

Module 16

Techniques of Visual Inspection

PART OF THE CWB CERTIFICATE PROGRAMS



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OF
VISUAL INSPECTION****CONTENTS**

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MODULE 16

TECHNIQUES OF VISUAL INSPECTION

Introduction

The role of the inspector in the fabrication of welded structures was discussed in Module 15. It was indicated that CSA W178.2 "Certification of Welding Inspectors" details the competency requirements for inspectors of welded components. Today few organizations employ inspectors solely for monitoring and verifying welding operations. In addition to these activities an inspector might also be required to check incoming material, measure its thickness, check the size and location of bolt holes, measure dimensions of welded shapes, and so forth. Thus the inspector must have a broad range of skills and knowledge in order to make an effective contribution to the shop operations. Nor are these just the prerogative of the inspector. The welding supervisor and indeed the welder should have many of these skills if 'quality' is to be built into the product.

Objectives

The objectives of this module, therefore, are to discuss a wide range of techniques in the inspection of welds and welded products and to cover what is traditionally termed 'visual' inspection. After successfully completing this module you should be able to:

- Explain various types and sources of measurement errors
- Discuss the use of various measuring devices
- Describe methods for checking distortion in a welded structure
- List types of base metal defects
- Measure various dimensions of welds
- Recognize other weld faults, such as undercut and cracks, discuss acceptance levels, and describe measurement methods.

Techniques of Visual Inspection

Vision requirements

First, the most important 'instrument' to consider is the human eye. For visual examination to be meaningful it is essential that the eye be well trained and functioning properly. As for any measuring instrument, checks at regular intervals should be carried out and any deficiencies corrected. Vision requirements are specified in CSA W178.2 "Certification of Welding Inspectors."

Basic ideas on measuring

Many inspection tasks involve measuring something and many of them involve measuring a length. This may be the size of a fillet weld, the width of a gap, or the distortion in a welded product. Regardless of the type of measurement, there are a few basic ideas that should be understood by the inspector.

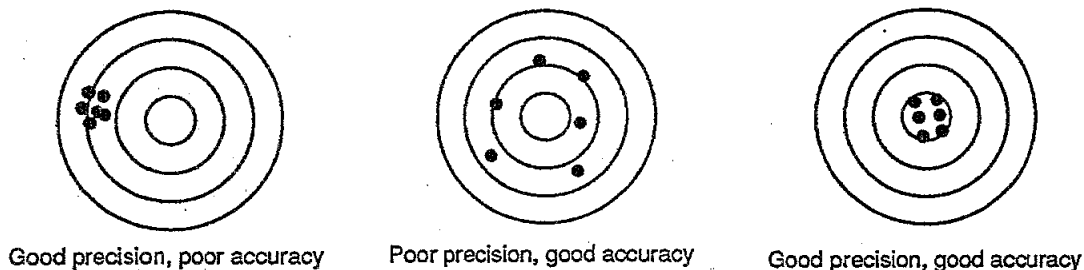


Figure 1. Illustration showing the difference between accuracy and precision.

Now, let us consider the difference between *accuracy* and *precision* of a measurement. *Accuracy* is how close repeated measurements are to the 'true' value; *precision* is how close repeated values are to each other. Fig. 1 illustrates the difference between accuracy and precision. You can see it is quite possible to make very precise measurements that are quite inaccurate. Precision depends to a large extent on the instrument used for the measurement. A micrometer, for example, has much greater precision in measuring length than a steel rule. The inspector must select a tool which has an adequate precision for the intended measurement.

The vernier

A simple method for improving the precision of measuring scales is the vernier. This was invented in 1631 and although used mainly on such instruments as callipers (Fig. 2), micrometers, and height gauges, it is also found on dials, protractors, or similar instruments using a scale. A ten division vernier scale is illustrated in Fig. 3. The second scale has ten divisions that occupy the same space as nine divisions on the main

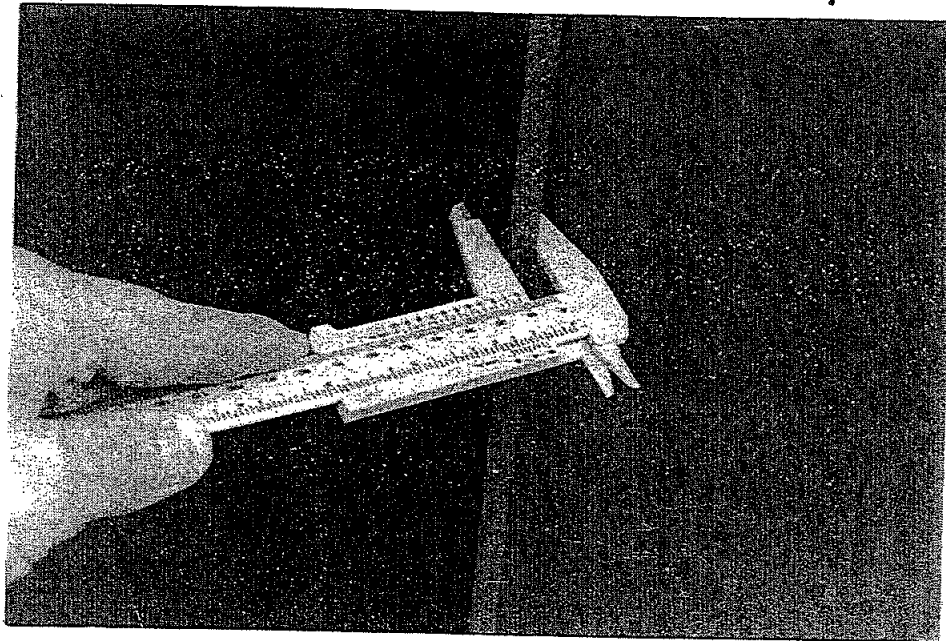


Figure 2. Measuring the thickness of a plate with callipers.

scale. Modern instruments often have digital readouts with four or five significant digits displayed. This gives the impression of a highly accurate instrument but, again, high precision does not mean high accuracy.

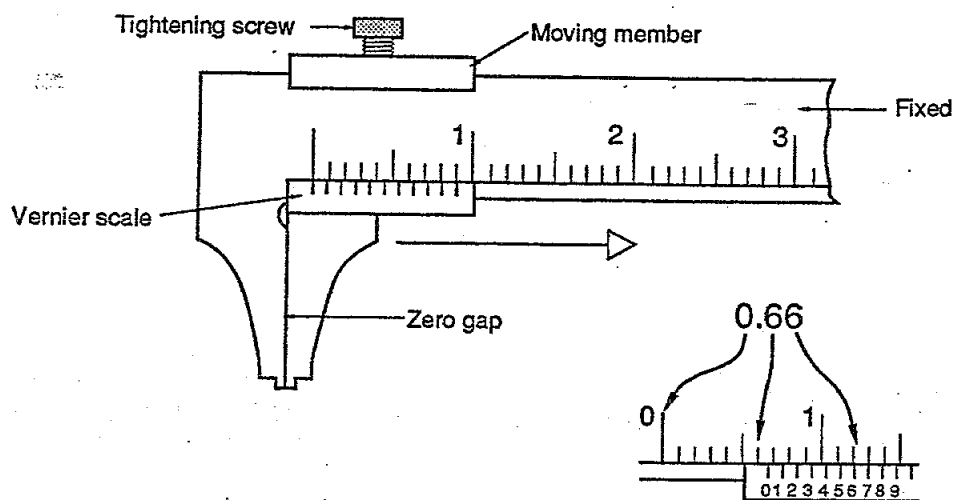


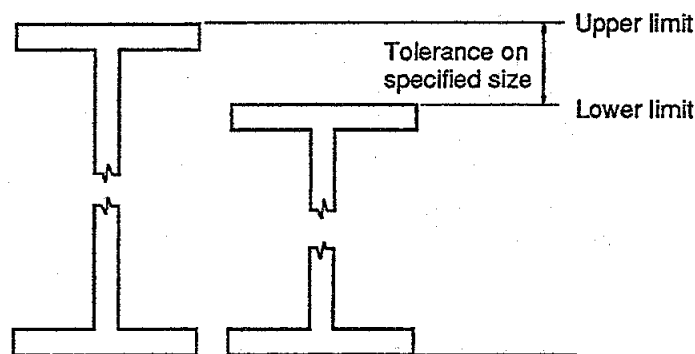
Figure 3. Callipers showing the principle of the vernier scale. This simple device increases the precision of measuring instruments.

Techniques of Visual Inspection

Types of error

In the left hand sketch of Fig. 1 two types of errors are shown. First, there is the general scatter among the cluster of points themselves. This is a *random* error. Then there is the shift of the whole cluster from the centre of the target. This is a *systematic* error. Systematic errors are very serious because they can be repeated with every measurement and you might not know they were there. For example, suppose there is an error in the position of holes on a drilling template used for locating bolt holes on a structure. Every time the template is used the error is transferred to the component.

Figure 4. The tolerance on a dimension is the difference between the highest and lowest value that it may have.



Tolerance

The tolerance is the difference between the highest and lowest value that a dimension is allowed to have. If it is outside the limits it is unacceptable. For example, CSA W59-M1989 Clause 5.8(j) gives the tolerance on the depth of welded built-up beams as ± 3 mm for depths not exceeding 900 mm. This tolerance is relative to the specified depth. Thus for a specified depth of 550 mm the upper and lower limits are 553 and 547 mm respectively, and a depth outside these limits would be unacceptable. See Fig. 4.

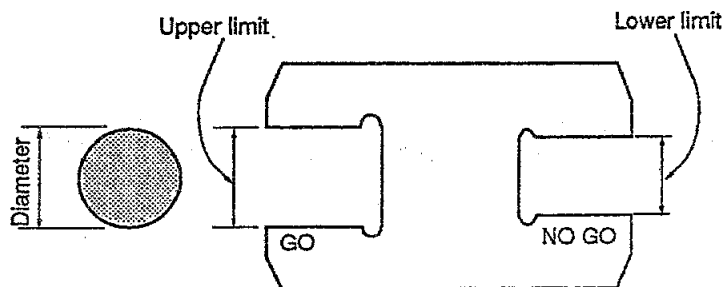
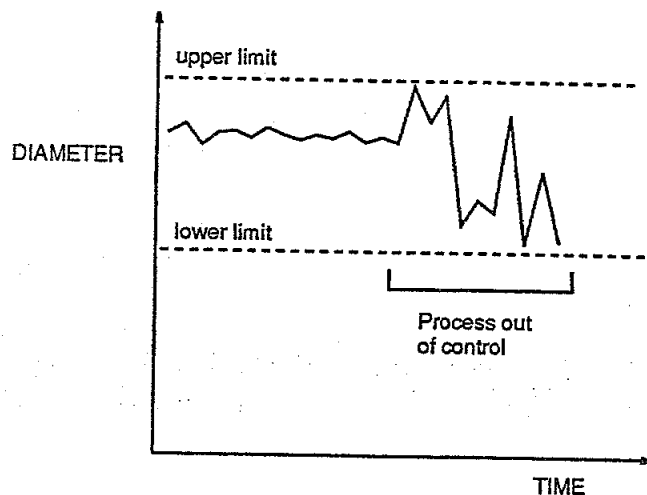


Figure 5. Limit gauge for checking the diameter of a bar. To be within tolerance, the bar must fit in the 'go' end (set at the upper limit) but not fit in the 'no go' end (set at the lower limit).

In many cases limit gauges can be used to establish the acceptability of a dimension using the go/no go approach which avoids having to measure the actual dimension (Fig. 5). This saves time but does not provide any information on what is being achieved. The latter information is becoming increasingly important with the use of modern statistical process control (SPC) methods. For example, tracking the actual values achieved in a product may indicate whether the process is going out of control before any components are actually rejected (Fig. 6).

Figure 6. In statistical process control actual measurements are made on the product and analysed. Even though a product may be within specification such information tells whether the process is under control.



Accuracy and calibration

To ensure accuracy in a measurement the instrument must be properly calibrated and the measuring technique must strive to minimize errors. Calibration procedures vary according to the instrument or measuring device but are all based on the idea of calibration against a traceable standard. That is, the device must be calibrated against another device which is itself calibrated against a standard and the calibration can be traced through to a national standard. Calibration intervals should be established as part of the formal calibration program. These might be based on importance, frequency of use, or type of instrument. Calibration records should be available that show when an instrument was last calibrated. Calibration should only be done following the correct procedures and minor adjusting or "fiddling" with an instrument should be avoided. For example, setting the zero on an ammeter does not calibrate it. It only sets the zero and the meter could still be inaccurate at, say, 400 amps. (Fig. 7).

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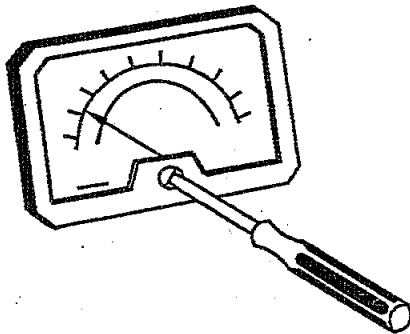


Figure 7. Adjusting the zero on an ammeter does not calibrate it.

Some of the techniques for minimizing errors in making specific measurements are discussed in subsequent sections, but a few general points are worth noting here.

When reading meters with needles, always stand directly in front of the meter to read it. Standing at the side may introduce a parallax error because the needle is displaced slightly from the scale (Fig. 8). High quality meters often have a mirror in the scale which allows you to line up the needle with its reflection before you take a reading.

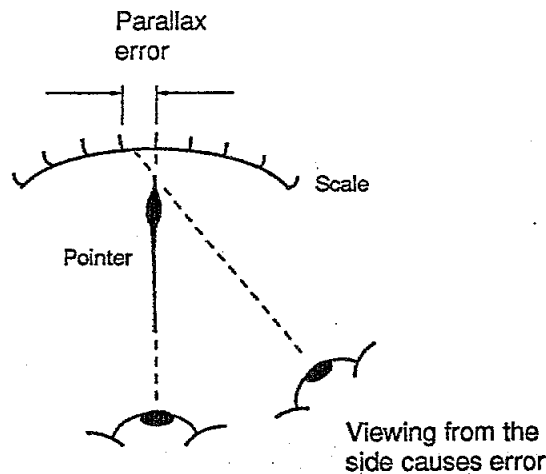


Figure 8. Sketch showing how a parallax error can occur when reading a scale.

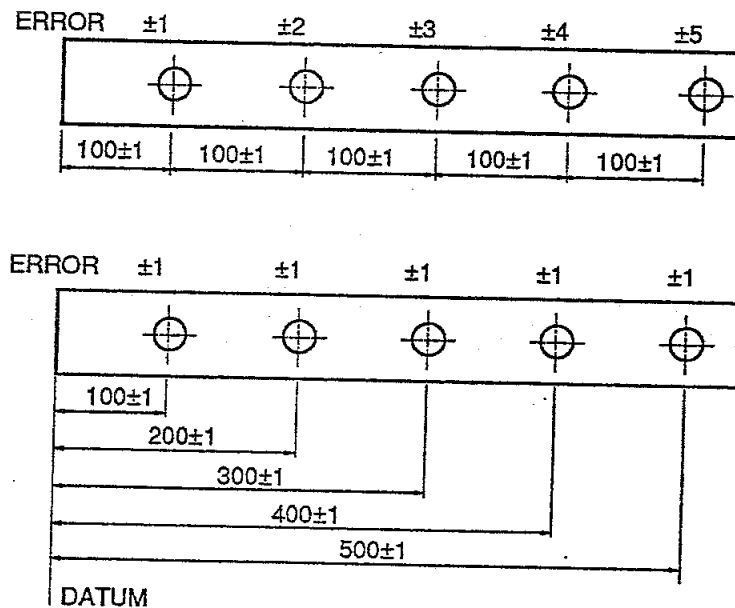


Figure 9. Making measurements from a common datum or reference line avoids cumulative errors.

Cumulative errors

Dimensions should be measured from a common datum or reference line as specified in the drawings. This avoids the risk of cumulative errors. A cumulative error can be illustrated (Fig. 9) by considering five holes that are to be drilled 100 mm apart in a straight line. The position of each hole has a tolerance of ± 1 mm. If the location of each hole is measured from the preceding hole then the previous error is added to the tolerance, i.e., there is a cumulative error. The fifth hole could actually have an error of ± 5 mm. If all hole positions are measured with respect to a single edge, then each hole will be subject to the same error of ± 1 mm. Be aware of what lines are specified on the drawings as datum or reference lines. There could be several depending on the structure. Fig. 10 shows part of a drawing for a vessel with a seam line clearly marked as a reference line. Use of the correct reference line is critical, for example, in determining the location of a nozzle in a vessel.

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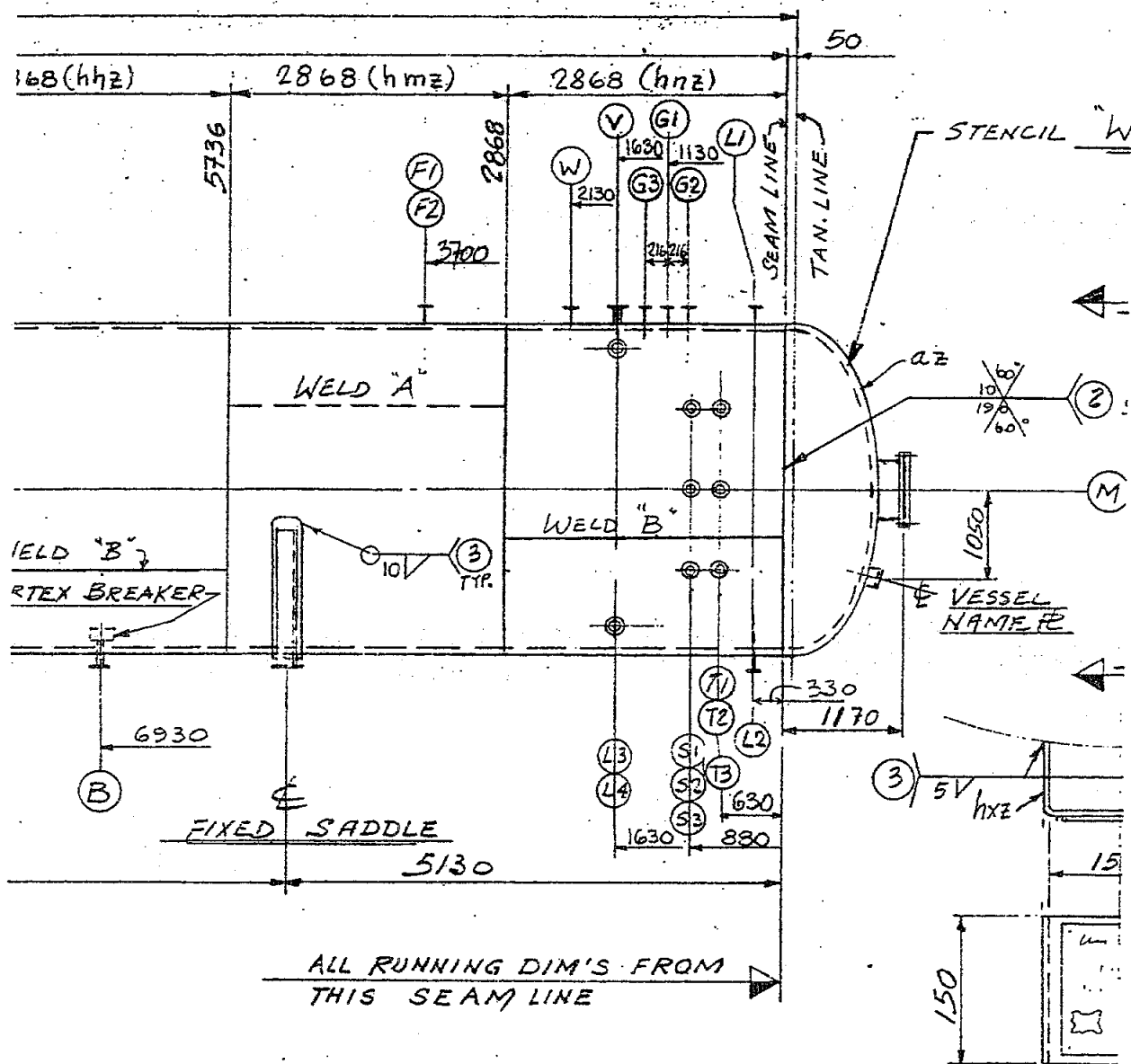


Figure 10. Part of a drawing for a pressure vessel showing the reference line to be used for measurements.

Units

As the change over from Imperial to S.I. (metric) units progresses you may be required to work in either set of units. Some codes and standards (such as CSA W59) are available in both systems. You should, however, stick to the system specified for the job and use instruments calibrated in those units. Avoid measuring in one system and converting.

Standards such as W59 that are published in the two systems are two distinct standards. They are not exact 'conversions.' For example, the allowable gap for a fillet weld is 1/16 in. in the Imperial version (W59-1989) and 2 mm in the S.I. version (W59-M1989). These are not the same—2 mm is actually 26% larger than 1/16 in.!

Care

Care of inspection tools is an essential part of the inspector's job. Avoid dropping or striking tools which could cause burrs, kinks, or springing frames. Check tools frequently for wear and proper adjustment. After use, wipe them clean with a suitable cleaning fluid, dry them, then wipe with a slightly oiled chamois or cloth to prevent corrosion. Measuring tools should be stored where they will not be damaged from damp, dust, or impact.

Measuring tools

For measuring dimensions greater than about 1 m the steel tape (Fig. 11) is the most widely used. A tape cannot be calibrated in the sense of adjusting it, but it can be checked against a standard and should be maintained in good working order. The standard recognized temperature for checking steel tapes is 20°C (68°F). Tapes usually have a hook or similar device at the end to hook over an edge which serves as the datum. Ensure this is not worn, damaged, or altered in any way and check that it does not introduce any zero error in the readings.

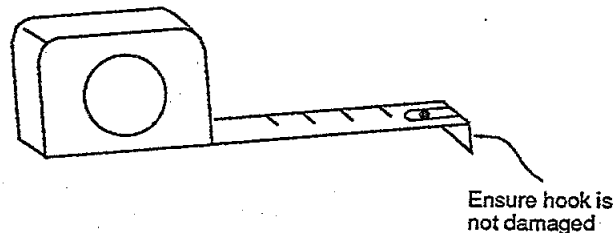


Figure 11. The steel tape.

