vendor's personnel.

Inspectors must be careful not to undermine the authority of their position by excessive familiarity with anyone which might, however slightly, influence objectivity. Inspectors must be clear that their loyalty

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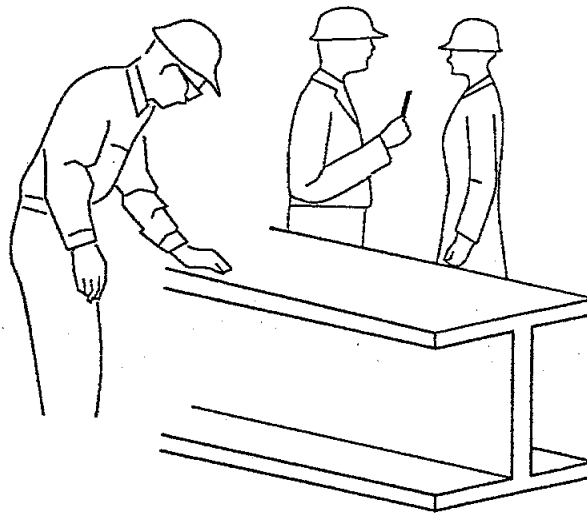


Figure 22. Inspectors are often working alongside people representing various interests: the fabricator, the client, the regulatory authority. Inspectors must have a clear understanding of whom they represent and to whom they report.

is to their own chain of command, and their responsibility is clearly defined (Fig. 22).

The inspectors are often the working link between outside authorities or customers and the production facility. The relationship with the Authorized Inspector and the Customer's Quality Assurance Representative, Inspector or Engineer is important. If an inspector becomes aware of faults in the quality assurance system or its application, these should be drawn to the attention of management through the Quality Assurance Manager, not to the attention of authorities or customers.

Proper relationships must also be developed with respect to vendors and their personnel at all levels. The authority vested in inspectors by the contract to stop work if necessary is a serious responsibility. This authority is available to them if they see an uncorrected situation which will place the integrity of the item or product in question. It is not a weapon or tool of punishment to be used on uncooperative vendor's staff. Inspectors must appreciate the necessity for confidentiality regarding the quality level or process used except as defined in reporting relationships. Inspectors in a plant or production facility often have access to process procedures which are proprietary. Inspectors are not spies to learn from one manufacturer and to reveal all to the next. The warning is that such activity might be seen as innocent shop-talk or gossip, yet could have far-reaching commercial implications. For example, an inspector in an automotive parts plant has no mandate to speak publicly of defects to anyone other than his or her employer.

Code of ethics

Proper reporting relationships, personal integrity, and professional competence are so fundamental to the inspector's role that CSA W178.2 lists a code of ethics. This is shown in the excerpt from W178.2 given in Fig. 23 and provides a useful guide to the professional conduct of the inspector.

FOR LEVEL III

10. Code of Ethics

10.1 A certified welding inspector recognizes that precepts of personal integrity and professional competence are fundamental, and as such shall:

- (a) Have proper regard for the safety, health, and well-being of the public;
- (b) Undertake only those assignments for which he or she is competent by virtue of certification, training, and experience and, where warranted, advise the engagement of such specialists as are required to facilitate the completion of assignments;
- (c) Protect to the fullest extent possible, consistent with the well-being of the public, any information given in confidence by an employer or colleague;
- (d) Indicate to the employer or supervisor any adverse consequence that may result from an overruling of his or her rejection of work by a nontechnical authority;
- (e) Be objective, thorough, and factual in any written report, statement, or testimony of the work and include all relevant or pertinent information in such documents;
- (f) Sign only for work that he or she has inspected or for work over which he or she has personal knowledge through direct technical control;
- (g) Strive to maintain personal proficiency by updating his or her technical knowledge and skills as required to properly practise welding inspection.

Note: Welding inspectors are cautioned against interference in the line relationship between welders, operators, or tackers and their supervisors. When any form of discrepancy arises the welding inspector should advise the supervisor or some other responsible person of the discrepancy.

Figure 23. Excerpt from the code of ethics from CSA W178.2 - 1990.

Duties of the Inspector

The specific duties of the "welding inspector" vary according to the contract, the reporting relationship and responsibility, and the type of operation.

Module 15 describes more fully some of the activities which might be part of the welding inspector's duties, but no attempt has been made to define the exact responsibilities because this is more properly part of a job description. However, the following examples are offered as indications of how the welding inspector's duties are seen by others. We have seen how CSA Standard W178.2-1990 "Certification of Welding Inspectors" describes the responsibilities of the welding inspector in the clauses related to competencies. The range of duties depend on the level of inspector with a Level III having the broadest range.