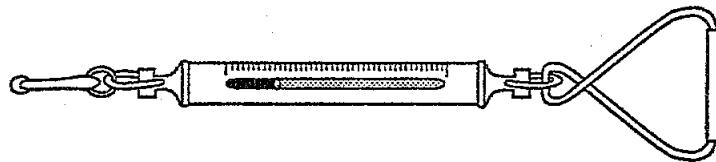


Figure 12. Tape tension handle.

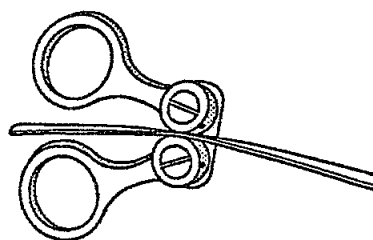


Figure 13. Tape clamp handle.

Using a steel tape

For accurate measurements long steel tapes should be used under proper tension. A tension handle (Fig. 12) with a tape clamp (Fig. 13) is attached to the end of the tape and correct tension applied (Fig. 14). Standard tension for most long steel tapes when fully supported throughout their entire length is 10 lbs for tapes up to 100 ft long and 20 lbs for tapes over 100 ft.

Support of a tape for long dimensions is important since sag will cause an error and result in the dimension being overestimated. A pot magnet or a small G clamp (Fig. 15) is useful to secure one end of the tape when the inspector is working alone.

If you take measurements outside in the cold allow the tape to adjust to the temperature for 15-20 minutes or use a tape that is stored outside. The tape and the structure will then be at the same temperature. The measurement obtained will not be the absolute (exact) value at the low temperature but the equivalent room temperature value, i.e., the length the structure would have it if it were in the shop at 20°C.

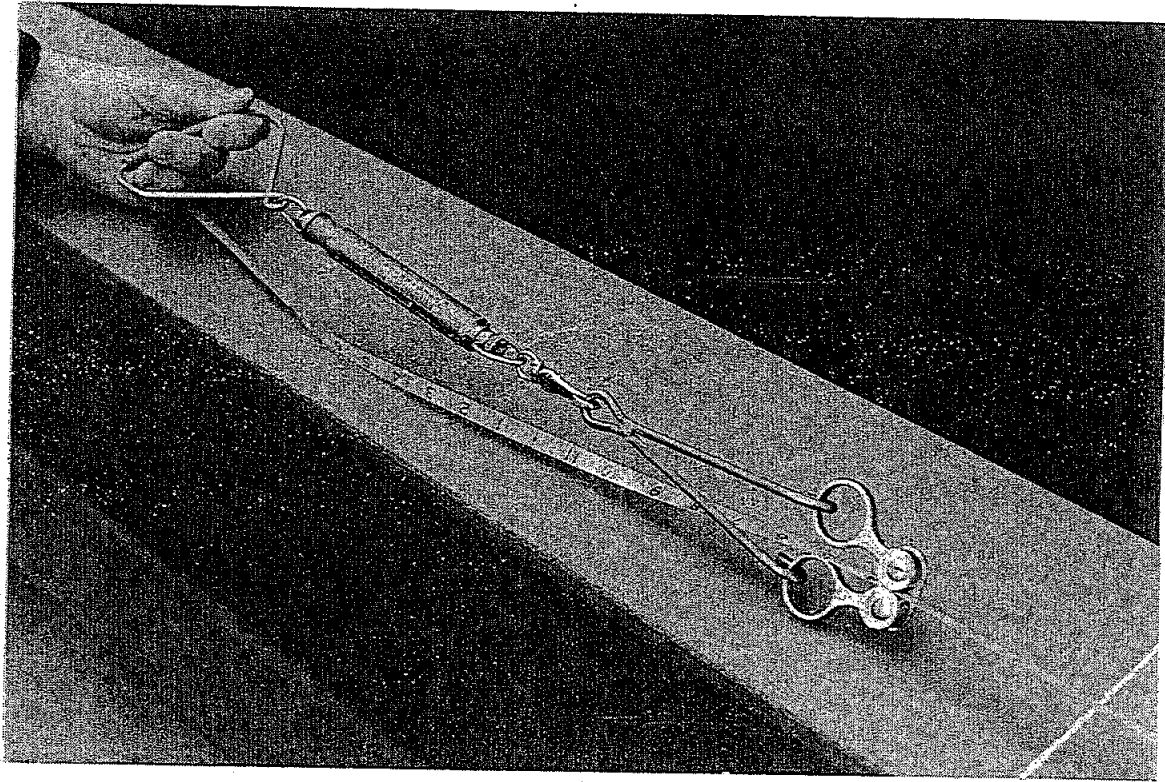


Figure 14. Using a tape clamp and tension handle to apply the correct tension on a tape for long measurements.

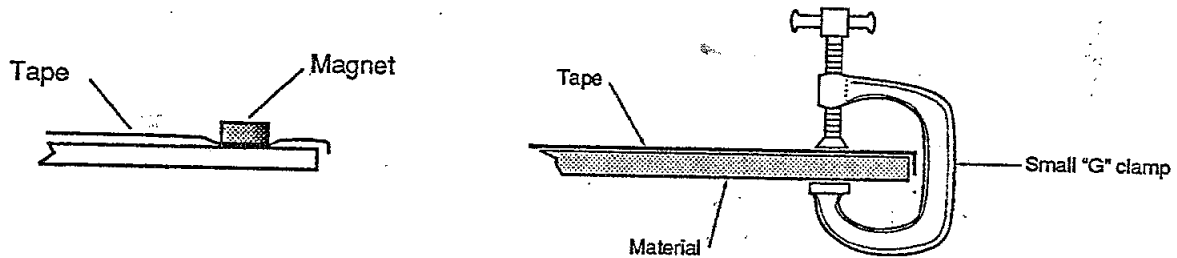


Figure 15. A pot magnet, and a G clamp for securing the end of a tape.

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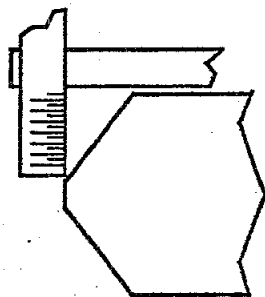


Figure 16. 6" steel rule (Engineer's rule).

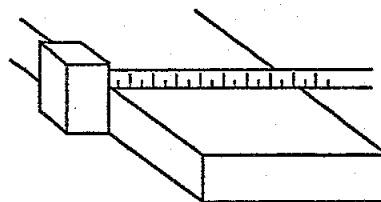


Figure 17. A small block can be used to provide a datum when measuring from an edge.

Steel rule

Shorter dimensions can conveniently be measured with a steel rule (Engineer's rule, Fig. 16). Ensure the ruler is at 90° to the edge or 90° to the surface when making a depth measurement. The zero of the scale on a steel rule is at the end of the rule unlike wooden rulers and it is important the end is not worn or damaged. When measuring from the edge of a component use a small flat block to establish the reference datum line (Fig. 17) rather than guess the zero portion.

Straight edges are used as reference lines and are useful for measuring distortion and flatness of welded components (Fig. 18). Vertical reference lines are easily set up using a plumb bob (Fig. 19) and both horizontal and vertical planes can be checked with a spirit level

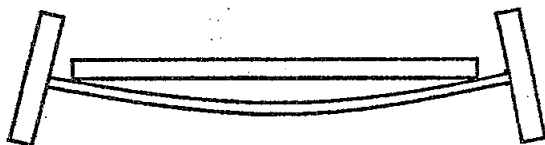


Figure 18. Straight edge, useful for checking flatness.



Figure 19. Plumb bob used as vertical reference line.

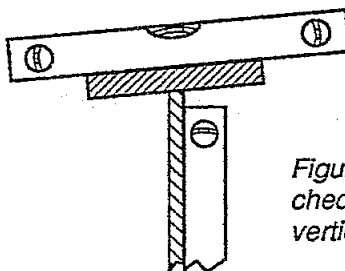


Figure 20. A spirit level can check both horizontal and vertical surfaces.

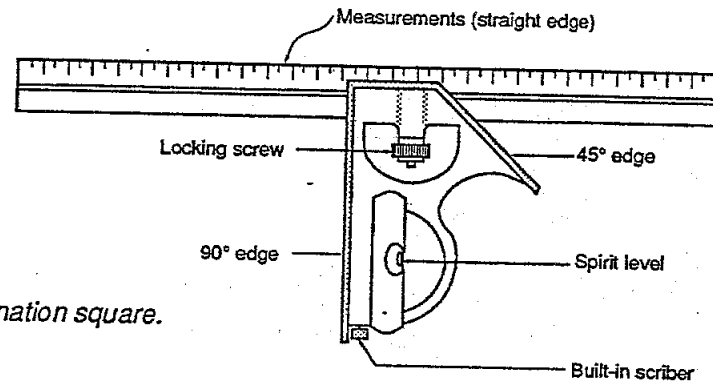


Figure 21. The combination square.

(Fig. 20). A most useful tool is the combination square (Fig. 21) which is valuable for checking 45° preparations, squareness checks, measuring, and straight edge checking. Most combination squares contain a built-in spirit level and scriber.

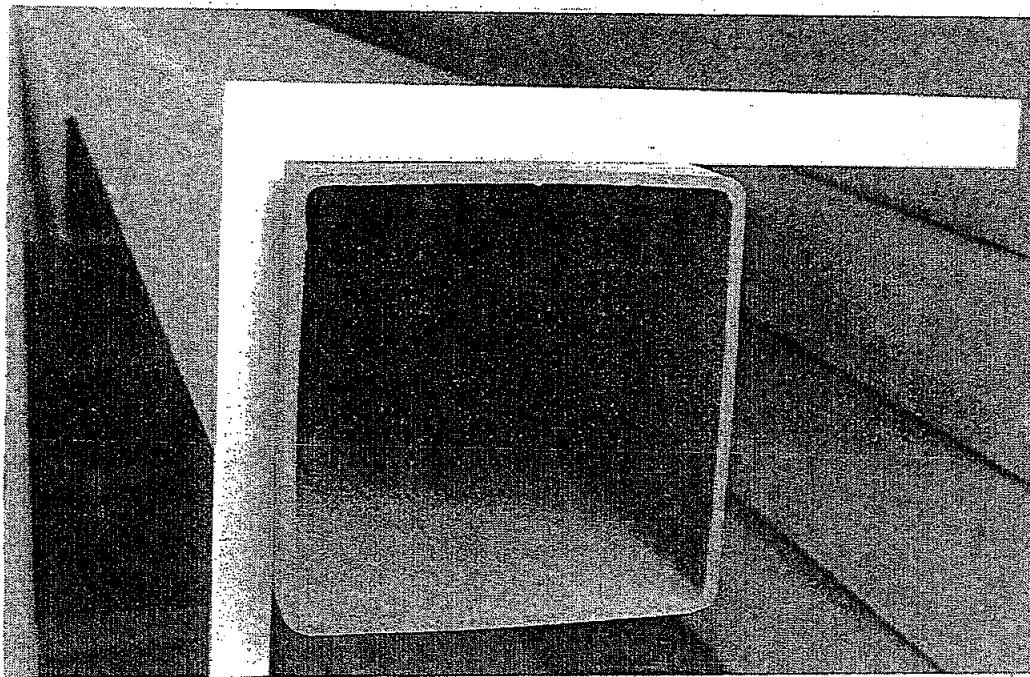


Figure 22. Using the inside edge of a try square to check squareness and wall flatness on a hollow structural section (HSS).

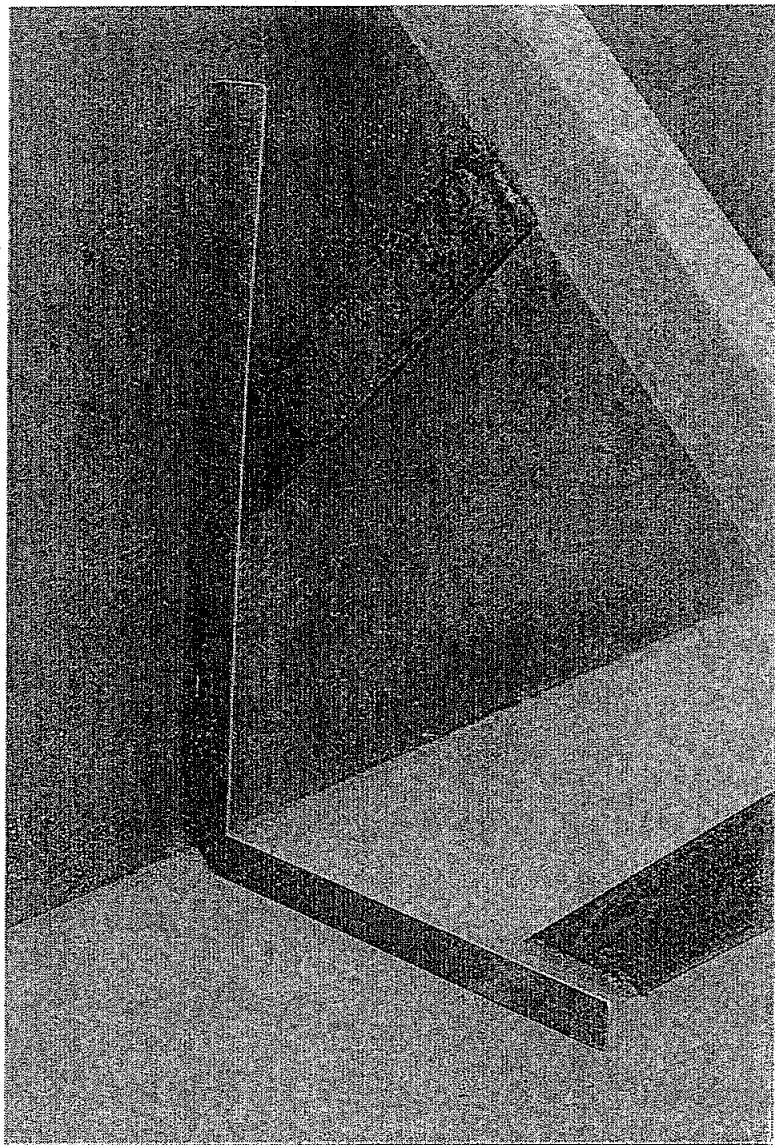


Figure 23. Application of try square. Note the corner is clipped to clear the fillet weld.

Try square

The fundamental instrument for checking squareness (90° angles) is the try square. Precision try squares have a thick stock and a thinner blade of hardened steel, but simple squares are commonly used in the shop. Both the inside (Fig. 22) and the outside edges can be used. A typical application would be checking the angle between two plates fillet welded together (Fig. 23). Note that for such uses the corner of the square is clipped to clear the fillet weld.

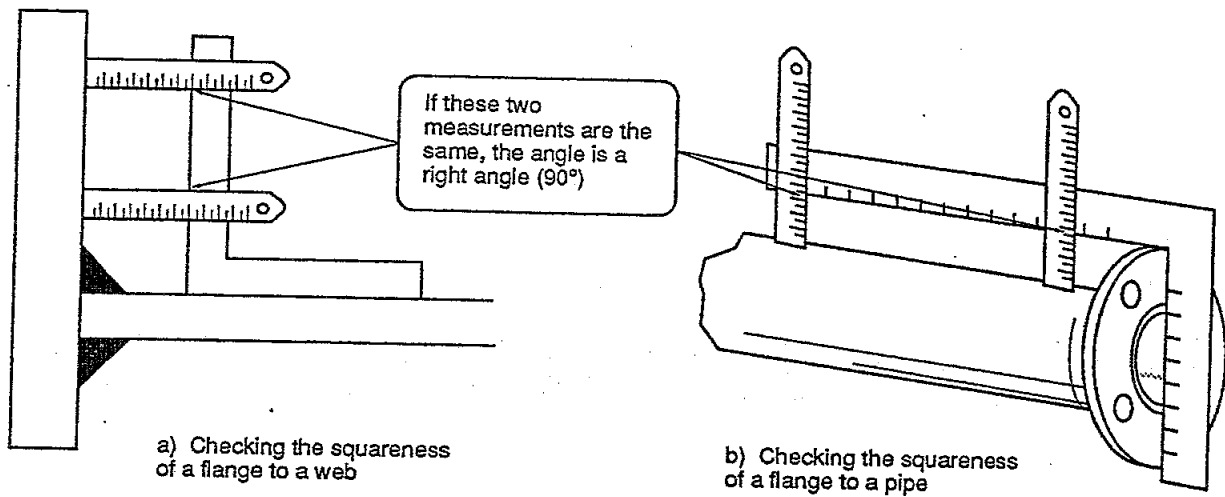
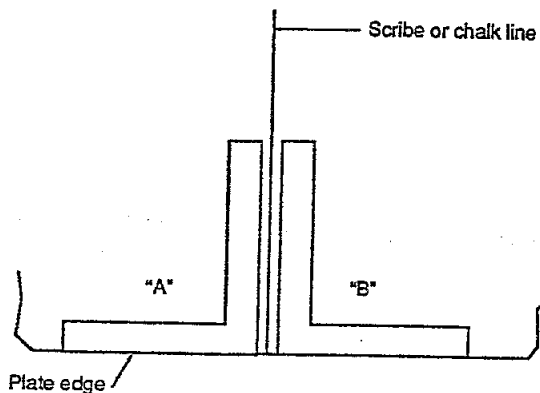


Figure 24. Checking a right angle without contacting one of the members. a) Checking web-to-flange squareness. b) Checking flange-to-pipe squareness.

If it is not convenient to place the square directly against the vertical member (e.g., because of a large fillet weld), gauge blocks, feeler gauges, or a rule can be used to check the gap at two locations as shown in Fig. 24. If the gap is the same the angle is 90°.

Try squares should be treated with care to avoid damage or distortion and should be checked regularly for squareness. A simple method of doing this is shown in Fig. 25. This method is quite sensitive as any error is doubled, but it requires a good straight edge on the plate. Other, less convenient, methods that do not require a reference edge are shown in Fig. 26.

Figure 25. Method for checking a square. Place the square against the plate edge in position "A" and scribe a line. Then move it to position "B" to check if the line is at right angles to the plate edge.



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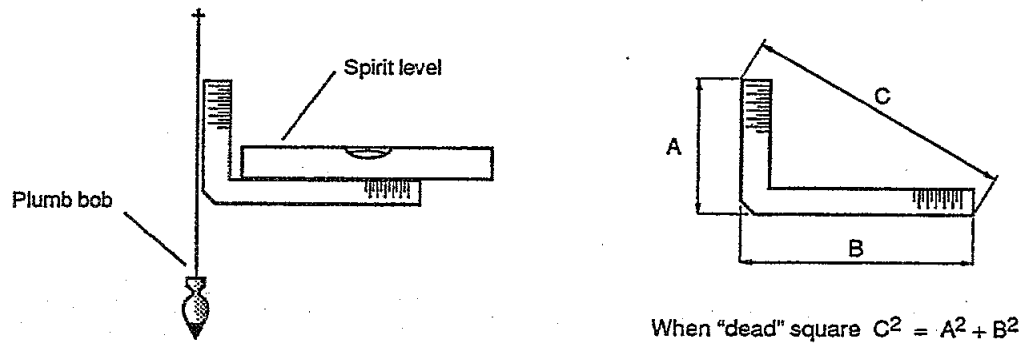


Figure 26. Other methods for checking a square.

Using a string

A string may sometimes be used to set up a reference line, for example, when measuring warpage in a plate. Measurements must be made in the horizontal direction so that they are at right angles to the sag in the string. An error will be introduced into the dimension if a vertical measurement is made (Fig. 27). Fig. 28 shows a method for measuring warpage in a plate. The string is run over two blocks of equal height so that the string clears all high spots. Measurements are then made of the inward or outward warpage or bulge using the string as a reference and allowing for the thickness of the blocks.

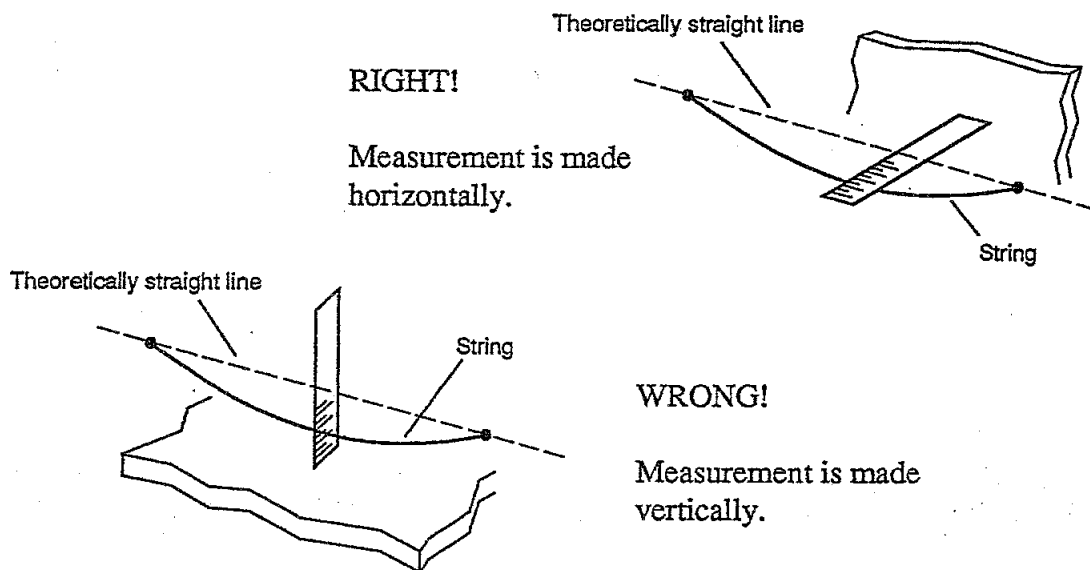


Figure 27. Using a string as a reference line. Measure in the horizontal direction to avoid errors due to sag in the string.

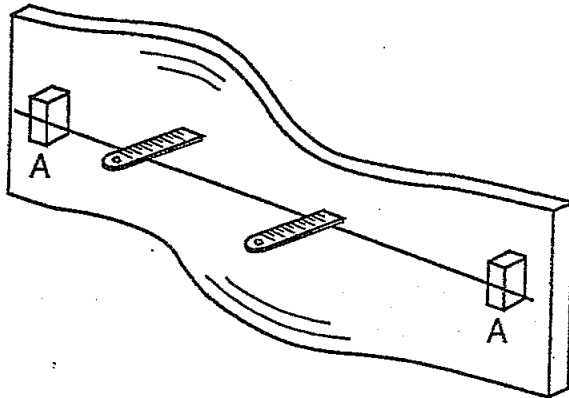


Figure 28. Method for measuring warpage in a plate using a string as a reference. The blocks "A" have equal height.

Other measurements

Gaps can be measured with feeler gauges (Fig. 29) or graduated tapered wedges (Fig. 30). Feeler gauges measure the narrowest point whereas the wedge usually measures the gap at the outside edge. Larger gaps or inside dimensions can be measured with callipers. The callipers are transferred to a rule to obtain the dimension using a flat block as a datum (Fig. 31). Outside callipers may be useful for measuring thickness (for example, at a weld) but only if the callipers can be removed without moving the calliper joint.

Angles, such as weld preparation groove angles, are measured with a protractor (Fig. 32) either by using the protractor directly on the workpiece or by setting the angle on a bevel gauge (Fig. 33) and transferring it to a protractor to read the value.

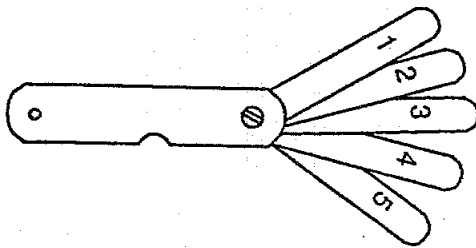


Figure 29. Feeler gauge.

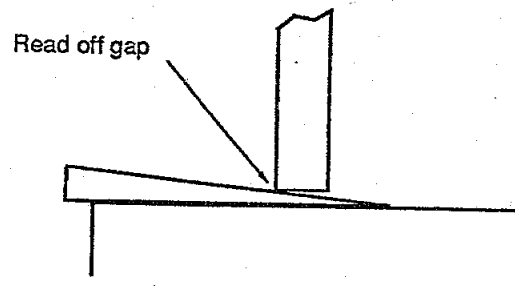


Figure 30. Graduated tapered wedge.

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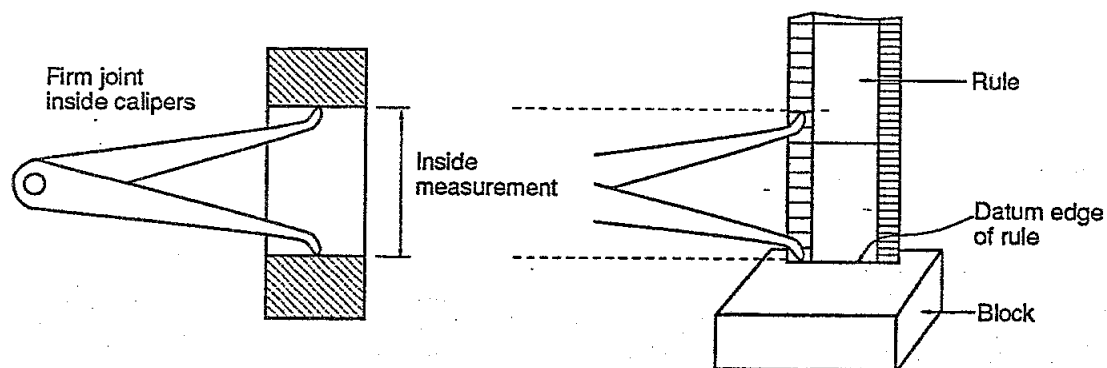


Figure 31. Using callipers for an inside measurement (e.g., hole diameter).

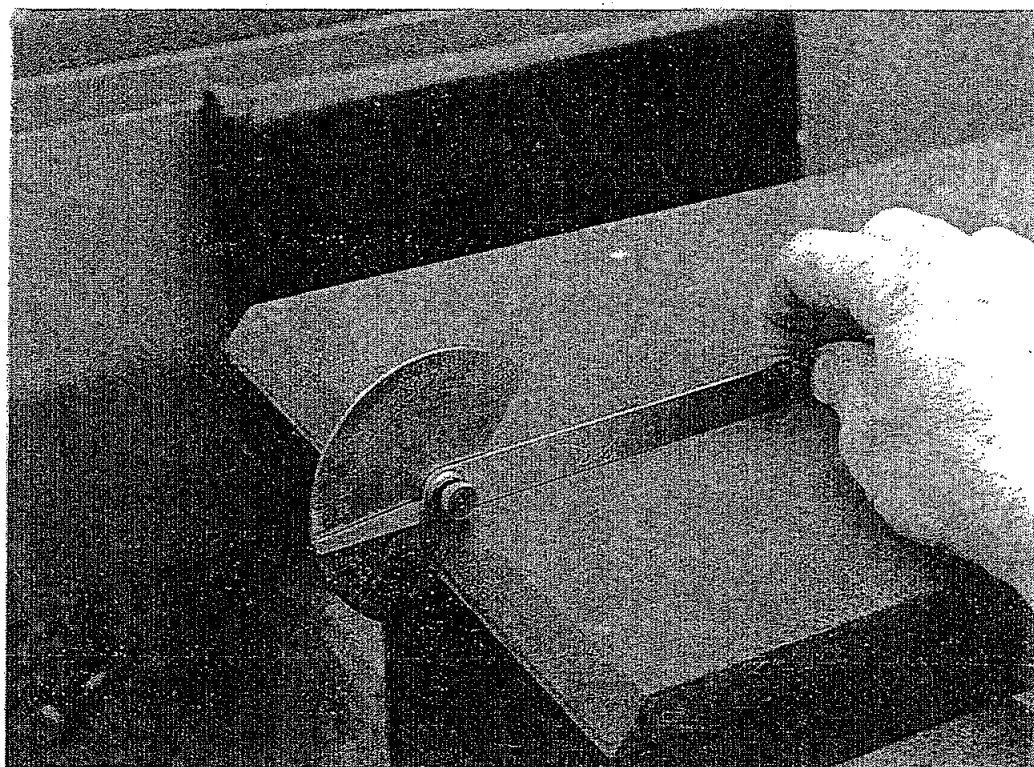


Figure 32. A protractor being used to measure a plate bevel.

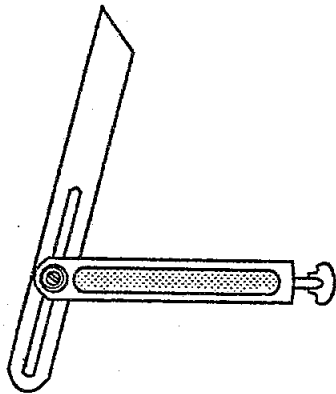


Figure 33. Bevel gauge.

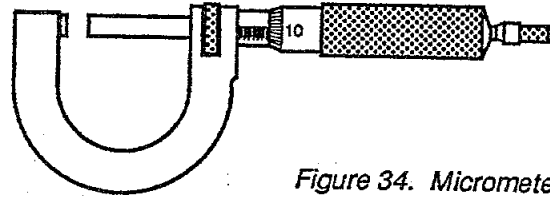


Figure 34. Micrometer.

Small dimensions where high precision is required are measured with a micrometer (Fig. 34). Micrometers are precise, delicate instruments that should be treated with great care: wipe the faces and the workpiece clean before making a measurement; do not use excessive measuring pressure (two 'clicks' of the ratchet are enough); do not leave the faces in contact when not in use.

 Calibration of a micrometer involves checking the zero error by closing up the faces and observing the reading. If this is not zero, the instrument can be adjusted to remove the zero error. Then the instrument can be checked (Fig. 35) with gauge blocks of various thicknesses to determine if it is accurate over the rest of the range (Fig. 36).

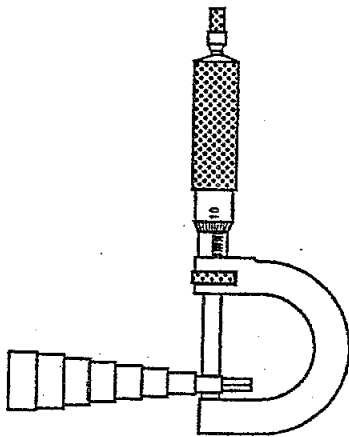


Figure 35. Micrometer calibration.

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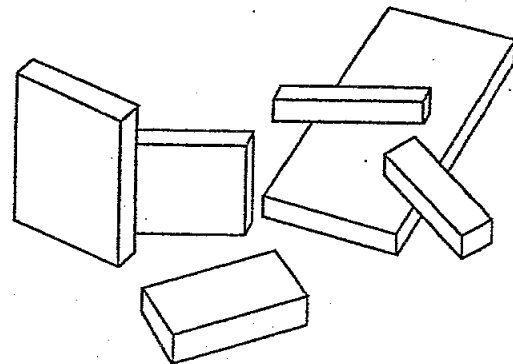


Figure 36. Other types of gauge blocks.

Techniques of Visual Inspection

Other measurements and tools

The inspector may be required to measure the temperature of something, for example, the preheat temperature of a plate before welding commences. The most convenient method is the thermocrayon (Fig. 37), often called by the popular trade name, Tempilstik. Each crayon corresponds to a specific temperature. To use, stroke the heated plate with the crayon. If the plate has a temperature higher than that indicated on the crayon, the mark will smear as the crayon material melts. Make sure the crayon is not directly exposed to the preheating flame. To establish the temperature of the plate you need several crayons covering a range of temperatures to find the highest one that just melts. In many cases the exact temperature is not required and only two crayons corresponding to the minimum and maximum temperature are needed.

Figure 37. Using a thermocrayon for temperature measurements.

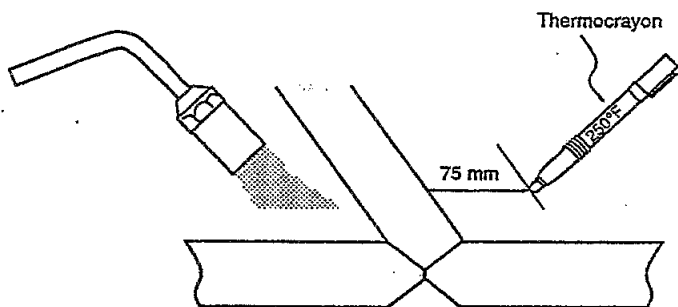
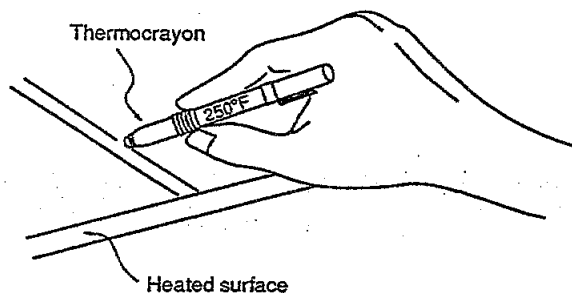


Figure 38. Check preheat temperature 75 mm away from the joint.

Where preheats are concerned you must take care to measure the temperature at the correct location. CSA W59-M1989 states that the surfaces of the parts on which weld metal is to be deposited must be at or above the specified minimum preheat temperature for a distance equal to the thickness of the part being welded but not less than 75 mm,

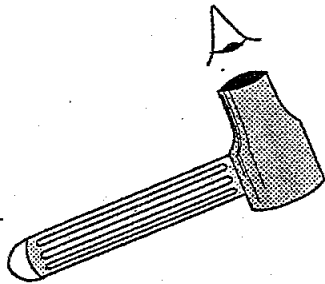


Figure 39. Magnifying glass.

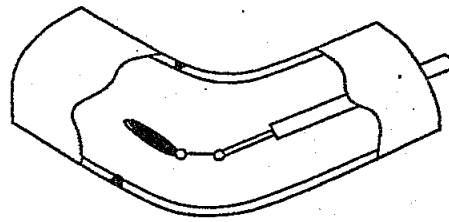


Figure 40. Inspection mirror.

both laterally and in advance of welding (Fig. 38). The specified minimum preheat must be achieved prior to starting to weld and must be maintained during welding.

A magnifying glass (Fig. 39) is a useful tool for the inspector to have. Some have built in lamps which are particularly useful where the component is not well lit. Some glasses have scales marked on the lens allowing precise measurements to be made. Mirrors are useful for inspecting areas with difficult access such as around bends in tubes (Fig. 40). Inaccessible areas may also require optic fibre devices to facilitate visual inspection.

Prior to welding, materials must be physically inspected for evidence of defects, particularly those defects that could arise from a previous stage of fabrication. Some of the defects that could be present in plate material are:

- Pipe—a solidification cavity which could appear as a lamination in the middle of an end section of a rolled plate.
- Blister—a raised portion on the surface caused by a gas bubble.
- Scab—a splash of metal in the ingot mold.
- Seams—these are long surface lines that can result from improper rolling.
- Mechanical slivers—loose or torn segments of steel rolled into the surface.
- Rolled-in scale—scale from a previous heating operation that has not been removed and becomes rolled into the surface, 0.25-1 mm deep (Fig. 41).

Inspecting
materials



Figure 41. Example of heavy rolled-in scale giving a 'washboard' effect.

Craters and pits may occur where forming (e.g., rolling a plate cylinder) has loosened rolled-in contaminants leaving behind a depression in the material and locally reducing the thickness. On the edge of the plate there may be evidence of laminations or delaminated regions (Fig. 42). These may open up when the surface of the plate is heated, when the plate is cut, or when it is welded.

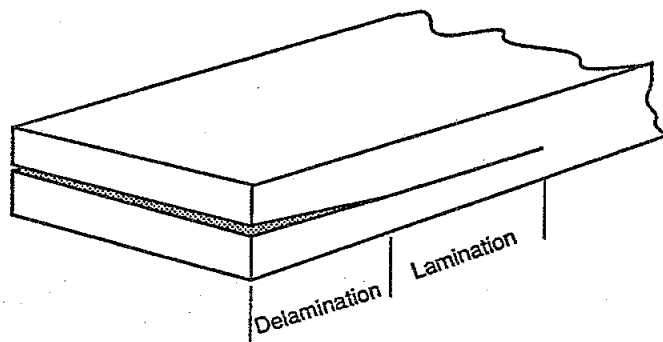


Figure 42. Laminations and delaminated regions in a plate.

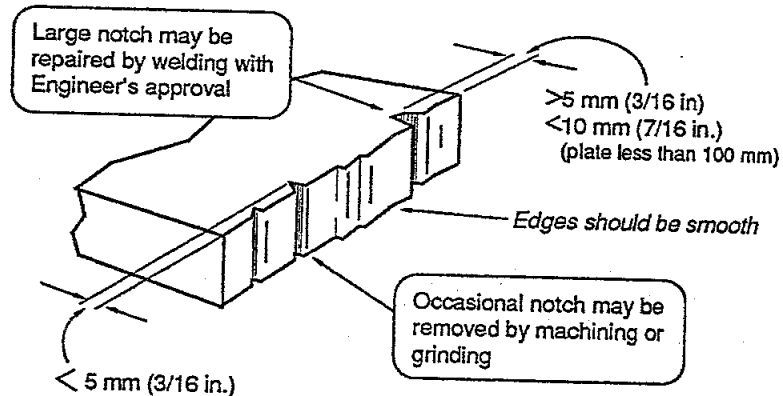


Figure 43. Flame cut edges. A 1 000 μm finish is generally acceptable for plate material up to 100 mm (4 in.) thick.

Flame cut edges

Flame cut edges must be inspected and CSA W59 gives acceptance criteria for these which are summarized in Fig. 43. The Standard requires the edge to be smooth but occasional notches, within the limits shown, may be removed by grinding or machining. Larger notches may be repaired by welding with the engineer's approval.

Acceptable flame cut edges are particularly important where a radius has been introduced in a change of section. The radius must be checked as well as freedom from notches exceeding the allowable size (Fig. 44).

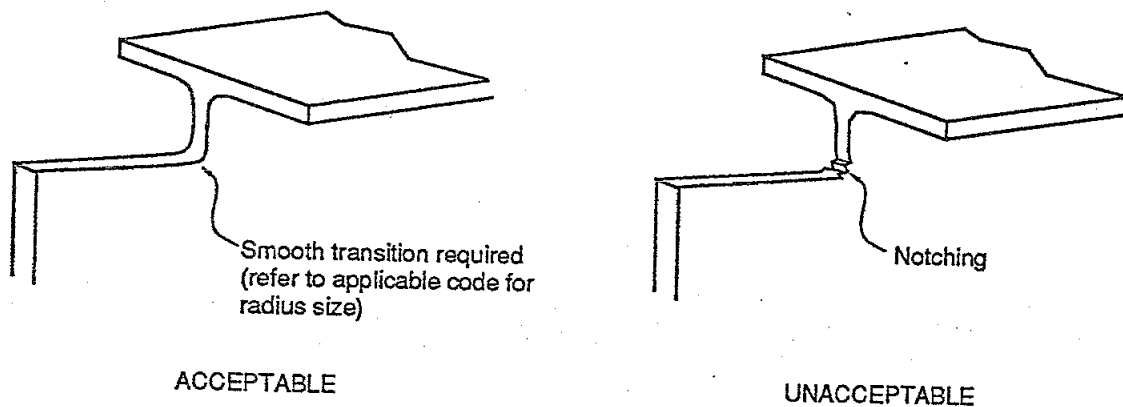


Figure 44. Re-entrant corners.

Inspection before welding—Fit-up

Surfaces and edges that are to be welded must be free of slag, rust, paint, and so forth within 50 mm of the weld to prevent weld contamination.

Material that has been formed should be examined for evidence of cracks on both the inside and outside of the bend. Examine the surfaces for excessive depressions or gouging from inappropriate forming dies. The radius of bend should be checked, and for large radii this is best done with a wooden template.

Inspection of fit-up prior to welding to ensure that it is within acceptable limits is important because not only can it affect the quality of the weld but it also minimizes the error in the final dimensions of the product. The two main fit-up dimensions are the gap between pieces to be welded and the misalignment normal to the plate surface. The presence of gaps has a major impact on the cost of welding because for gaps larger than a certain size the fillet weld size must be increased to compensate (Figs. 45 and sidebar). Gaps must be checked *before* welding because in many cases (such as HSS fabrication) there is no way of verifying the gap size after welding and thus the size of fillet weld that should have been used.

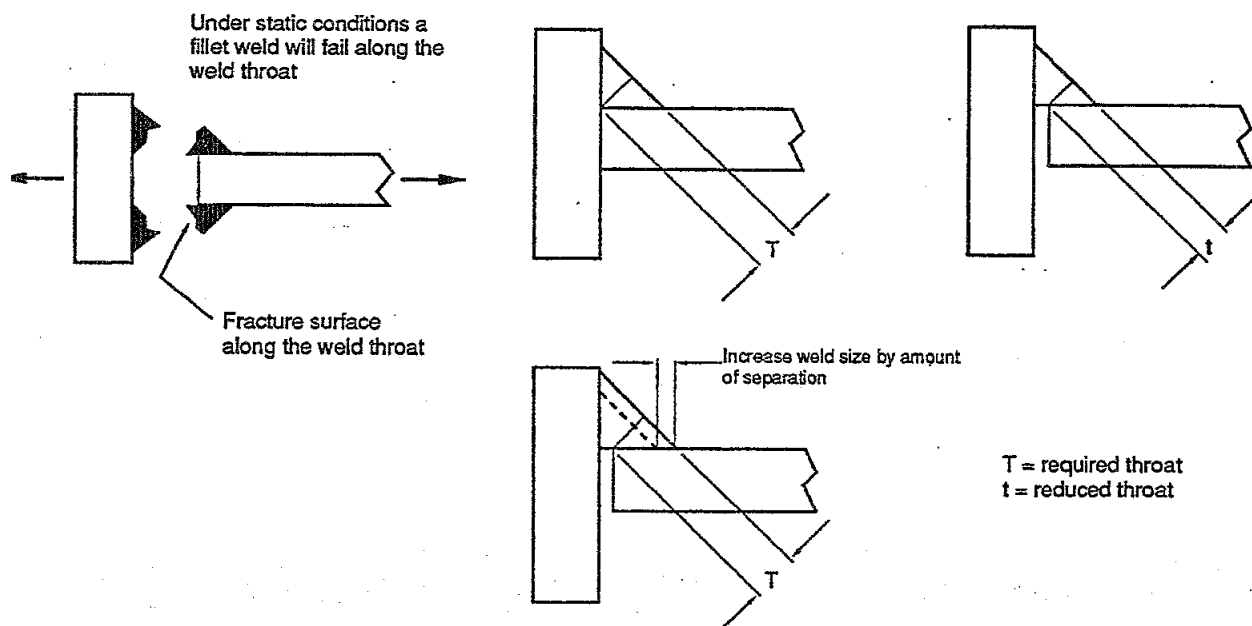
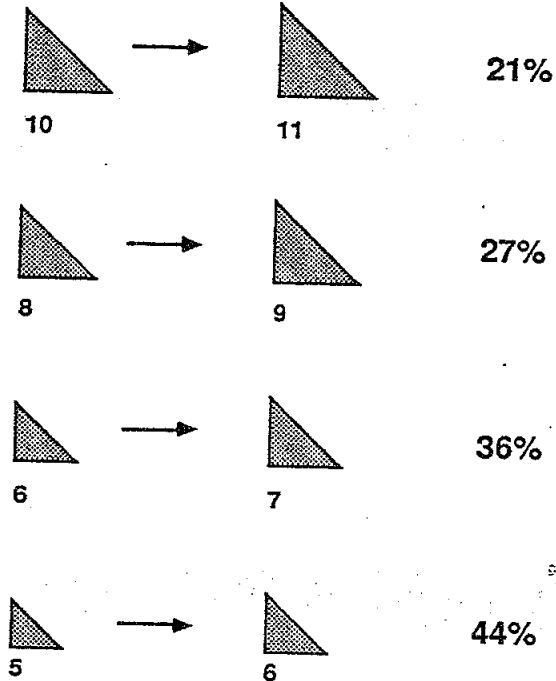


Figure 45. Fillet weld gap. When the gap exceeds specified limits, the fillet size must be increased to compensate for the gap.