The American Welding Society's publication, "Welding Inspection" (refer to the additional resources section) states that the duties of the typical welding inspector are as follows:

1. Interpretation of drawings and specifications
2. Verification of procedure and welder or welding operator qualifications
3. Verifying the application of approved welding procedures
4. Selection of production test samples
5. Interpretation of test results
6. Preparation of reports and keeping of records.

Of particular importance in defining the responsibility of the inspector is the power to stop work or call for immediate remedial action to resolve a quality problem.

Qualifying as a welding Inspector

Competence as a welding inspector is developed through a combination of education, training and experience. The relative importance of each of these can be seen from Fig. 24 which details the formal eligibility requirements to meet CSA W178.2.

Credit is given by various standards for formal training. The guidelines from CSA W178.2 shown in Fig. 25 indicate the scope of technical knowledge needed by the welding inspector.

Basic Concepts of Quality Assurance

Years of Experience for:			<i>LEVEL III TEST QUESTION.</i>	
Level I	Level II	Level III	Educational Background	
4	5	7	A	Elementary School
3	4	6	B	2 years College in Engineering Technology OR Secondary School Equivalent
2	3	5	C	3 years College in Engineering Technology OR 2 years College in Welding Technology
1	2	4	D	4 years University in Science or Engineering OR 3 years College in Welding Technology
1/2	1	3	E	4 years University in Welding Technology

Refer to the original in CSA W178.2 - 1990 for conditions under which the experience requirements may be reduced.

Figure 24. Experience requirements for welding inspectors (CSA W178.2 - 1990).

Figure 25. Guidelines showing scope of technical knowledge required for welding inspectors. (CSA W178.2 - 1990).

*Recommended Course Guidelines

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

A1. Design

A1.1

Drawings

Outline of Types of Drawings
Reading of Shop Drawings
Symbols for Welding and NDE

A1.2

Design Concepts

Application and Design of Joints

A1.3

Codes, Specifications and Standards

Definitions, Functions, Types
Certification Standards
Qualification Standards

A2. Materials

A2.1

Base Metals

Mechanical Properties
Examination of Metals
Steel Types
Heat Treatment of Steel
Cast Irons
Stainless Steels
Aluminum Alloys
Other Alloys

Basic Concepts of Quality Assurance

A2.2

Welding Consumables

Steel Electrodes
Stainless Steel Electrodes
Aluminum Alloy Electrodes
Nickel Electrodes

A2.3

Welding Metallurgy

Welding Low Carbon Steel
Welding Low Alloy Structural Steel
Welding Stainless Steel
Welding Aluminum Alloys
Hard Facing

A3. Production

A3.1

Preparation of Joints

Edge Preparation

A3.2

Fit-up of Joints

A3.3

Production Methods and Economics

A3.4

Health and Safety Precautions

A3.5

Elements of Supervision

A4. Welding

A4.1

Processes

Arc Welding
Features of the Electric Arc
Other Heat Sources

A4.2

Equipment

Fundamental Electricity
Arc Welding Equipment

A4.3

Welding Procedures

Essential Variables
Nonessential Variables
Control

A4.4

Side Effects

Distortion and Residual Stress
Heat Effects

A5. Quality Assurance

A5.1

Basic System Function Concepts

Authority
Design
Material Control
Monitoring
Verification Control
Corrective Functions
Recording
Auditing
Performance

A5.2

Basic Concepts of Quality Control

Role of Welding Inspector
Factors Affecting Weld Quality
Potential Weld Faults

A5.3

Nondestructive Examination

Visual Examination
Radiographic
Ultrasonic
Eddy Current
Magnetic Particle
Liquid Penetrant
Acceptance Criteria

A5.4

Mechanical Testing

A5.5

Chemical and Metallographic Testing

A6. Qualification

A6.1

Welders

A6.2

Equipment

A6.3

Procedures

A6.4

Material

A6.5

Inspectors

A6.6

NDE Technicians*

Summary

The activities of the welding inspector are not simply limited to the examination of completed welds but extend to many areas of inspection as integral parts of a planned system for achieving quality. Such a system is usually documented in the form of a quality assurance program.

In this module we have discussed some general ideas on quality, conformance, and nonconformance. We have shown the contents of a quality assurance manual and illustrated how activities are planned and carried out according to prescribed procedures. We have covered the types of requirements for quality assurance in welded structures.

The techniques for fulfilling requirements for quality comprise quality control, and we have discussed the use of Inspection and Test Plans or Manufacturing Procedures and Inspection Plans. Finally we have described skills needed for a welding inspector and the requirements for becoming certified under the CSA standard.