Overwelding



The significance of overwelding

In the sketch the % increase in the weight of the deposited weld metal is shown for an increase in 1 mm of the fillet weld size.

Depositing larger welds than necessary can incur an enormous economic penalty.

There is a cost to poor fit-up, since a gap larger than 1 mm (1/16 in) requires the fillet weld size to be increased by the amount of the gap.

As an example, if a 5 mm fillet weld is specified and a 2 mm gap is present, a 7 mm weld must be deposited requiring almost *twice* the weld metal that would be required with good fit.

Techniques of Visual Inspection

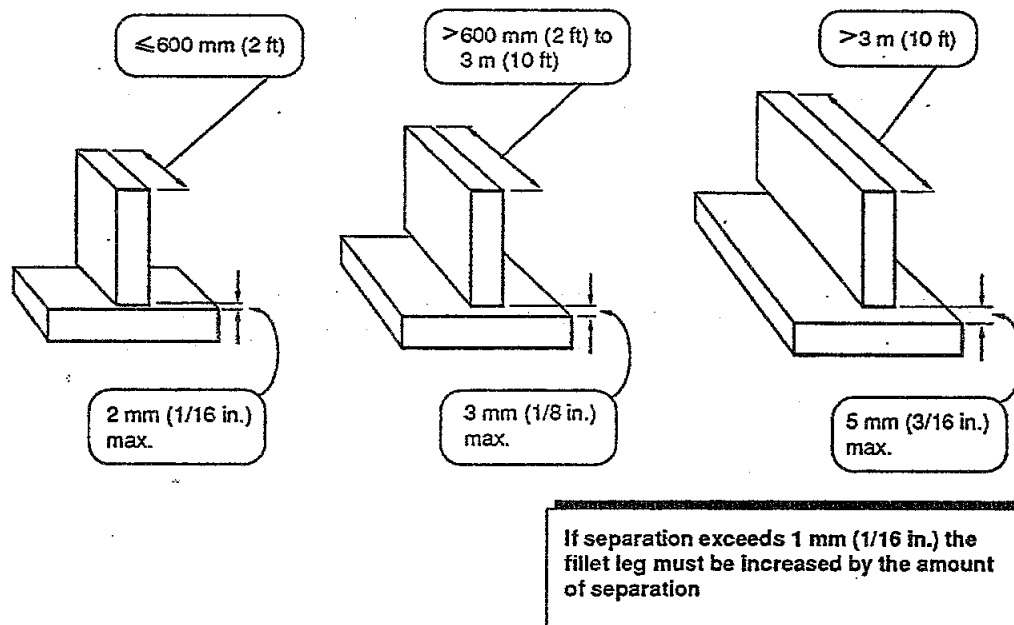


Figure 46. Summary of fit-up requirements for fillet welds from CSA W59.

The requirements of CSA W59 for fit-up of parts to be fillet welded are summarized in Fig. 46. Note that in the S.I. edition the maximum gap for welds not exceeding 600 mm is 2 mm but the fillet size must still be increased if the gap exceeds 1 mm. In the Imperial edition both these figures are 1/16 in.

The maximum misalignment (offset) in W59 for parts to be groove welded is 10% of the thickness of the thinner part but no greater than 3 mm (Fig. 47). This limit, however, may be smaller where backing bars are used since the maximum gap onto the bar is 2 mm.

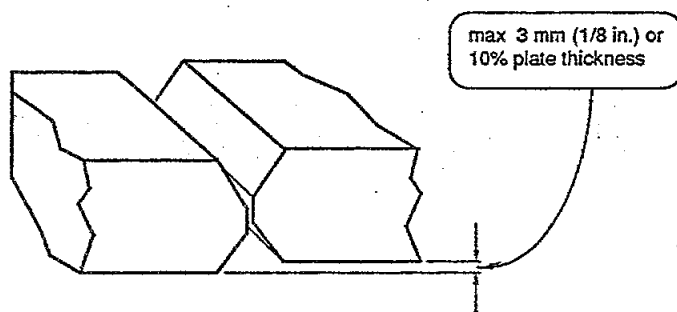
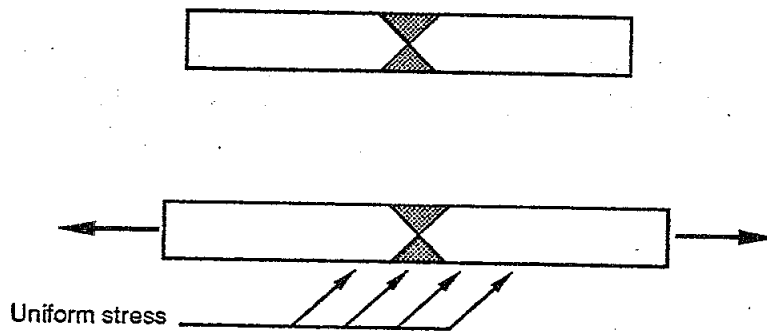


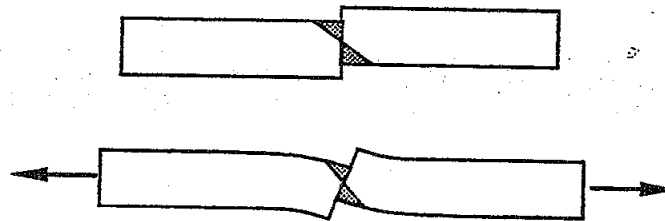
Figure 47. Alignment requirements for groove welds (W59).

Effect of misalignment

Two welded plates in perfect alignment will stretch uniformly



Hence stress at the joint: $S = \text{tensile stress}$



Misaligned plates will also stretch, but local bending will occur at the joint as the forces tend to line themselves up. Hence stress at the joint:

$S = \text{tensile stress} + \text{bending stress}$

Measuring fit-up

Misalignment can be measured with a rule (Fig. 48) if done before welding or with some types of welding gauges. The Welding Institute gauge from TWI in England has this capability and is useful for making measurements after welding (Fig. 49). Care should be taken when measuring misalignment of longitudinal seams in pressure vessels where the plate is curved. Use the gauge at an angle as close as possible to the weld to avoid the effect of the plate curvature (Fig. 50).

Techniques of Visual Inspection

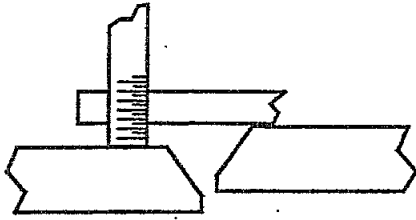


Figure 48. Measuring misalignment before welding with a rule.

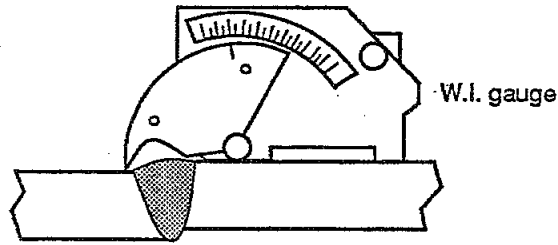
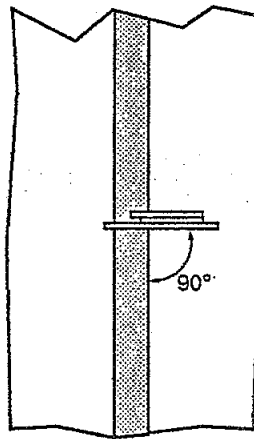
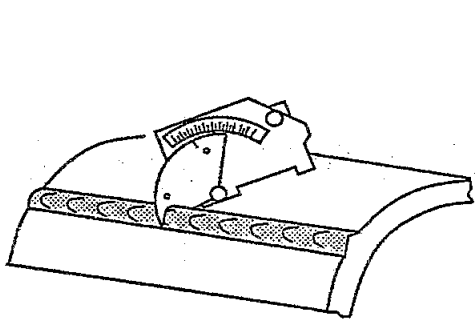
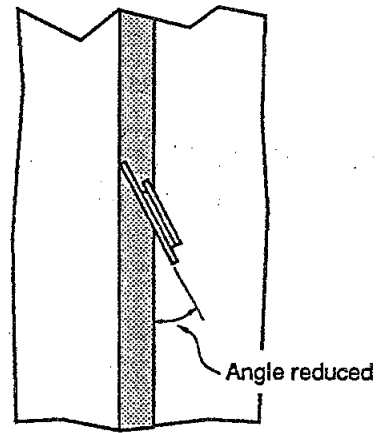


Figure 49. Measuring misalignment after welding with the W.I. gauge.



Flat plate



Vessel

Figure 50. Measuring misalignment on a vessel seam.

Gaps can be measured using a tapered wedge (Fig. 51). Another convenient method is to use wires (e.g., electrode wires) of known diameter as feeler gauges. They also provide some information on the depth of the gap. In some cases the gap can be measured at the end of the weld (Fig. 52) after the weld is completed.

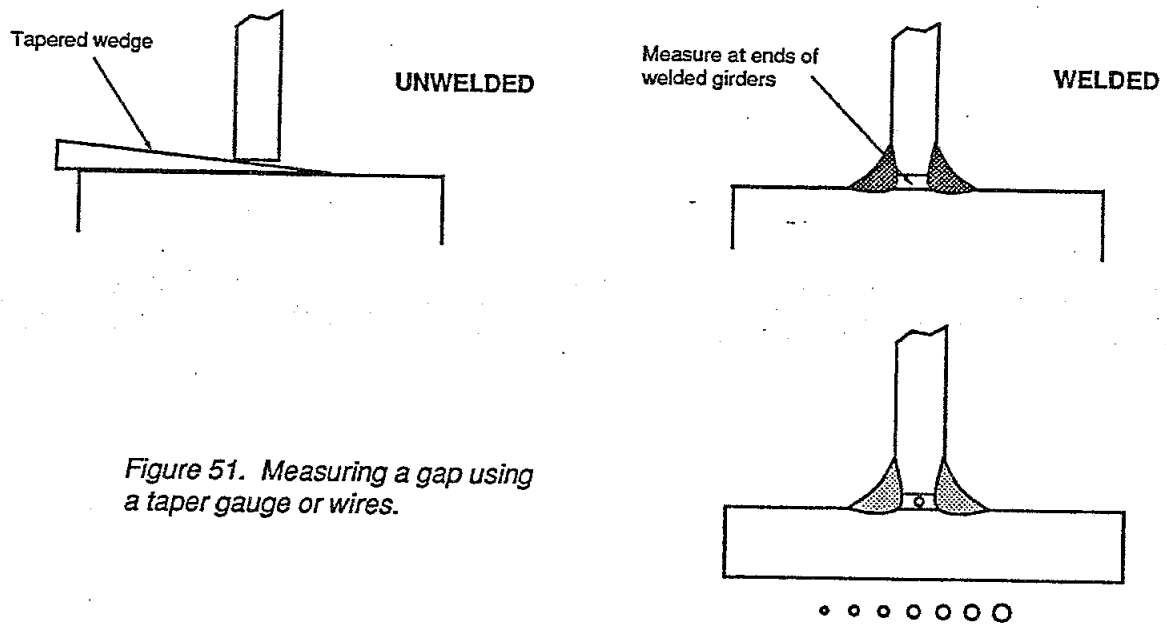


Figure 51. Measuring a gap using a taper gauge or wires.

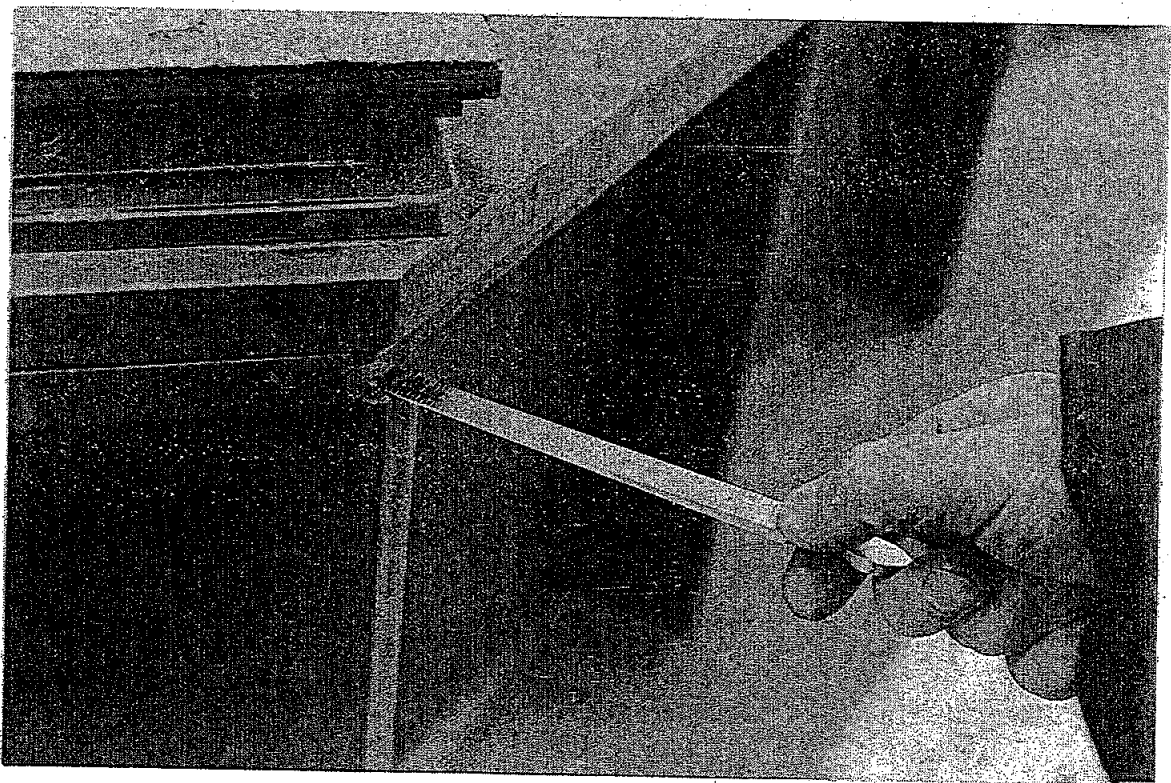


Figure 52. Using a taper gauge to check a gap at the end of a weld.

Techniques of Visual Inspection

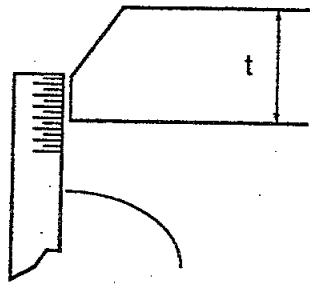
Table 1. Summary of tolerances on weld groove preparation (CSA W59-M89 Clause 5.4.5.1).

	Root Not Gouged	Root Gouged
1) Root Face of joint	$\pm 2\text{ mm}$	Not limited
2) Root opening of joints:		
Without steel backing	$\pm 2\text{ mm}$	+ 2 mm, - 3 mm
With steel backing	+ 6 mm, - 2 mm	Not applicable
3) Groove angle of joint	+ 10°, - 5°	+ 10°, - 5°

Groove preparation

The tolerances on weld groove preparation according to CSA W59 are summarized in Table 1. Note that the tolerances are greater if welds are backgouged or made onto a backing bar. These tolerances are the workmanship tolerances applied to the specified value. They are not to be confused with the range of values allowed for prequalified joints under Clause 10 of the Standard. For example, a prequalified groove weld detail with a groove angle of 60° could be detailed on the drawings with an angle of 75° since the groove angles given in Clause 10 are minimum values. The specified value of 75° would then be subject to the workmanship tolerances of +10° -5° on the shop floor, i.e., limits of 70° and 85°. There are, however, some exceptions noted in Clause 10 where the workmanship tolerances cannot be applied: where a root face R_f is designated R_f , maximum it is not subject to the "plus" workmanship tolerance. Likewise, a root opening designated as G_{min} shall not be subject to the "minus" workmanship tolerance.

As discussed earlier, the dimensions can be measured with a steel rule (Fig. 53) and the bevel angle with a protractor (Fig. 54). Accuracy of bevel angles is particularly important for partial joint penetration groove welds since the depth of the bevel determines the weld size (Fig. 55). A small error in the location of the bevel may be magnified into a larger error in the depth of bevel. Similarly, a small error in angle can affect the actual weld size.



This measurement gives both root face and depth of preparation

Figure 53. Measurement of groove weld preparation with steel rule.

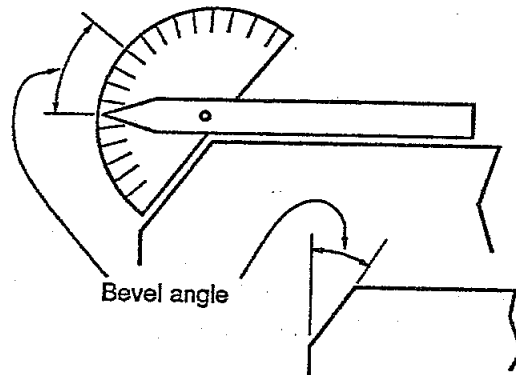
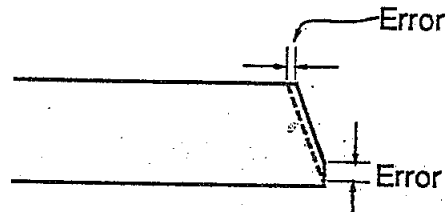
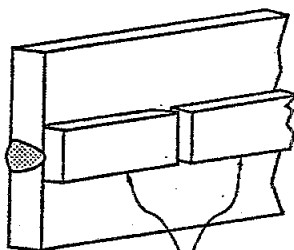


Figure 54. Measurement of bevel angle with protractor.

Figure 55. Bevel preparation is critical in partial joint penetration groove welds. Small errors in the bevel may have large effects on the actual weld size.

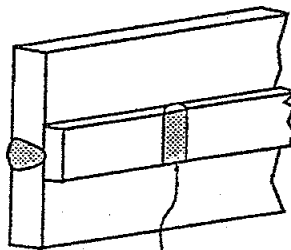


When steel backing bars are used each section of bar must be welded to the next to form a continuous length and eliminate the possibility of the main weld being deposited over a gap (Fig. 56). W59-89 makes an exception for statically loaded hollow structural sections because of limited access.



Individual lengths of backing bars

UNACCEPTABLE



Backing bars welded into one continuous length

ACCEPTABLE

Figure 56. Backing bars are normally required to be welded together to avoid a gap which may initiate cracks.

Measuring welds

The first item in inspecting welds is to determine that the welds have been deposited in the correct locations and that there are no missing welds. This is usually done by marking off on a drawing each verified weld.

In discussing the inspection of weld dimensions it is important to understand the meanings of the various terms used. The terminology used for weld dimensions is summarized in Fig. 57 for fillet welds and Fig. 58 for groove welds. Fillet welds are always specified (in North America) in terms of the weld size which is the leg length of the largest ideal weld (isosceles triangle if an equal leg fillet is specified) that can be contained by the real weld. Although it is the throat dimension that determines the strength of a fillet weld, leg sizes are easier to measure. For a convex fillet weld the size is determined by the shorter of the two measured leg lengths. For a concave fillet weld the throat dimension must be measured because the weld size is smaller than either of the two measured leg lengths (Fig. 57).

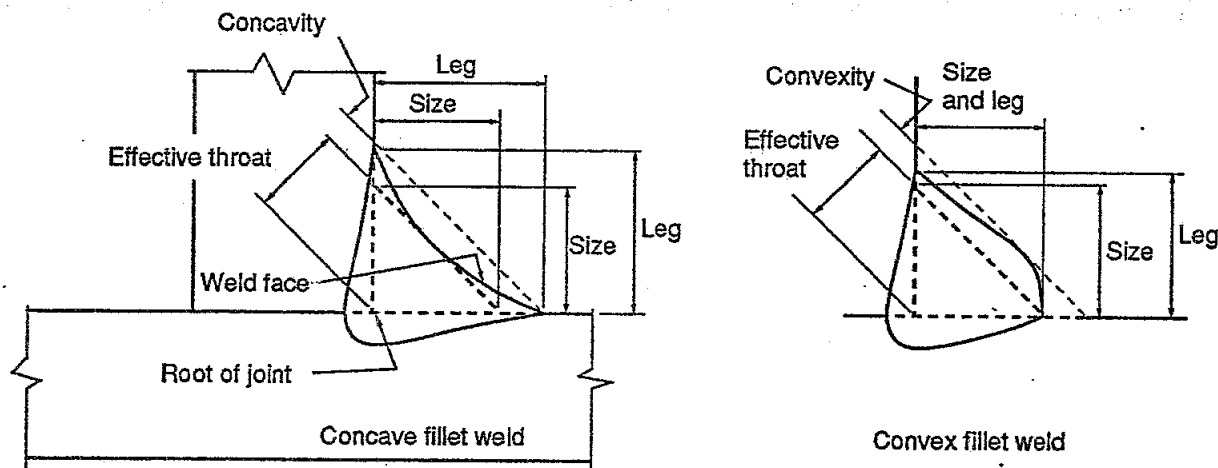


Figure 57. Terminology for fillet welds.

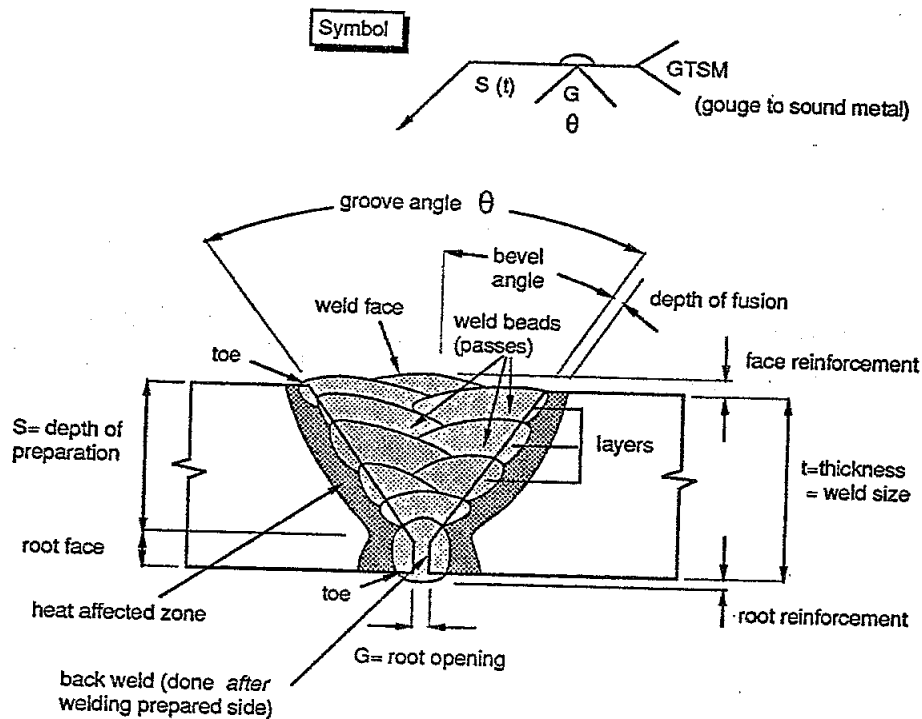


Figure 58. Terminology for groove welds.

TEST QUESTION

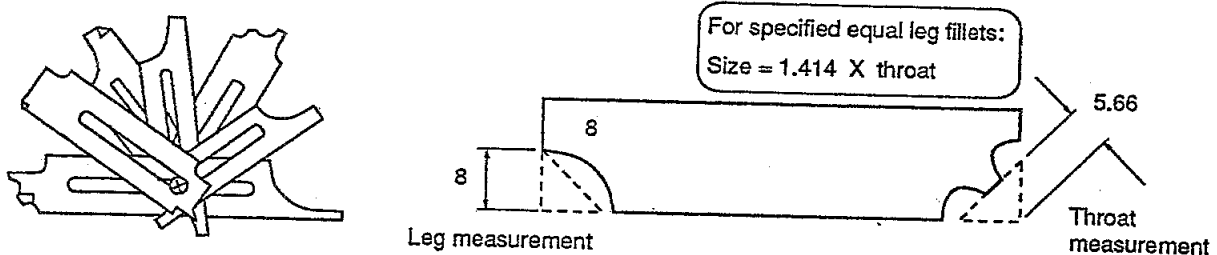
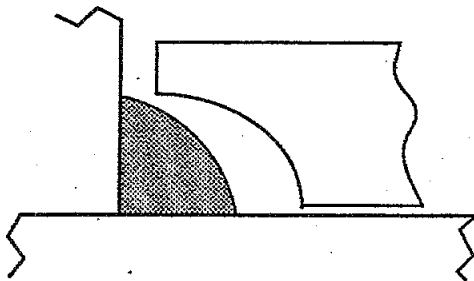


Figure 59. Typical gauges for measuring fillet weld sizes.

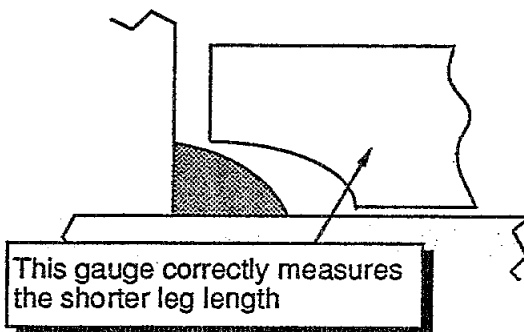
TEST QUESTION

Fillet weld sizes are measured with welding gauges such as the ones illustrated in Fig. 59 and the sidebar shows the method of use. Weld profiles are more difficult to measure but simple convexity and concavity can be determined from the throat measurement. Acceptable and unacceptable fillet weld profiles as required by CSA W59 are shown in Figs. 61 and 62. Unacceptable weld profiles may be corrected by grinding or depositing additional weld metal as shown in Fig. 63.

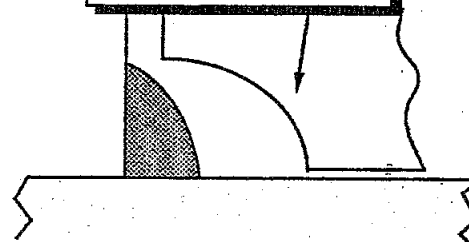
Measuring fillet welds



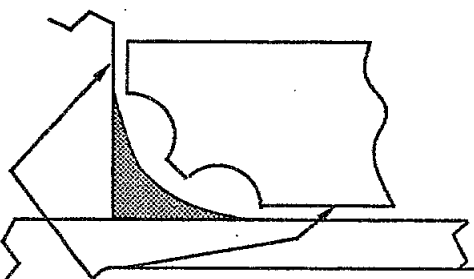
For CONVEX or FLAT fillet welds use gauge to measure leg length.



This gauge incorrectly measures the longer leg length

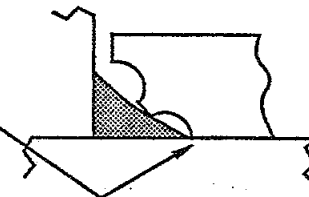


For fillet welds with unequal leg sizes (where an equal leg fillet was specified) always measure the shorter leg length



For CONCAVE fillet welds use gauge to measure the throat.

For concave fillet welds gauge should touch both sides. For welds of unequal leg size concave fillet gauge may give false indication of size. In this case, if equal leg size had been specified, use the special throat gauge shown in Figure 60.



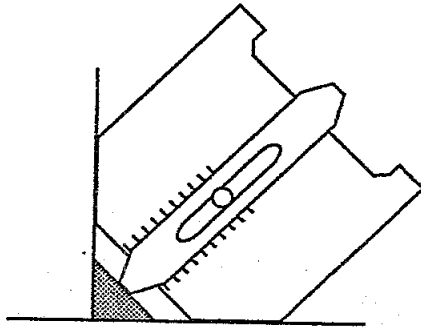
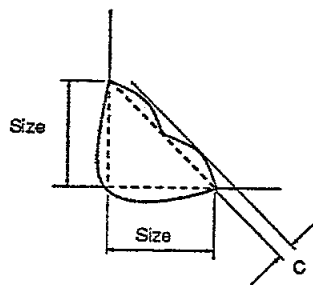
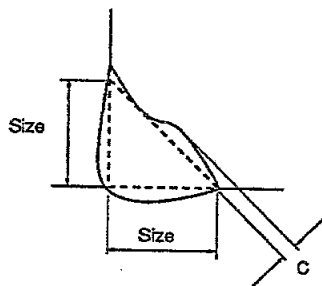
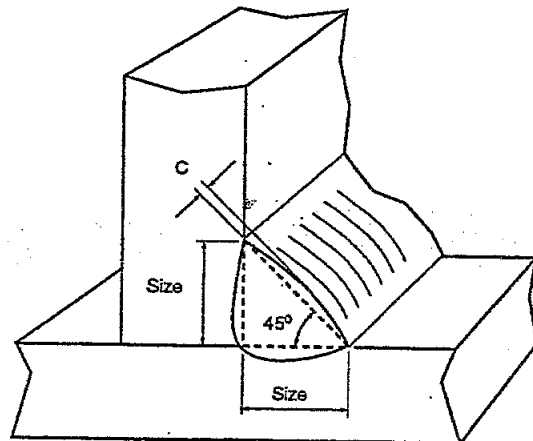
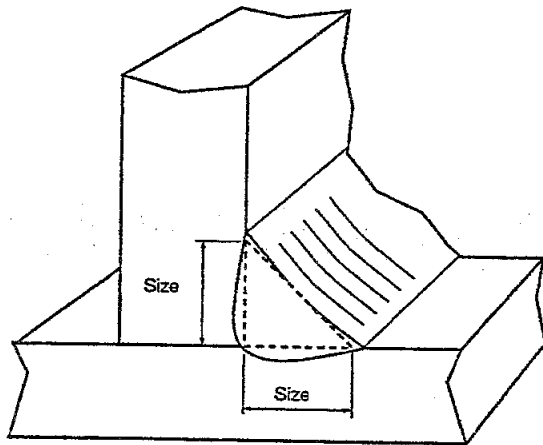


Figure 60. This gauge can measure the weld throat, convexity and concavity in a fillet weld.



According to CSA W59-M1989, convexity, C , of a weld or individual surface bead shall not exceed 0.07 times the actual width of the weld or individual bead plus 1.5 mm.

Figure 61. Fillet welds considered acceptable to CSA W59-89.

Techniques of Visual Inspection

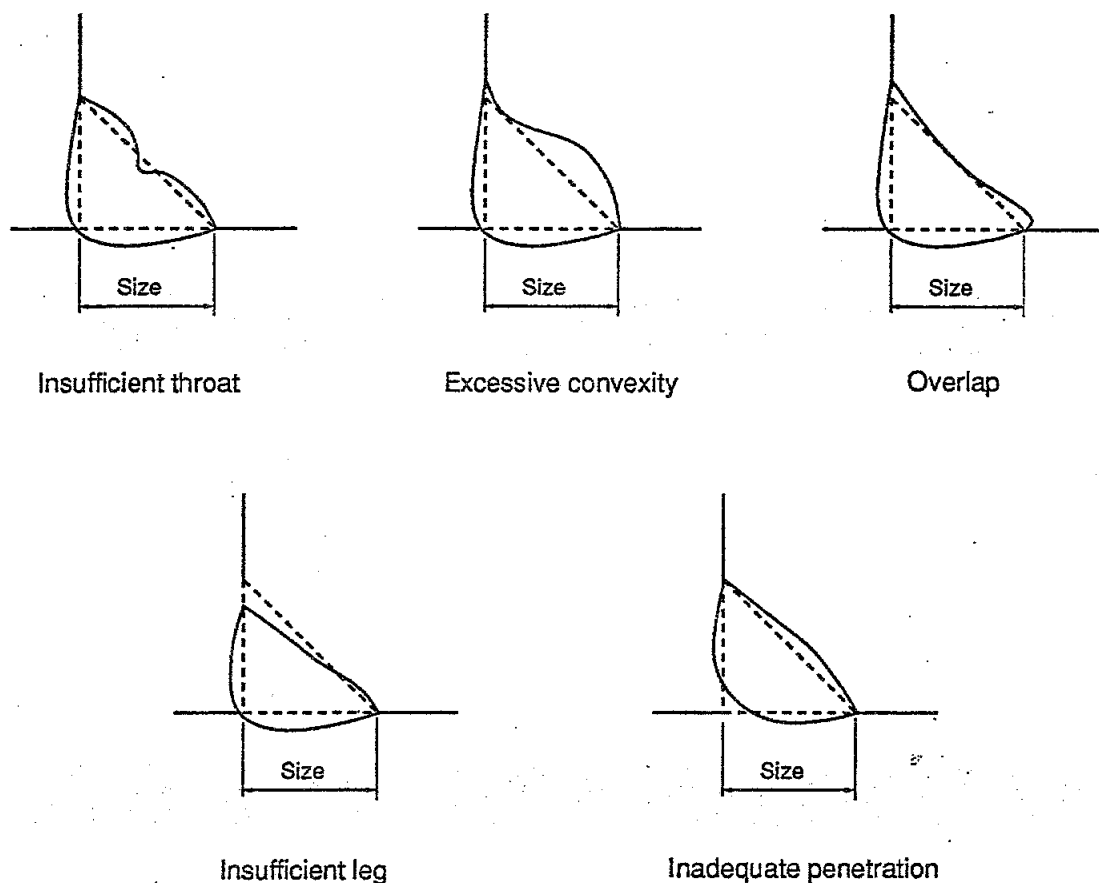


Figure 62. Examples of fillet welds considered unacceptable to W59-89.

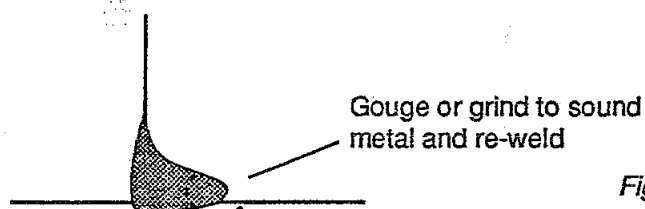


Figure 63. Repairing overlap.

For a groove weld the important dimension is the thickness of the weld as expressed in terms of reinforcement or reduction in thickness (Fig. 64). These dimensions can be measured with depth gauges (Fig. 65), welding gauges (Fig. 66, WI gauge) or callipers, at the end of a weld where the callipers can be removed (Fig. 67).

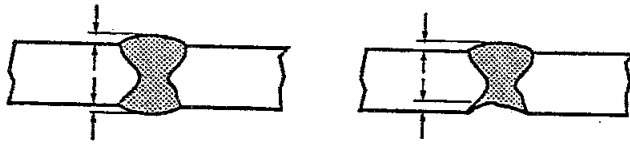


Figure 64. Reinforcement and reduction in thickness are important dimensions in groove welds.

Figure 65. Measuring the reduction in thickness of a weld conditioned by grinding using depth gauge.

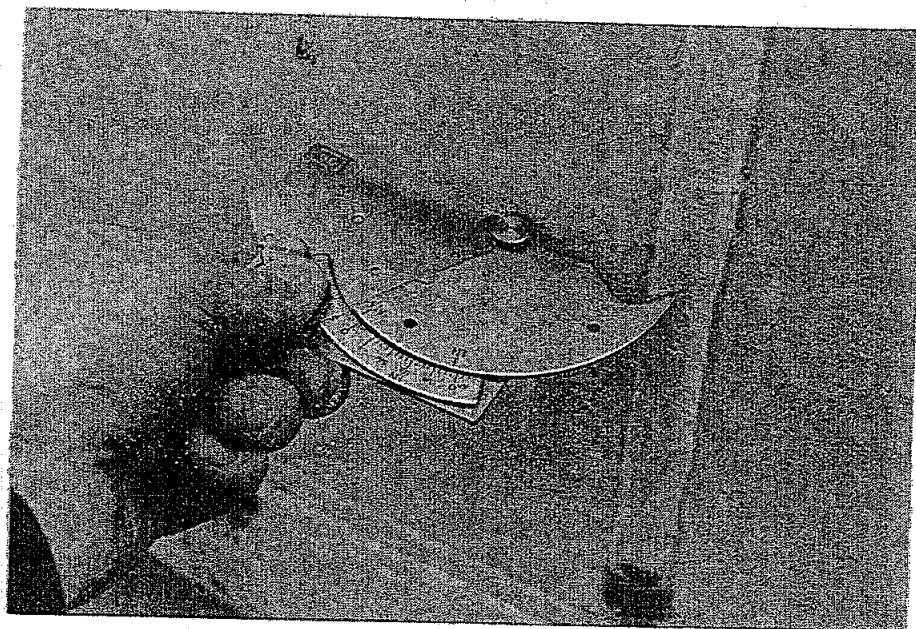
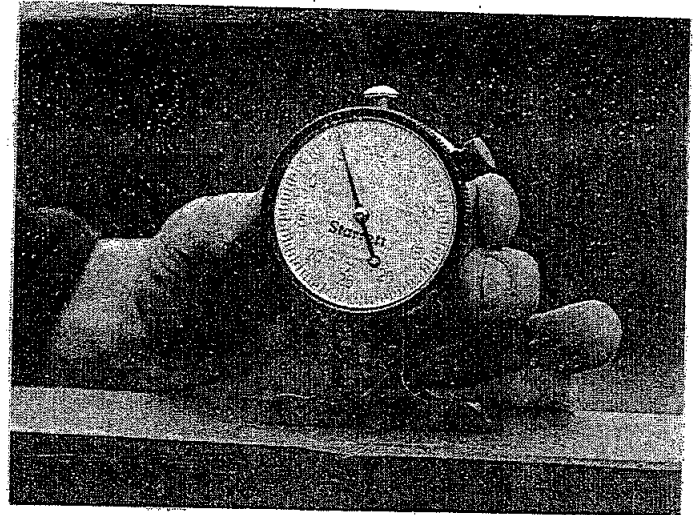


Figure 66. Measuring reinforcement with the W.I. gauge.

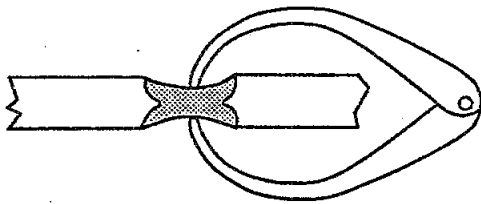


Figure 67. Callipers could also be used to measure reduction of thickness at the end of the weld. Check dimension against a rule.

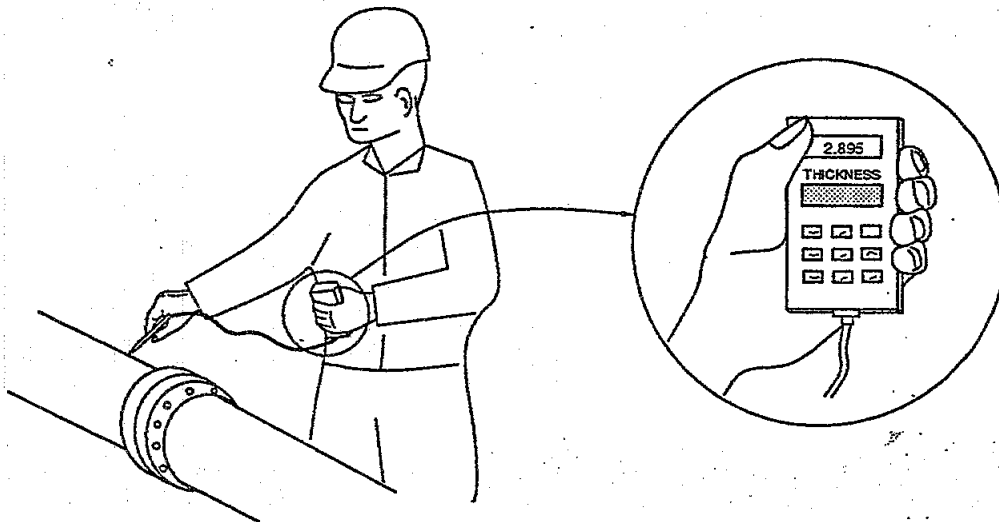


Figure 68. Thickness measurements using an ultrasonic thickness meter.

Flare welds

Ultrasonic thickness gauges that provide a direct reading may be useful for measuring the size of groove welds as well as the thickness of the base metal (Fig. 68).

Flare welds and skewed fillet welds present some difficulties in measuring the size. The size of a flare weld is determined by the throat thickness which, in qualifying the welding procedure, is established by sectioning trial welds. Since the throat thickness cannot be measured directly when inspecting a flare weld, it is common practice to define the weld size in terms of some other easily measurable quantity such as the face width (Fig. 69). Remember, however, that the relationship between these quantities is weld process dependent and would have to be redefined for any change in procedure such as amperage or number of passes.

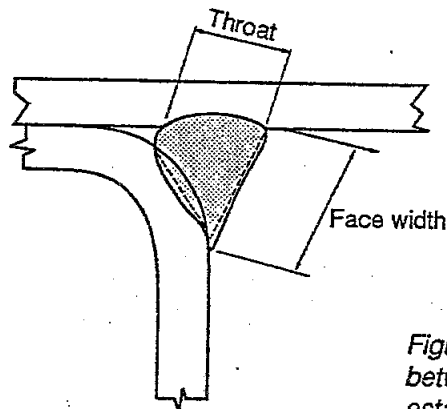


Figure 69. Measuring a flare weld. The relation between face width and throat size must be established for each set of welding conditions.

Skewed fillets

For skewed fillet welds the weld size is defined in terms of the leg length which can be measured directly although a suitable gauge or template that can accommodate the angle is needed (Fig. 70). The relation between leg length and effective throat size is determined by the geometry and is given in CSA W59. For angles less than 60° the weld cannot be classed as a fillet weld because root penetration cannot be relied on, and it must be treated as a partial joint penetration groove weld. In this case, face width becomes the most accessible characteristic dimension to measure and define the weld size.

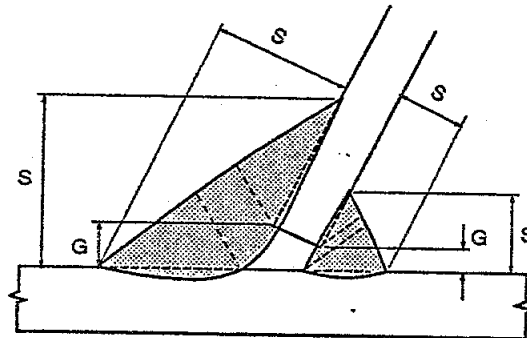


Figure 70. Skewed fillet weld. CSA W59 gives a relation between S and the size of an equivalent 90° fillet weld in terms of G and the skew angle.