It is hoped this module has provided a useful introduction to some basic concepts of quality assurance and helps in understanding the role welding inspectors play in achieving quality in welded structures.

Additional Resources

Burgess, N.T. "Basic Concepts in Quality Assurance," Quality Assurance of Welded Construction, Applied Science Publishers, London, 1983.
Davis, H.E., Troxell, G.E. and Hauck, G.F.W., "The Testing of Engineering Materials," McGraw-Hill, New York 1984.
"Welding Inspection," American Welding Society, Miami, 1968.

BASIC CONCEPTS OF QUALITY ASSURANCE

MODULE 14

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 53) 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 9 and answer the following questions:

1. Write down your definition of quality assurance. Compare your answer with the definition given on page 3.
2. Products or services that do not meet the customer's requirements are termed:
 - a) compliant
 - b) traceable
 - c) nonconforming
3. True or false?

"If a product does not meet the customer's requirements it must always be scrapped."
4. Which of the following standards comprises a series for quality assurance?
 - a) CSA S473
 - b) CAN3 - Z299
 - c) CAN/CSA - Z184
5. True or false?

"According to the ISO 9000 series, a systematic and independent examination to determine whether quality activities and related results comply with planned arrangements and whether these arrangements are implemented effectively and are suitable to achieve objectives, is termed a *quality audit*."
6. Arrange the following words in order to represent quality assurance programs from the simplest to the most stringent:

reacting
verifying
sorting
preventing.

Basic Concepts of Quality Assurance

Guide 2

Read carefully pages 10 to 21 and answer the following questions:

1. The most common method of documenting a quality assurance program is in a —?
2. In a company's organization chart, can the inspector report to the immediate supervisor responsible for producing the work?
3. According to the example of a QA manual given on pages 11 to 21, who has the final authority on quality related matters?
4. What standards does the example QA program meet?
5. According to the example, how would you know when a piece of equipment is due to be calibrated?
6. According to the example, how could you find out where to look for a list of qualified welders?
7. True or false?

"According to the example, NDE technicians are permitted to make up and approve their own NDE procedures following their own format if they wish."

Guide 3

Read carefully pages 22 to 27 and answer the following questions:

1. What standard is used in Canada for certifying companies for welding steel structures?
2. The provincial laws covering pressure vessels generally require compliance with the codes written by which body?
 - a) AWS
 - b) ASME
 - c) CWB
3. For welds subjected to hydrogen sulphide service conditions, what heat affected zone and weld metal tests are often called for?
 - a) Creep test
 - b) Grain size test
 - c) Hardness test

4. The information that a designer transfers to the fabricator is usually contained in what three documents?
5. Which of the following would an inspector employed by the fabricator normally work to?
 - a) Design drawings
 - b) Shop drawings and detail drawings
 - c) Codes and standards
6. True or false?

"Fabricators often use internal standards to translate code requirements for use by production personnel."

Guide 4

Read carefully pages 28 to 37 and answer the following questions:

1. True or false?

"Quality control comprises the operational techniques to verify compliance with requirements."
2. The evaluation of a batch of product from examination of a small number of units from the batch is termed—
 - a) physical testing
 - b) nondestructive inspection
 - c) sampling inspection
3. The amount of rework provides an indication of potential quality problems. Make a list of some other costs that can be incurred as a result of undetected nonconformances.
4. Recording details of each weld, such as procedure parameters, identity of the welder, conditions of fit-up, etc., is termed—
 - a) weld monitoring
 - b) weld procedure data sheet
 - c) weld inspection report
5. Which of the following would be considered as elements in a quality system for welding?
 - a) approval testing of welder
 - b) verification of filler metals
 - c) welding procedure specifications

Basic Concepts of Quality Assurance

6. According to the sample Manufacturing Procedure and Inspection Plan (page 34), are CWB qualified welders required for tack welding?
7. Can an inspector use his or her own knowledge of the intended application of the product to decide whether to accept a nonconforming item?

Guide 5

Read carefully pages 38 to 47 and answer the following questions:

1. What is the standard in Canada for the certification of welding inspectors?
2. Can a person who wears glasses become a certified welding inspector for visual inspection of welds?
3. List some of the personality characteristics you think would be beneficial for a welding inspector. Compare your list with that on page 41.
4. Under the CSA standard for the certification of welding inspectors, are Level I inspectors permitted to work on their own without the direction of another inspector?
5. Would Level III inspectors be expected to be able to prepare welding inspection procedures?
6. If, as an inspector, you do not feel qualified to undertake an assignment, should you—
 - a) take the assignment and do the best you can
 - b) take the assignment but omit those parts you are not sure of
 - c) advise the engagement of specialists needed to complete the assignment