Undercut

The acceptance criteria for undercut, as given in CSA W59, depend on the application. For structures that are dynamically loaded, i.e., fatigue loaded, the allowable undercut is very small. This is because fatigue cracks nearly always start from the toe of a weld and the presence of undercut facilitates crack initiation. The acceptance criteria for

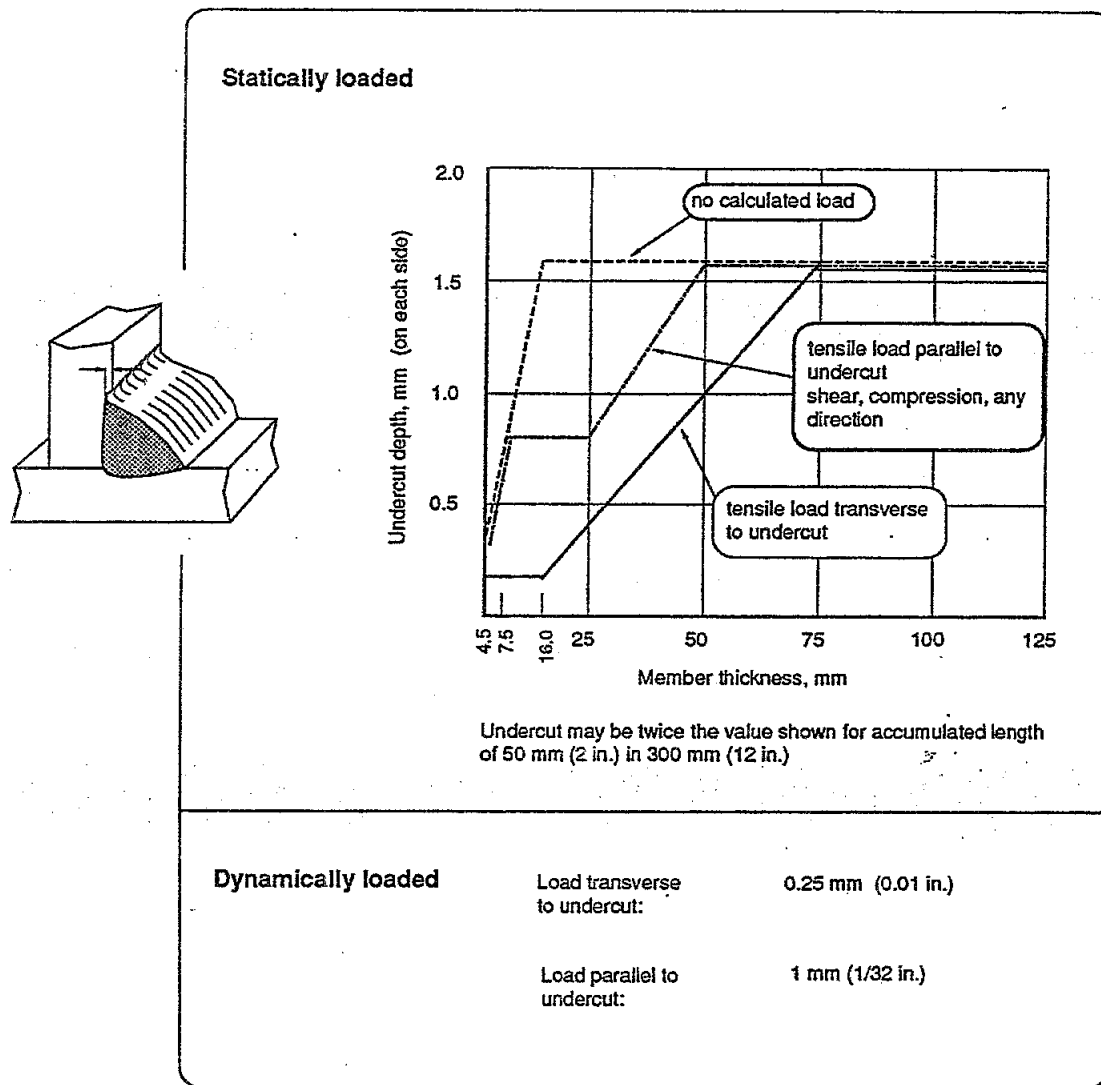


Figure 71. Acceptance criteria for undercut (CSA W59-M1989).

undercut according to CSA W59-M1989 are given in Fig. 71. Some of the acceptance levels for undercut are very small. For example, the Standard only allows 0.25 mm for dynamic loading transverse to the weld.

Undercut can be difficult to measure—particularly when the strict requirements for dynamically loaded structures apply. The W.I. gauge has a feature which allows depth to be measured as shown in Fig. 72 and is useful for determining undercut.

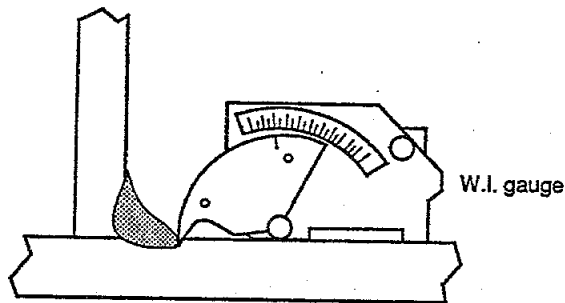


Figure 72. Measuring undercut using the W.I. gauge.

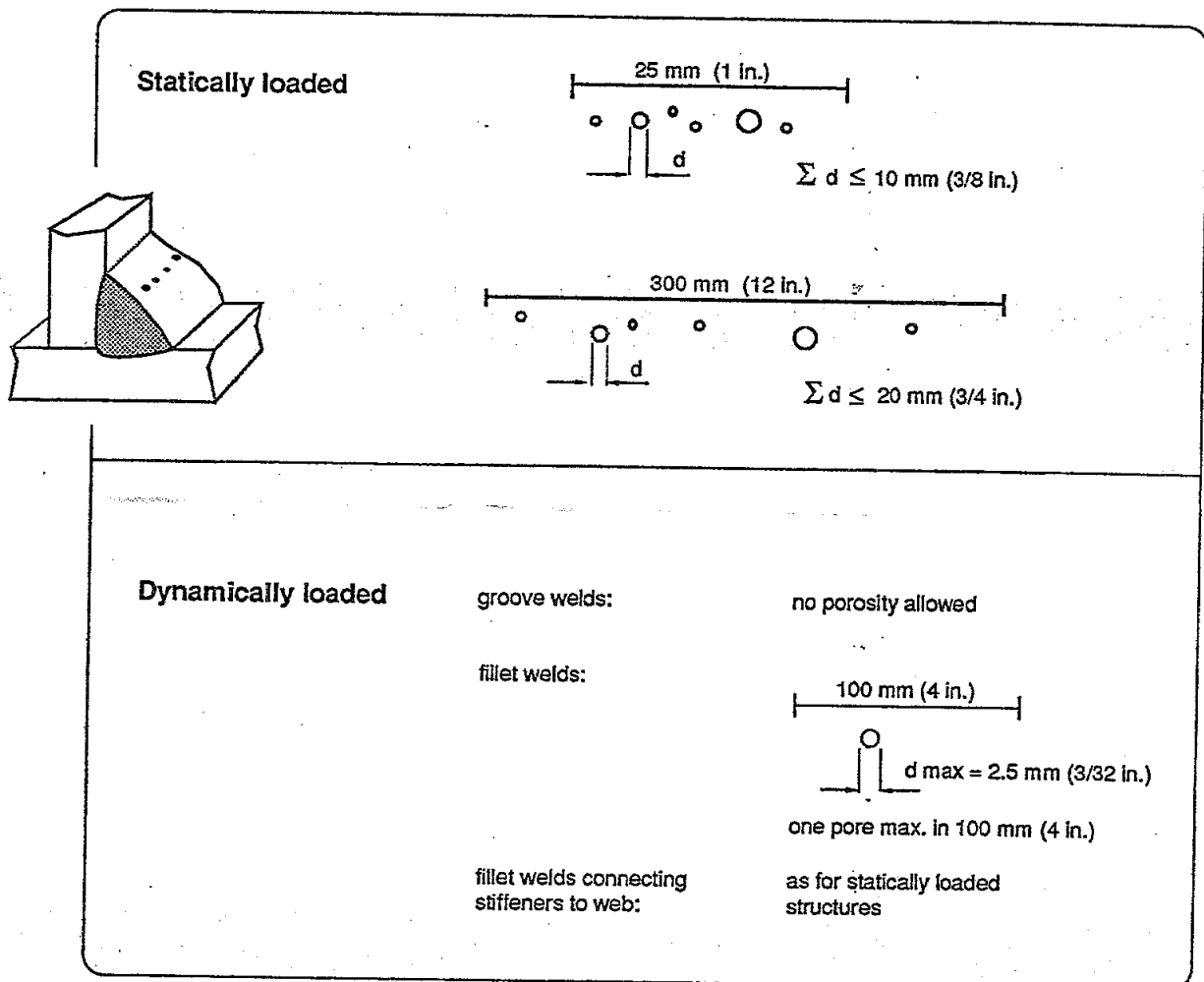


Figure 73. Acceptance criteria for porosity (visual examination - CSA W59).

Techniques of Visual Inspection

Porosity

Visual inspection for porosity applies to porosity that can be seen in the surface of the weld metal. The relevant clauses in CSA W59 specifically refer to 'visible' porosity. The inspector cannot 'guess' what may be below the surface although further investigation of a weld by other means may be warranted. As with undercut the acceptance criteria depend on whether the structure will be statically or dynamically loaded. The porosity requirements of CSA W59 are shown summarized in Fig. 73.

Porosity is easily measured. For relatively large porosity a 6" steel rule may be adequate. For smaller pores a hand magnifying glass or microscope with a graduated viewer will provide a precise measurement.

Cracks

Cracks are often subsurface (such as the lamellar tear shown in Fig. 74) and require nondestructive methods to detect them. Even when they break the surface they may be very fine and surface inspection methods, such as magnetic particle, are required to find them. Large cracks, however, may easily be visible and therefore detectable during a visual inspection. Cracks are not permissible (according to most standards) and their presence may be a symptom of a loss of control of the welding procedure. Observation of cracks in a visual inspection usually justifies a more detailed examination.

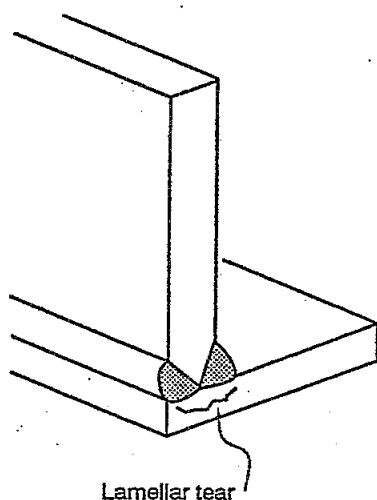


Figure 74. Lamellar tearing is a welding crack that can occur in plate with poor through-thickness ductility. In this case it is completely subsurface although it often breaks the surface in corner joints. Ultrasonics is usually needed to reliably detect lamellar tearing.

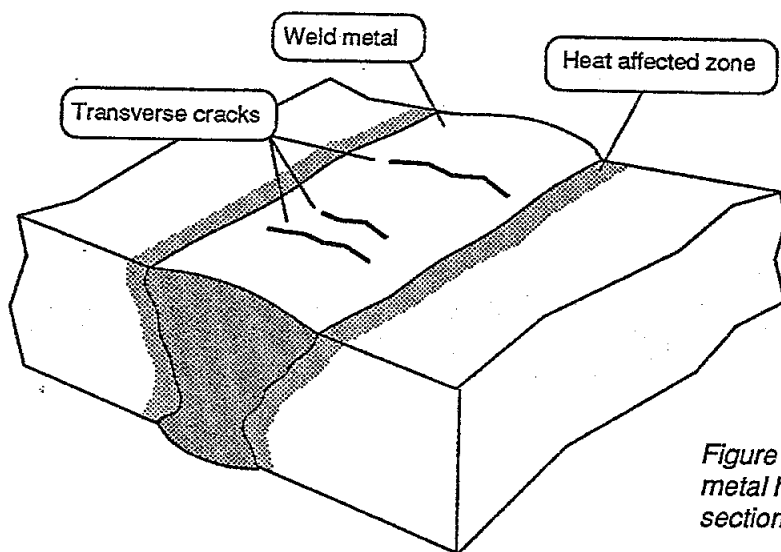


Figure 75. Typical location of weld metal hydrogen cracks in a heavy section weld.

The two main types of cracks that may be visible at the surface are hydrogen cracks and solidification cracks. Hydrogen cracks form after the weld has cooled down due to the embrittling effects of hydrogen. Cracks may form in the weld metal or the heat affected zone and in any direction. The most common weld metal hydrogen cracks in structural fabrication are transverse to the weld axis in heavy section multipass welds (Fig. 75). Hydrogen cracks in the heat affected zone are usually longitudinal and run along the toe of the weld (Fig. 76).

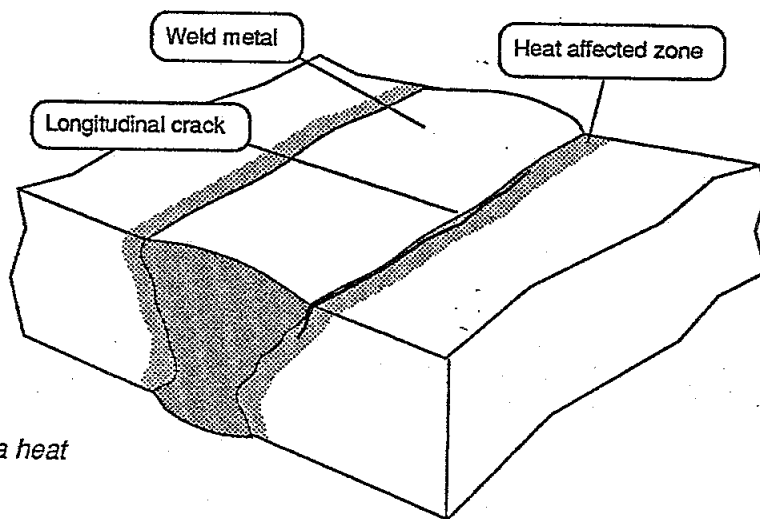


Figure 76. Typical location of a heat affected zone hydrogen crack.

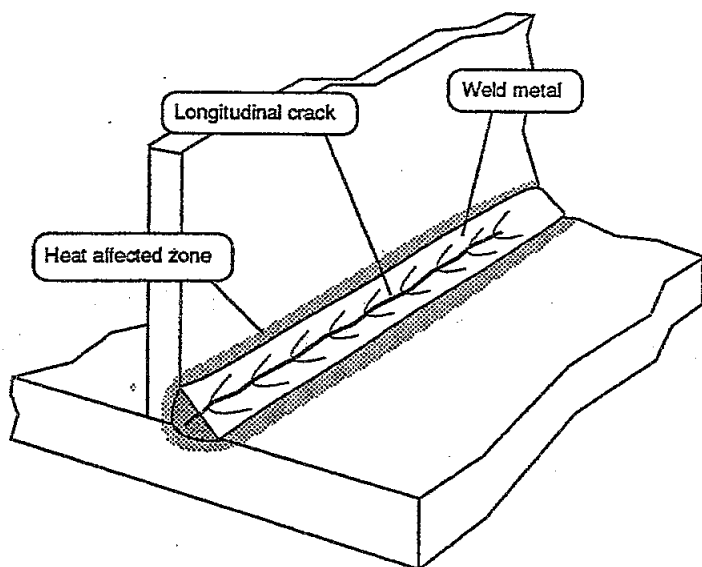


Figure 77. Typical centreline solidification crack.

Repair of cracks

T.Q.

Arc strikes

The most common type of solidification cracks are weld metal centreline cracks. Sometimes they can be very long, running the entire length of a weld. They are often the result of an incorrect welding procedure, for example, excessive travel speed or current and are more likely with mechanized processes such as submerged arc. Fig. 77 illustrates a centreline crack.

* Cracks must be repaired using proper procedures and with careful inspection during and after the repair. It is essential to ensure that all the crack is removed and that no new cracks are introduced in the repair. A typical sequence for the repair of cracks is:

- a visual examination
- NDE to define the extent of the crack
- gouging to remove the crack
- NDE to ensure complete removal
- weld
- NDE to verify soundness of the repair.

Arc strikes that are not melted out by the weld may constitute a potential source of fracture initiation. Because they cool so quickly they are hard and often contain cracks. The fabrication standard may contain special requirements with regard to arc strikes. CSA W59-89, for example, requires that on dynamically loaded structures arc strikes should be ground smooth and checked for soundness.

Tack welds

Tack welds and temporary welds are also governed by specific requirements in the standards, such as CSA W59 or AWS D1.1. The inspector should recognize whether such welds are approved, whether they have been made to an approved procedure, and whether they require to be removed.

Craters

Under the requirements of CSA W59 no craters are allowed, regardless of whether it is a static or dynamic application. Craters form at the ends of welds when the arc is suddenly extinguished and the metal shrinks leaving a depressed weld that often contains cracks radiating from the middle (Fig. 78). This is prevented by using the correct termination technique wherein the arc is held over the end of the weld for a short period of time before extinction to allow the crater to fill.

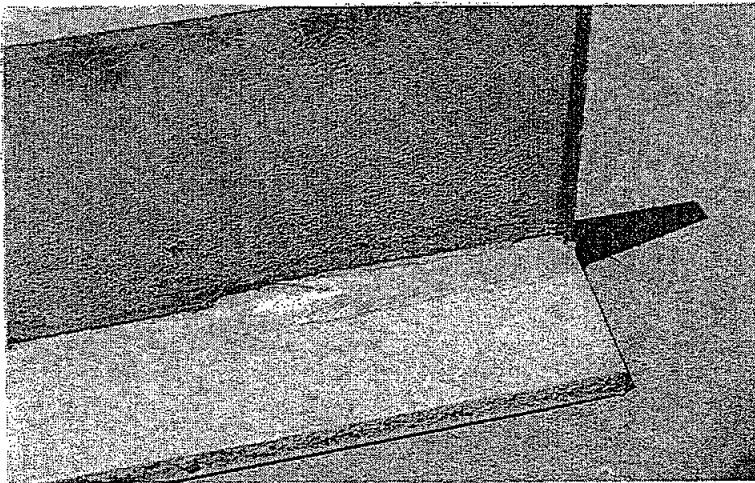


Figure 78. Crater at the end of a fillet weld.

When inspecting for craters, the inspector must determine if there are any unfilled or incorrectly filled craters. CSA W59 unfortunately, does not provide details of what constitutes an acceptably filled crater but measurements of the profile may be necessary to establish whether a rejectable crater is present.

In addition to craters there are other types of shallow depressions, such as pockmarks, that are usually not rejectable where all other criteria are met (Fig. 79). Pockmarks can be formed from gas trapped between the weld metal and the slag above it. This gas, unable to escape, forms a bubble that depresses the weld surface as it solidifies. Presence of pockmarks may indicate contamination, incorrect procedure, or an excessive flux burden.

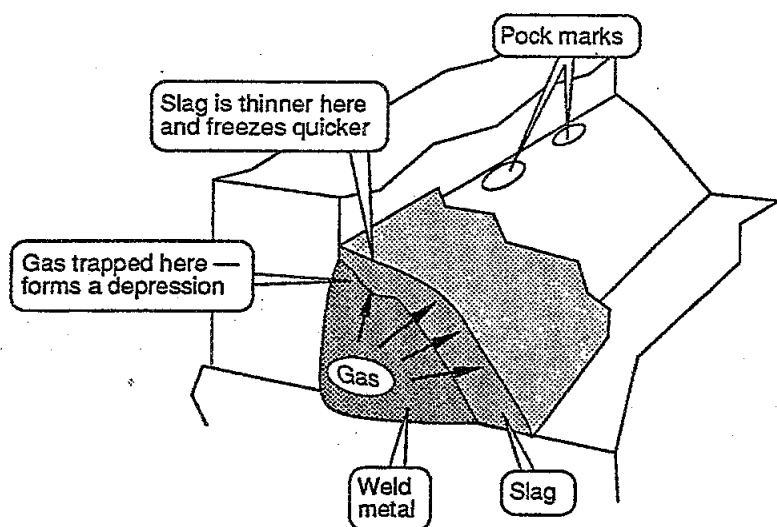
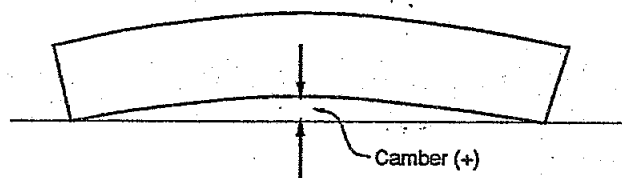


Figure 79. Pockmarks on the surface of a fillet weld showing how they are formed.

Figure 80. Camber in a built-up section.



Measuring dimensions of built-up sections after welding

A built-up section may have a specified camber which is defined in Fig. 80. The specified camber must be distinguished from out-of-straightness which is a tolerance on straightness. A camber, too, will have a tolerance.

The tolerances on straightness and camber as given in CSA W59 are summarized in Table 2. The length L is the test length which may be equal to the member length or some shorter length. Note that the tolerances depend on the application. The permissible variation in camber is different in AWS D1.1 and this is illustrated in Fig. 81. Note AWS does not allow any negative tolerance.

Table 2. Tolerances on straightness and camber (CSA W59-M1989).

NO SPECIFIED CAMBER (STRAIGHTNESS)

G40.20 - Columns—Typ WWF 550 - 350

Length $\leq 14\,000$ mm, Tol = $\pm \frac{\text{Length (mm)}}{1\,000}$; 10 mm max.

Length $> 14\,000$ mm, Tol = ± 10 mm + $\frac{\text{Length} - 14\,000}{1\,000}$

G40.20 - Beams—Typ WWF 1 800 - 700 & WRF 1 800 - 1 000

Tol = $\frac{\text{Length (mm)}}{1\,000}$

DEVIATION FROM SPECIFIED CAMBER

W59 Beams

Tol = $\pm (6 + L/4\,000)$ mm L = Test Length

AWS D1.1. - Beams

Tol = $-0, + 1/4$ in. $\times \frac{\text{No. of ft of Test Length}}{10}$; 3/4 max.

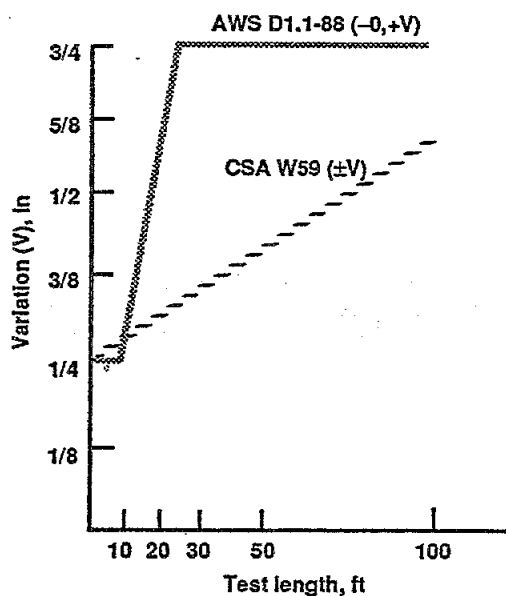


Figure 81. Permissible variation in specified camber.

Figure 82. Camber specified and measured at mid-point only.