ANSWERS

Guide 1

1. See page 3
2. c)
3. False
4. b)
5. True
6. Sorting, verifying, reacting, and preventing

Guide 2

1. Quality assurance manual
2. No
3. Quality assurance manager
4. CAN3-Z299.1-85 and ISO-9002-1987
5. It should be marked on the equipment according to procedure #3
6. Check in procedure #14 - welding
7. False

Guide 3

1. CSA W47.1
2. b)
3. c)
4. Design drawing, codes and standards, technical specification
5. b) and c)
6. True

Guide 4

1. True
2. c)
3. See Figure 15 on page 30 for examples of "hidden" costs
4. a)
5. All of them
6. Yes
7. No

Guide 5

1. CSA W178.2
2. Yes
3. See page 41
4. No
5. Yes
6. c)

MODULE 14

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 term *quality assurance* ?
 - a) The totality of features and characteristics of a product or service that bear on its ability to satisfy stated or implied needs
 - b) All those planned and systematic actions needed to provide adequate confidence that a product or service will satisfy given requirements for quality
 - c) The operational techniques that are used to fulfil requirements for quality
 - d) The continuing monitoring and verification of the status of procedures, methods, and processes to ensure requirements for quality are being met
 - e) A systematic and independent examination to determine whether quality activities comply with planned arrangements
2. Which of the following is a standard for a quality assurance program?
 - a) CSA W59 - M1989
 - b) CAN/CSA - Z184
 - c) CSA W186 - M1990
 - d) CAN3-Z299.1 - 85
 - e) CAN/CSA - W117.2 - M87
3. Which of the following would be a basis for the *simplest* quality assurance program?
 - a) *Verifying* conformance of products throughout the process
 - b) *Reporting* nonconformance at each stage of production
 - c) *Reacting* to nonconforming products to prevent their recurrence
 - d) *Sorting* the good from the bad
 - e) *Preventing* the occurrence of nonconforming products
4. Which of the following is the normal reporting relationship for an inspector?
 - a) The inspector reports to the person performing the work
 - b) The inspector reports to the supervisor of the person doing the work
 - c) The inspector reports to someone independent of the person doing the work or their supervisor
 - d) The person doing the work reports to the inspector
 - e) The supervisor of the person doing the work reports to the inspector

Basic Concepts of Quality Assurance

5. In what part of a quality assurance manual would the commitment of management and the authority of the Quality Assurance Manager usually be stated?
- a) Statement of policy
 - b) Control of the program manual
 - c) Quality records
 - d) Statement of certification
 - e) Revision record sheet
6. Which of the following standards is used for certifying companies for welding steel structures?
- a) CSA W59 - M1989
 - b) CAN3 - Z299.1 - 85
 - c) CSA W186 - M1990
 - d) CSA W178.2 - 1990
 - e) CSA - W47.1 - 1983
7. Which of the following documents is an inspector employed by the fabricator *not* likely to be referring to?
- a) Shop and detail drawings
 - b) Design drawings
 - c) Internal standards
 - d) Internal contract documents
 - e) Codes and standards
8. Which of the following would be an element in a quality system for welding?
- a) Approval testing of welders
 - b) Verification of filler metals
 - c) Welding procedure specifications
 - d) All of the above
 - e) None of the above
9. An "engineering critical assessment" is—
- a) A method by which a nonconforming item is accepted by determining that it would meet the performance requirements for the intended application
 - b) A review of the acceptance criteria if they are considered to be not stringent enough
 - c) A method by which conforming items can be rejected if the inspector does not think they meet the performance requirements
 - d) A review of the NDE practices following a high rejection rate
 - e) A method of changing the acceptance criteria based on the rejection rate

Basic Concepts of Quality Assurance

10. What certification would reflect the competency of an inspector to prepare welding inspection procedures and implement welding inspection aspects of quality programs?
- a) Certification to CSA W47.1 - 1983
 - b) Certification to Level I of CSA W178.2 - 1990
 - c) Certification to CSA W47.2 - M1987
 - d) Certification to CAN3 - Z299.1 - 85
 - e) Certification to Level III of CSA W178.2 - 1990

Basic Concepts of Quality Assurance

Canadian Welding Bureau Answer Sheet - Module 14

Complete the "Answer Sheet" and compare the results with the "Test Key". If you have a pass mark less than 70%, you are advised to re-study the material.

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

QUESTION	ANSWERS				
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 key below is provided for your use in the event that you wish to retest yourself.

QUESTION	ANSWERS				
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

Basic Concepts of Quality Assurance

Canadian Welding Bureau Test Key - Module 14

Compare your answer sheet to this key.

QUESTION	ANSWERS				
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