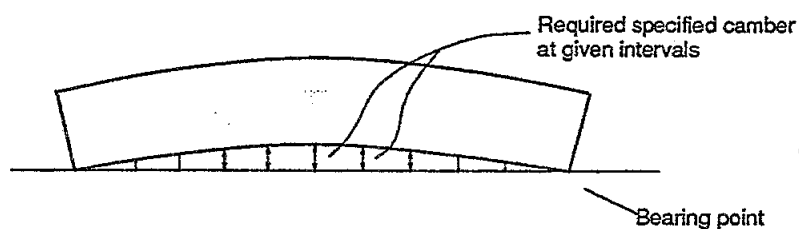
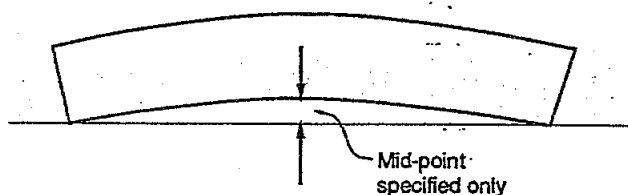
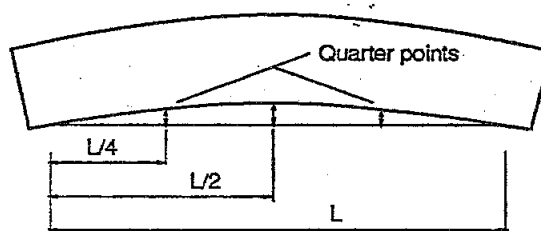


Figure 83. Camber diagram with camber specified at given intervals.

Figure 84. Checking camber at quarter points when a camber diagram is specified.



Camber may be specified at the mid-point of a member only or it may be specified at given intervals. In the first case the requirements of CSA W59 can be applied directly to a single measurement at the mid-point (Fig. 82). Where a camber diagram (Fig. 83) is specified it is normal practice to check the camber at the quarter points as well (Fig. 84). Although not a provision of CSA W59 it is normal practice to reduce the tolerance at the quarter point in proportion to the specified camber:

$$\text{Tolerance at mid-point} = \pm(6 + L/4\ 000) \text{ mm} \quad (\text{W59})$$

Tolerance at quarter points

$$= \pm(6 + L/4\ 000) \times \frac{\text{Specified camber at quarter point}}{\text{Specified camber at mid-point}}$$

The sidebar gives an example of applying this procedure. Note that AWS D1.1 does include a formula for points other than the mid-point:

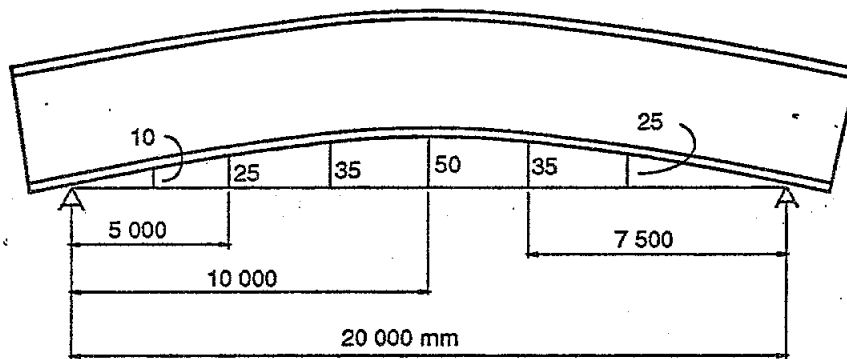
$$-0, + 1/8 \text{ in.} \times \frac{\text{No. of ft from nearest end}}{10}$$

Where the camber is a simple curve it is easily measured from a line joining two end points to the outside of the flange. In some cases, such as a continuous girder bridge, the camber is not symmetrical (Fig. 85), there being a camber diagram for each separate piece. For this type of girder, measurements are taken from a line stretched across the web between two points to the inside of the flange (Fig. 86). In measuring camber or straightness a string can be used as the reference line remembering to position the member in such a way that measurements are made at right angles to the sag in the string. In some cases it may be necessary to check with the web vertical and allowance should be made for deflection of the girder under its own weight. For this situation an optical measuring system may be more appropriate than a string.

Warpage and tilt

A flange can distort in two ways relative to the web: angular distortion symmetrical with respect to the web (warpage) and unsymmetrical tilt. Tolerances are usually applied to the combined distortion which is defined in Fig. 87. The tolerances for combined warpage and tilt as given in CSA W59 and CSA G40.20 are shown in Fig. 88.

EXAMPLE



- 1) How would you check the camber on this girder?
- 2) What is the permissible camber range at each position?

Answer:

- 1) Lay the web horizontal and stretch a line between the bearing points. Camber should be checked at the mid-point and quarter points.
- 2) Mid-point camber range:

$$\text{Tol}_{\text{m.p.}} = \pm \left(6 + \frac{20\,000}{4\,000} \right) = \pm 11$$

Range is 50 ± 11 or from 39 to 61 mm

Quarter point camber range:

$$\text{Tol}_{\text{q.p.}} = \pm 11 \times \frac{25}{50} = \pm 5.5 \text{ mm}$$

Range is 25 ± 5.5 or from 19.5 to 30.5 mm

Note: AWS D1.1 does *not* allow the camber to be less than the specified value (-0 tolerance). It also includes a formula for points other than the mid-point:

$$-0, +1/8 \text{ in} \times \frac{\text{No. of ft. from nearest end}}{10}$$

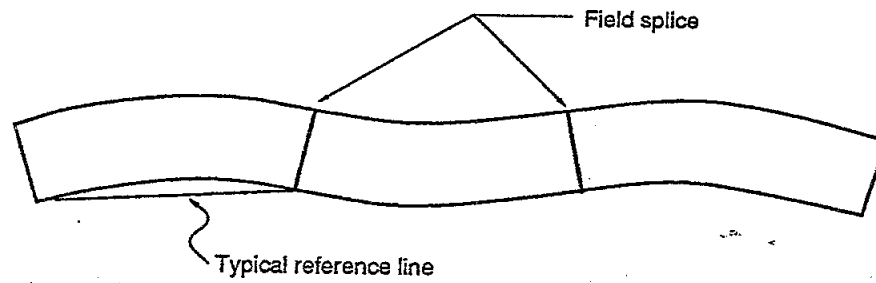


Figure 85. Non-symmetrical camber in a continuous bridge girder.

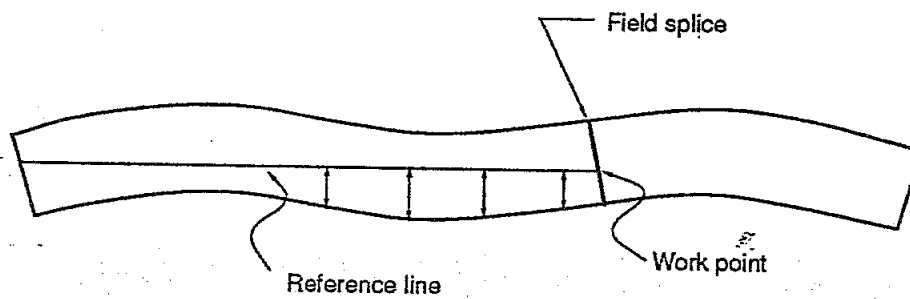


Figure 86. Measuring non-symmetrical camber.

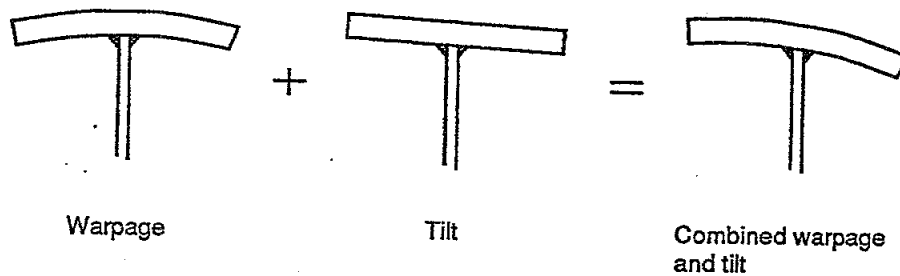


Figure 87. Warpage and tilt components of flange distortion.

Techniques of Visual Inspection

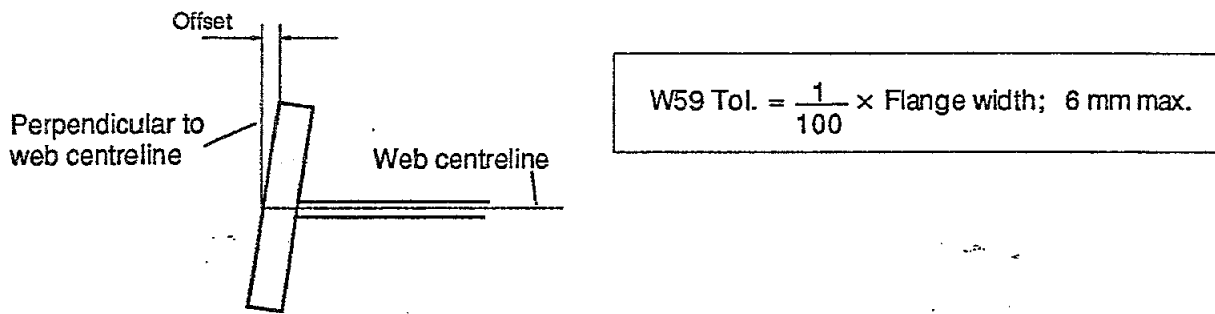


Figure 88. CSA W59-M89 requirements for combined warpage and tilt.

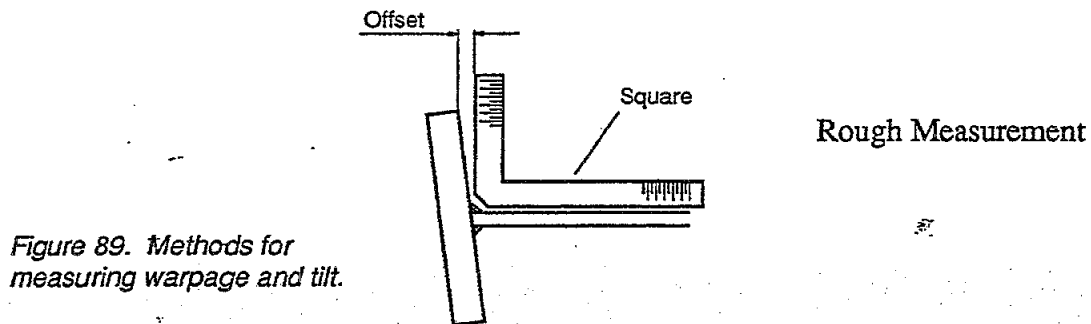
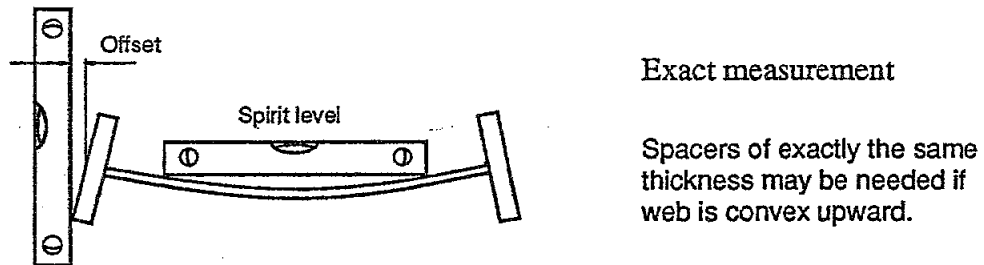


Figure 89. Methods for measuring warpage and tilt.



Warpage and tilt can be measured with a square and a ruler or by using spirit levels to establish reference lines (Fig. 89). A more accurate method is to use a special device to define the reference lines as shown in Fig. 90. Such a device is useful on relatively deep girders where the web may not be flat. Special care is needed to measure the correct dimension when both warpage and tilt occur (Fig. 91). For irregular shapes where the flange is not normal to the web (e.g., bathtub girder) a special template should be made (Fig. 92).

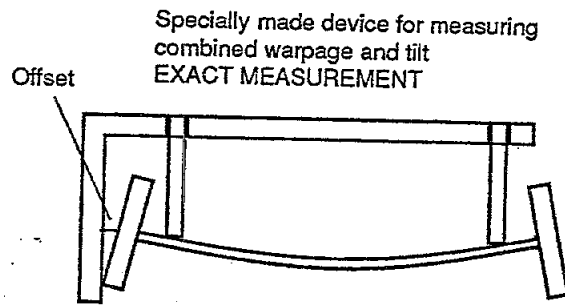


Figure 90. Special device for deep girders.

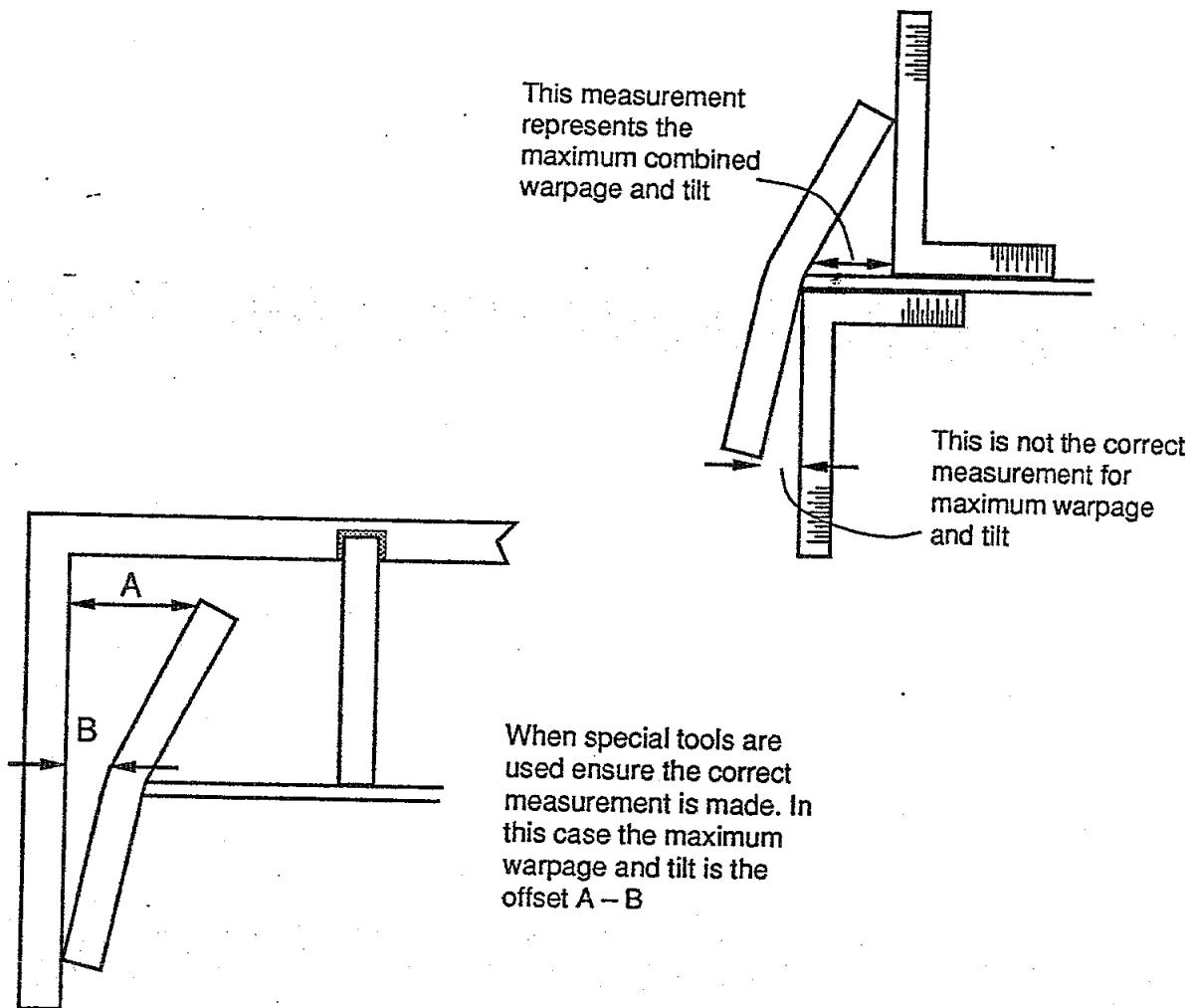


Figure 91. Measurement of maximum warpage and tilt when both are combined.

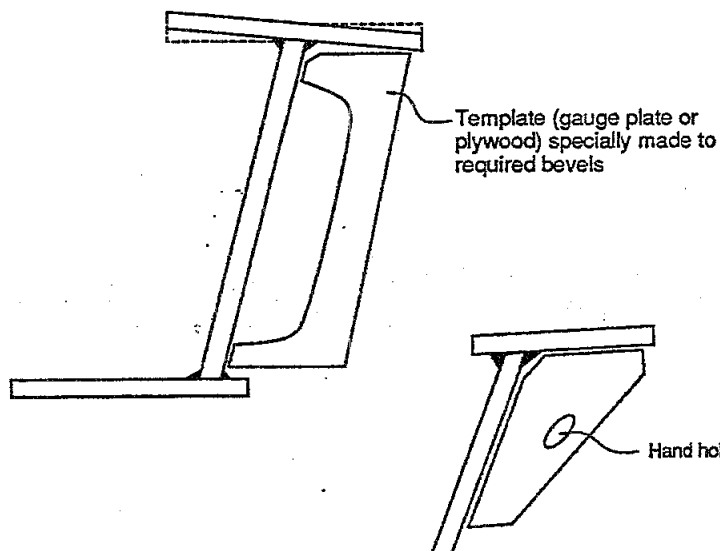


Figure 92. Checking irregular shapes (bathtub bridge sections) for flange tilt.

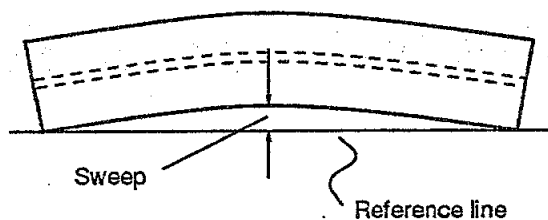


Figure 93. Definition of sweep.

Sweep

Sweep is a curvature in the plane of the flange (Fig. 93) and the tolerances (CSA W59) are the same as those for straightness. Measure a sweep with a ruler and a taut string as the reference line with the web in the vertical position to avoid error due to sag in the string.

Web flatness

Web flatness defined in Fig. 94 can be checked with a straight edge and a ruler as illustrated in Fig. 95. The straight edge should be the depth of the web and the maximum deviation is measured. The straight edge should be positioned both parallel and perpendicular to the flange, avoiding interference from the welds. Typical maximum permissible deviations from flatness for a specific case are shown in Table 3.

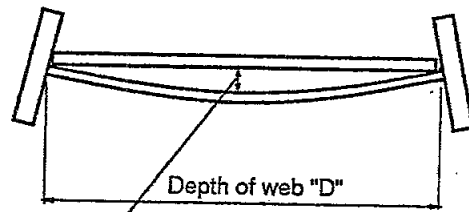


Figure 94. Definition of web flatness.

$$\text{Deviation from flatness} = \frac{1}{150} \times \text{Depth of web}$$

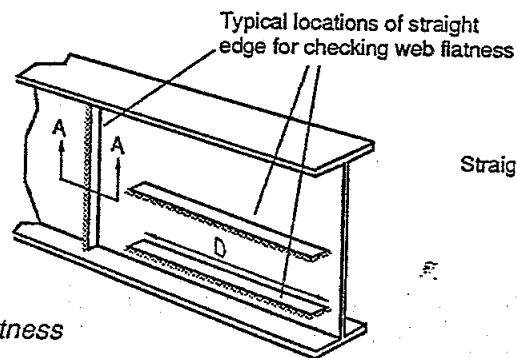


Figure 95. Measuring web flatness with a straight edge and ruler.

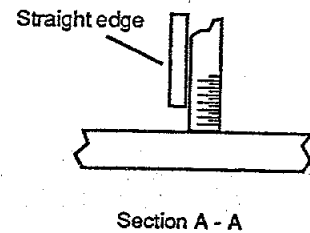


Table 3. Maximum permissible variations from web flatness according to CSA W59-M1989 Appendix I (no intermediate stiffeners, static loading).

Thickness of Web (mm)	Depth of Web (mm)										
	900	1200	1500	1800	2100	2400	2700	3000	3300	3600	3900
Any	6	8	10	12	14	16	18	20	22	24	26

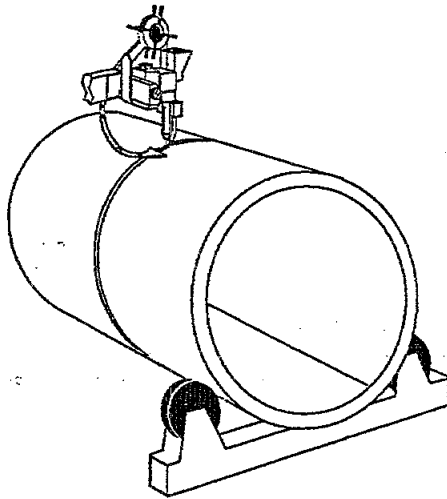


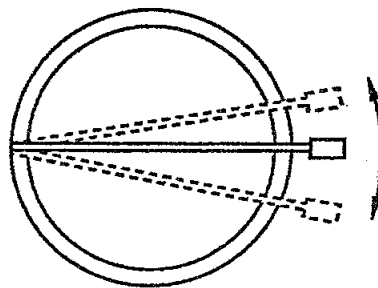
Figure 96. Typical vessel made from cans welded together.

Measuring dimensions in vessels

A few special techniques are required when measuring the dimensions of welded cylinders and vessels. Typically, plates are formed and longitudinal seams welded to form cans. Several cans may be circumferentially welded to produce the vessel (Fig. 96). Prior to rolling, the plate length and other dimensions are checked to ensure the correct circumference is obtained after welding. Out of roundness is checked after welding.

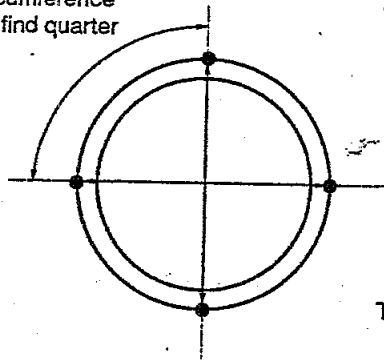
Average outside diameter can be found by dividing the total outside circumference by π (3.1416). Diameter at a specific location can be measured directly as in Fig. 97. To check the cylinder for "out of round" the cylinder must first be placed on end with the walls in the true vertical position verified with a level or plumb bob. This is important for light wall and unsupported cylinders. The circumference is taped top and bottom and verified. The top circumference is then divided by four and the quarter points marked on the cylinder. A plumb bob line is dropped

Figure 97. Measuring diameter at a specific location.



Move the tape back and forth to find the largest dimension. This will be the outside diameter at this point.

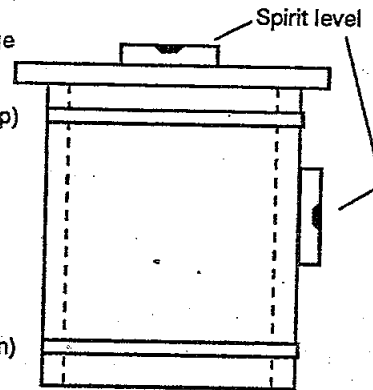
Divide circumference
by four to find quarter
points



Straight edge

Tape (top)

Tape (bottom)



Cylinder must be in true
vertical position

Figure 98. Checking a cylinder for out-of-round.

from these points to the lower circumference and the lower quarter points marked. The taped dimensions between the quarter points should be in agreement for true roundness (Fig. 98). Thin wall cylinders are usually maintained round by inserting "spiders." Heavier walls can be maintained with props of scrap angle. Fig. 99 shows a cylinder with internal support to maintain shape and facilitate shipping.

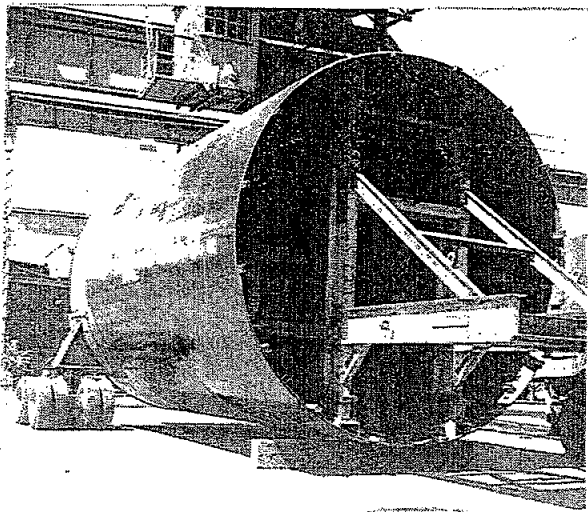


Figure 99. Thin cylinder internally
supported to allow shipping.

Misalignment in cylindrical sections

Closed sections such as pipe, cylinders for pressure vessels and even box-type sections may introduce additional problems in maintaining joint misalignment within workmanship standards. In the case of a joint between two pipe sections any differences in pipe radii will produce an "inherent" misalignment which is beyond the control of the fitter or welder (Fig. 100).

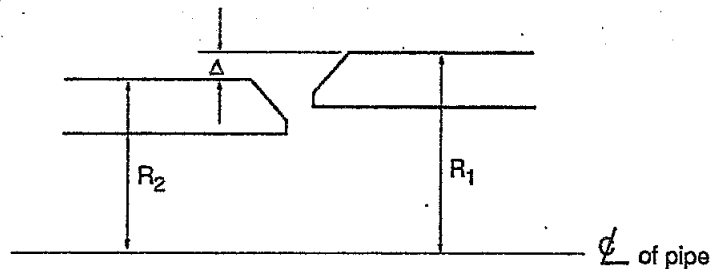


Figure 100. Definition of 'inherent' misalignment between two pipes due to differences in radii.

Pipe sections can be checked prior to fitting to determine "inherent" misalignment by measuring the circumference of the pipes. To be within the allowable total misalignment

$$\frac{C_1 - C_2}{2\pi} < \text{Allowable misalignment}$$

where C_1 = circumference of the larger pipe
 C_2 = circumference of the smaller pipe
 π = 3.14

When a difference in radii exists it is important that the misalignment is averaged over the total circumference by an appropriate fitting sequence as shown in Fig. 101.

CSA-Z184-M86 "Gas Pipeline System," for example, allows an offset of 1.6 mm in addition to that caused by dimensional variations provided the latter is uniformly distributed around the pipe circumference.

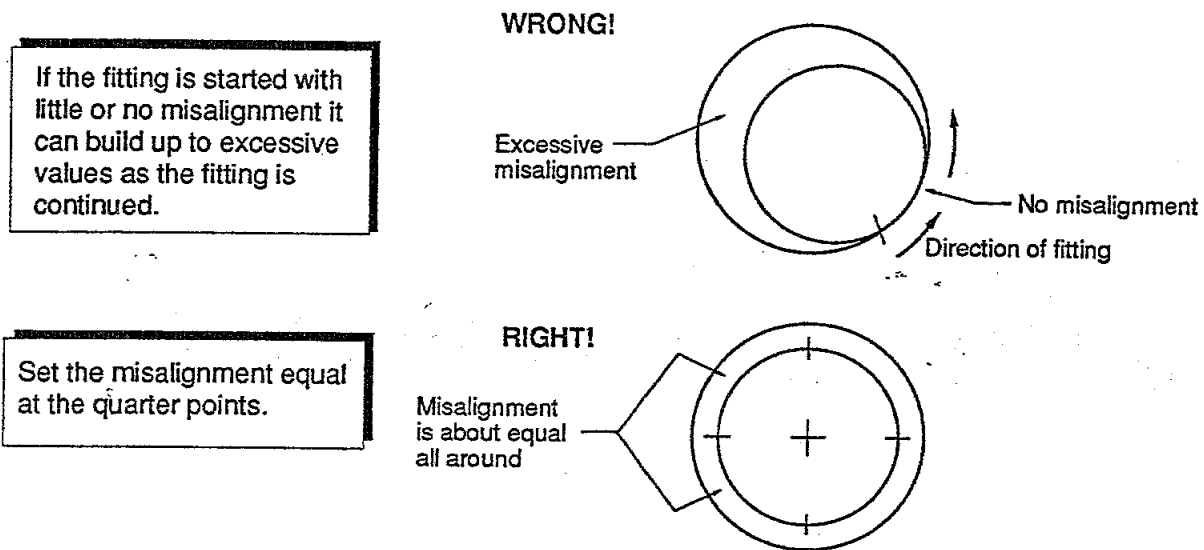


Figure 101. Method of fitting to minimize misalignment due to differences in radii.

Verification of weldments requiring machining

Often the inspector is required to check machined components. In simple welded components machining is often used to provide a flat surface thereby compensating for distortion and other irregularities. Machining a welded component can introduce a number of problems that the designer and the inspector should be aware of.

As an example, Fig. 102 shows a fabricated flange for a large diameter nozzle. The flange may become distorted due to welding leaving insufficient material for subsequent machining. At each stage of fabrication a tolerance on flatness should be specified:

- after splicing the flange material
- after fitting the flange to the neck
- after final welding of the neck to the flange.

The flange material requires enough extra material to compensate for all these tolerances. If the flange material exceeds the minimum thickness by an amount that compensates for all the distortion expected the need for any straightening is eliminated.

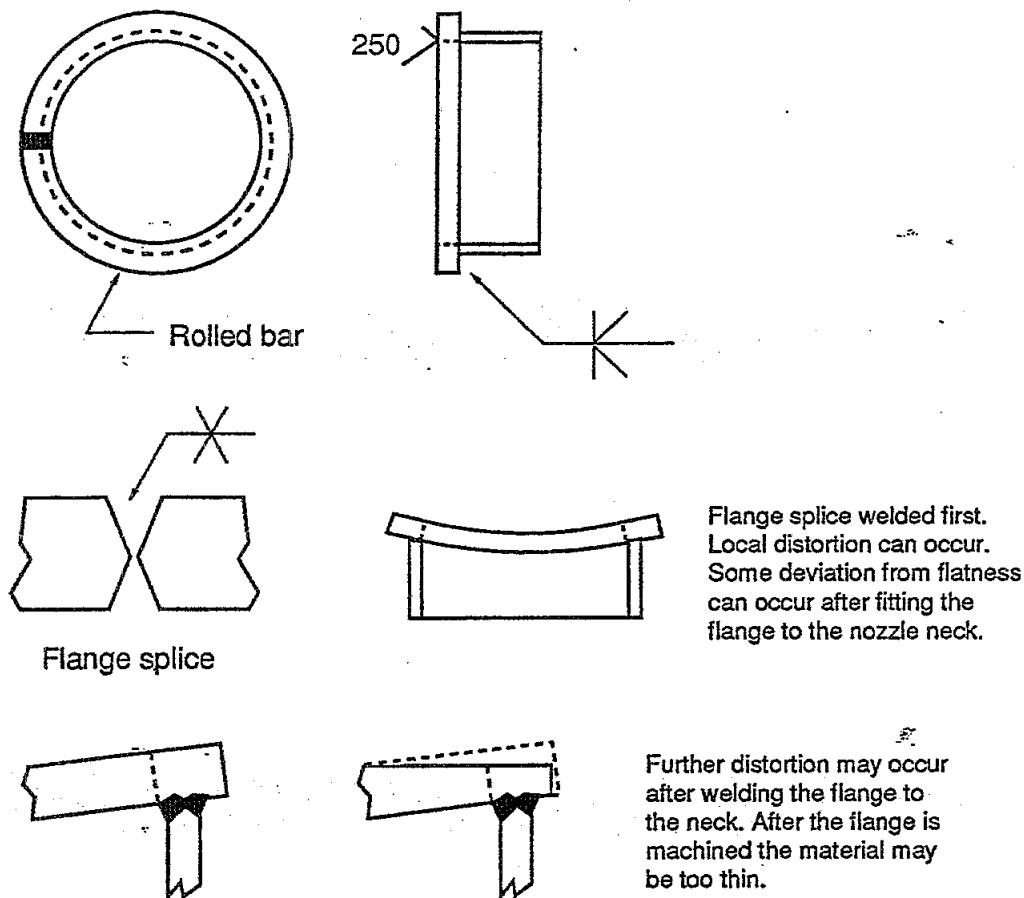


Figure 102. Fabricated nozzle. If subsequent machining is specified, the design and material thickness must take into account possible accumulated distortion.

While being under thickness in this situation is essentially a design problem, the inspector should be aware of the following:

- check for flatness before machining
- verify the minimum thickness after machining at several locations at both inside and outside diameters
- the surfaces of fabricated components will deviate from flatness due to welding distortion and other effects. Hence machining of these surfaces will produce a variation in thickness.

In a typical product there would be many other dimensions specified each with a specified tolerance. These would be measured using the tools and techniques described here. Some distortion is inevitable in a welded structure although the welding procedures and assembly sequence should be designed to minimize it.

Summary

Visual inspection is the most important of the inspection methods available but today's inspector is usually called upon to do far more than just inspect welds. The inspector must be competent in many inspection techniques, be capable of using measuring instruments and recording devices, as well as recognizing defects in welds and base metal. This module has therefore aimed at presenting and discussing many of the techniques used in the visual inspection of welded components.

Types of errors, the meaning of terms such as 'accuracy' and 'precision' and the importance of calibration are introduced. The use of simple measuring tools, such as tapes, and their correct use is discussed. Various procedures for checking squareness and distortion are described.

Good inspection prior to welding is emphasized and the examination of base metal defects, flame cut edges, and joint fit-up is discussed with reference to CSA W59-M1989 requirements. This leads into a discussion of weld dimensions, their measurement, and other types of weld defects such as undercut, porosity, and cracks.

A number of techniques for specific measurements including camber, flange distortion, and web flatness are included. The module finishes with a discussion of a few techniques required in the inspection of welded cylinders, vessels, pipes and machined components.

It is hoped that a knowledge of the contents of this module and competence in the techniques described will assist the inspector and contribute to the effective application of visual inspection.

GUIDES AND EXERCISES

MODULE 16

TECHNIQUES OF VISUAL INSPECTION

TECHNIQUES OF VISUAL INSPECTION

MODULE 16

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 (starting on page 70) for accuracy. If any of your answers are wrong, re-study 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. To ensure that callipers are accurate you would—
 - a) use a vernier
 - b) calibrate them
 - c) always take a reading to three decimal places
2. True or false?

“Systematic errors can always be avoided by using a sufficiently precise measuring instrument.”
3. State one disadvantage of using a ‘go/no-go’ type gauge for determining whether a product is within tolerance.
4. A high quality measuring instrument—
 - a) should not be calibrated unless something goes wrong
 - b) should be calibrated by the operator every time it is used
 - c) should be calibrated regularly as specified in a formal calibration program
5. True or false?

“When reading a meter with a pointer always stand directly in front to avoid a parallax error.”
6. State one reason for measuring dimensions from a single reference line or datum.

Techniques of Visual Inspection

Guide 2

Read carefully pages 9 to 19 and answer the following questions:

1. When making accurate measurements with a long steel tape it is important that the tape—
 - a) be held loose so it does not stretch
 - b) be held under the correct tension applied with a tension handle
 - c) be held as tight as possible so there is no slack
2. What are two ways of checking if a surface is vertical?
3. How would you check that a flange is at right angles to the web if a try square could not contact the flange because of the fillet weld?
4. Describe a simple method for checking a square.
5. True or false?
"When using a string as a reference line to measure distortion in a plate always make the measurements horizontally from the string to the plate."
6. What instrument(s) would you use for checking the angle of a weld preparation?

Guide 3

Read carefully pages 20 to 31 and answer the following questions:

1. According to CSA W59-M1989 what is the minimum distance from the weld at which to measure the preheat in plates 44 mm thick?
 - a) 75 mm
 - b) 44 mm
 - c) no minimum
2. A 'pipe' is a solidification cavity in steel. Where would you most likely find such a defect when inspecting a rolled plate?
 - a) On the plate surface
 - b) In the middle of an end section
 - c) Large pores throughout the plate thickness

3. True or false?

"According to CSA W59-M1989 occasional notches on a flame cut surface may be removed by grinding or machining if less than 5 mm deep."

4. Give one reason why the size of a gap between parts to be fillet welded together is important.

5. For two 38 mm thick plates to be groove welded without a backing bar what is the maximum misalignment permitted by CSA W59-M1989?

6. Why is the preparation of a partial joint preparation groove weld particularly important?

Guide 4

Read carefully pages 32 to 39 and answer the following questions:

1. Is the size of a fillet weld always the same as the measured leg length?

2. If the leg lengths of a convex fillet weld are unequal which one determines the weld size?

3. What dimension is measured to determine the size of a concave fillet weld?

4. What are two important dimensions when checking a complete penetration groove weld?

5. True or false?

"There is a simple relation between face width and throat size for flare welds that can be used in all cases."

6. What is the minimum angle between two pieces for which a weld can be classed as a fillet weld?

- a) 60°
- b) 45°
- c) 90°

Techniques of Visual Inspection

Guide 5

Read carefully pages 39 to 45 and answer the following questions:

1. Give one reason why undercut is important in dynamically loaded structures.
2. According to CSA W59-M1989 the maximum allowable depth of undercut for a weld loaded dynamically transverse to the weld is—
 - a) 0.25 mm
 - b) 1 mm
 - c) up to 1.5 mm, depending on thickness
3. How much porosity (by visual examination) is allowed in a dynamically loaded groove weld according to CSA W59-1989?
4. A lamellar tear may result from—
 - a) excessive welding speed
 - b) nitrogen contamination of the weld
 - c) poor through-thickness properties of the plate
5. Where would you most likely find cracking that has resulted from excessive current in a single pass weld?
 - a) Along the centreline of the weld metal
 - b) In the mid-thickness of the plate beneath the weld
 - c) At the weld toe in the heat affected zone
6. True or false?

"CSA W59 does not specifically require weld craters to be filled."

Guide 6

Read carefully pages 46 to 55 and answer the following questions:

1. A specified curvature of a flange in the plane of the web is known as—
 - a) camber
 - b) sweep
 - c) warpage
 - d) tilt

2. True or false?

"If a camber diagram is specified it is necessary to check camber at one point only."

3. The maximum combined warpage and tilt of a flange allowed by CSA W59-M1989 is—

- a) $1/10 \times$ flange width, no maximum
- b) 6 mm
- c) $1/100 \times$ flange width, 6 mm maximum

4. For a deep girder where the web may not be flat, is a simple try square the best tool to use for measuring flange warpage and tilt?

5. When measuring web flatness what length straight edge should be used?

6. According to CSA W59-M1989 what is the maximum deviation from flatness of a web 1 500 mm deep?

Guide 7

Read carefully pages 56 to 61 and answer the following questions:

1. What is the average diameter (o.d.) of a cylinder with a taped circumference of 9 425 mm?

2. True or false?

"Out of roundness is easily checked by measuring the circumference of the cylinder at various points to see if they agree."

3. State one way in which misalignment can be minimized when two pipes or cylinders are welded together.

4. True or false?

"It is possible to determine whether misalignment tolerances can be met by measuring the circumferences of the two end sections of pipes before welding."

5. True or false?

"If the component is to be finally machined it really doesn't matter whether dimensional tolerances are met during fabrication."

ANSWERS

Guide 1

1. b)
2. False
3. It does not give the actual measurement which could be useful in process control
4. c)
5. True
6. To avoid cumulative errors

Guide 2

1. b)
2. Use a plumb bob or a spirit level
3. Measure with a rule from the flange to the try square at two points. The two readings should be the same (see page 15)
4. Place the square against a straight edge of a plate, scribe a line, then flip it over and check if the line is square (see page 15)
5. True
6. Bevel gauge and/or protractor

Guide 3

1. a)
2. b)
3. True
4. If larger than a certain size the fillet weld size must be increased by the amount of the gap
5. 3 mm
6. The depth of preparation determines the weld size

Guide 4

1. No, the size is smaller than the measured leg length for a concave fillet
2. The smaller one
3. Throat
4. Reinforcement and reduction in thickness
5. False
6. a)

Guide 5

1. Undercut may help to initiate fatigue cracks at the toes of welds
2. a)
3. None
4. c)
5. a)
6. False

Guide 6

1. a)
2. False
3. c)
4. No. See page 52 and 53 for better methods
5. The depth of the web
6. 10 mm

Guide 7

1. 3 000 mm (3 m)
2. False
3. Align the pipe centres so that any misalignment due to differences in diameter is evenly distributed around the circumference
4. True
5. False

MODULE 16

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 re-study the material.

1. A certain instrument (such as a micrometer) can measure a dimension to 2 decimal places. This indicates the:
 - a) Cumulative error
 - b) Accuracy
 - c) Tolerance
 - d) Precision
 - e) Systematic error
2. When verifying the location of a number of holes on a structure:
 - a) Measure the distance between each hole, neglecting the tolerance
 - b) Measure the distance between each hole using the tolerance for each hole
 - c) Measure the distance between each hole but add on the tolerance of the previous hole
 - d) Measure the distance of each hole from a specified reference line using the tolerance specified for that hole
 - e) Measure the distance of each hole from a specified reference line but adding the tolerance of the previous hole
3. How would you check that a surface (of, say, a pressure vessel) is vertical?
 - a) Use a try square between the vessel and the floor
 - b) Line up the edge of the vessel with a column in the shop
 - c) Use a spirit level or a plumb bob
 - d) Measure with a tape from the top to the base at four locations
 - e) Use a try square between the surface and a straight edge placed across the top of the vessel
4. When using a string as a reference line when measuring distortion in a flat plate the measurement should be made horizontally on to a vertical plate—
 - a) Because it avoids error due to sag in the string
 - b) Because it is difficult to ensure the plate is completely horizontal
 - c) It does not matter in which direction the measurement is made
 - d) The plate may be horizontal if a tension clamp is used
 - e) A string must never be used as a reference line

5. You are required to verify the 65°C preheat level of a three pass weld in 44 mm thick plate welded to CSA W59-M1989. You would:
- a) Check the preheat before welding 44 mm from the weld and not worry if it dropped below 65°C during welding
 - b) Check the preheat before welding 44 mm from the weld and ensure it did not fall below 65°C during welding
 - c) Check the preheat 75 mm from the weld immediately after the final pass
 - d) Check the preheat 75 mm from the weld before welding and ensure it did not fall below 65°C during welding
 - e) Check the preheat 44 mm from the weld immediately after welding
6. According to CSA W59-M1989 what is the tolerance on the weld groove preparation for the root opening, without steel backing, and without gouging the root?
- a) +6 mm, -2 mm
 - b) ± 2 mm
 - c) $1/10 \times$ plate thickness
 - d) Not limited
 - e) None
7. For a concave fillet weld with unequal leg sizes (where an equal leg fillet was specified) what is the weld size equal to?
- a) The shorter measured leg length
 - b) $1.414 \times$ the measured throat
 - c) The larger measured leg length
 - d) The average of the two measured leg lengths
 - e) $0.707 \times$ the measured throat
8. If a 5 mm fillet weld is originally specified but a gap of 2 mm exists, what is the minimum measured leg length that a convex fillet weld should have according to CSA W59-M1989?
- a) 7 mm
 - b) 5 mm
 - c) 5×0.707 mm
 - d) 6 mm
 - e) 1.414×0.707 mm
9. On dynamically loaded structures, what does CSA W59-M1989 require for arc strikes?
- a) They must be gouged out, welded up, and ground smooth
 - b) They must be ground out, welded up, then ground smooth
 - c) They may be left in place except on tension members
 - d) There is no specific requirement
 - e) They must be ground smooth and checked for soundness

Techniques of Visual Inspection

10. When a flange was welded to a web it tilted by 3 mm and warped by 2 mm. When checked with a square one edge of the flange was 5 mm from the square and the other was 1 mm. What value is used to compare with the allowed amount of 6 mm?

- a) 6 mm
- b) 1 mm
- c) 5 mm
- d) 3 mm (average of 5 and 1 mm)
- e) 4 mm (5 - 1 mm)

**Canadian Welding Bureau
Answer Sheet - Module 16**

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

Techniques of Visual Inspection

Canadian Welding Bureau Test Key - Module 16

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