DESTRUCTIVE TESTING METHODS

Training Workbook

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Written by
the Staff of Hobart Institute
of Welding Technology

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TOPIC 1

INTRODUCTION TO DESTRUCTIVE TESTING METHODS

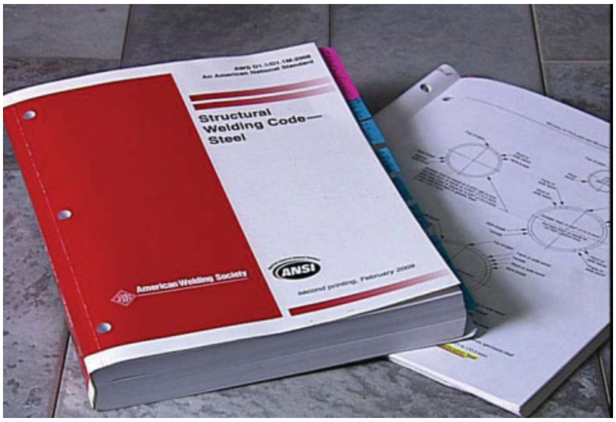
OBJECTIVE

To know the mechanical properties of metals and welds and the type of tests used to evaluate these properties.

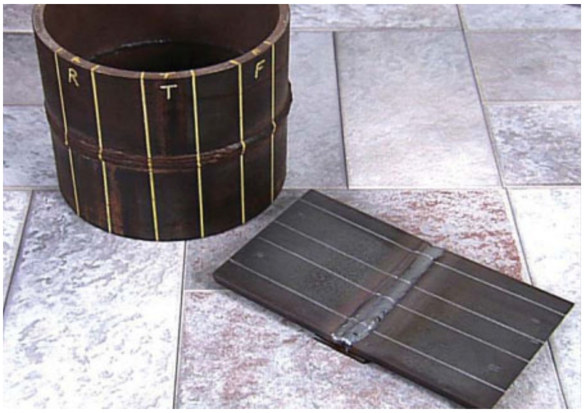
INTRODUCTION

Destructive testing is an evaluation process of a weld or base metal specimen. Evaluation takes place during and/or after the destruction of the specimen. It is a function performed by quality control to measure properties of metals and welds.

The term weld soundness is commonly used to describe the degree of freedom from discontinuities contained with a weld. Cracks, inclusions, porosity and lack of fusion reduce weld soundness, which may prevent the weld from performing in service. In addition to weld soundness, the mechanical, chemical and metallurgical properties of the welded joint are important to insure reliability of the weldment in service.



In design, materials are selected to provide these properties. The process of welding must enable the materials to maintain these properties through development and use of a proven procedure. Welding codes use a variety of destructive testing methods to evaluate materials so that design performance requirements can be met.



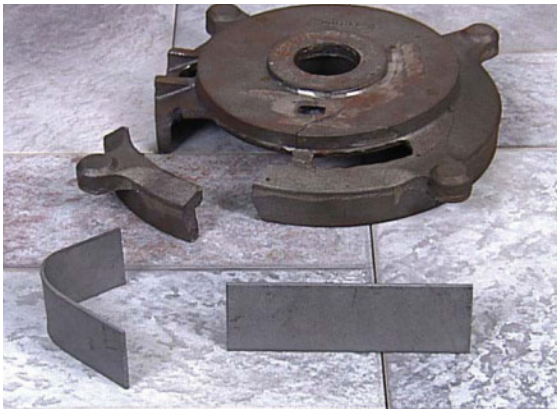
Destructive testing processes are also specified to evaluate the results of welding procedures. Procedure and welders are qualified by destructive tests.

Destructive testing can also be used to spot check the quality of production weldments. This is commonly known as work sampling.

MECHANICAL PROPERTIES

The most important mechanical properties of welded joints include strength, ductility, toughness and hardness.

One important measure of strength is the material's ultimate tensile strength. This is determined by subjecting weld metal or a weld joint to a pulling load until it fails. The maximum stress developed is a good indication of the amount of load the material can sustain. Yield strength is another important measurement of the material's load carrying capacity. The yield strength is the stress at which the material will change permanently in dimension, usually length, and cross sectional area.



Ductility is the property of a metal which allows it to be drawn or stretched without fracture. A ductile material can be bent. A material which is not ductile is referred to as brittle.

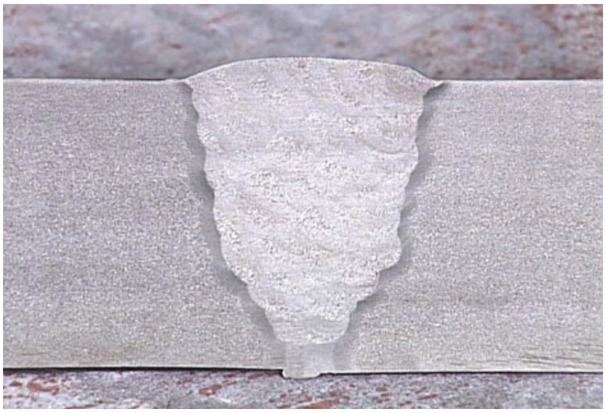
Toughness is the ability of a material to sustain sudden shock loading at various temperatures without failure. The energy absorbed by the specimen will vary depending on temperature. For example, steel will possess lower toughness properties as the temperature is reduced.

The property of hardness is defined as the metal's resistance to indentation from the force of a hardened substance. Hardness of metals is measured by forcing a hardened steel ball or a diamond into the surface of a metal. The Brinell, Rockwell and Vickers tests are commonly used to evaluate this property.

CHEMICAL PROPERTIES

Destructive testing also includes chemical tests. Welded joints may be cut to remove sections for analysis of alloying elements.

Specialized equipment in laboratory conditions is used to evaluate chemical composition. For example, spectrographic analysis could be used. Chemical composition is important to weldments which require corrosion resistance. Chromium and nickel contents and carbide formations are analyzed to determine the weldment's ability to perform in service.



One method of determining metallurgical structures is through etching the welded joint. This method consists of cutting a specimen, polishing the cut surface, applying an etching acid, and visually inspecting the etched surface.

Variations of the process include viewing the etched surface with different degrees of magnification. This form of examination is known as macro or micro examination, depending upon the magnification used.

DESTRUCTIVE TESTING

ESTABLISH PROCEDURE

SELECT AND PREPARE SPECIMENS

EVALUATE RESULTS

CONCLUSION

Destructive testing can be a very effective tool to determine weld quality if:

1) The destructive testing procedure is established.
2) Specimens are properly selected and prepared.
3) Results are evaluated in accordance with prescribed standards.

TOPIC 1

REVIEW QUESTIONS

1. List the three major groups of properties evaluated by destructive testing:

2. Name three functions of destructive testing:

3. Name the four most common mechanical properties related to welding:

4. The process of selecting production weldments for test is called:

TOPIC 2

TENSION TESTING

OBJECTIVE

To know the procedure used to perform tensile tests and the results derived from the test.

INTRODUCTION

The tension test is used to determine the behavior of a material as it is pulled gradually beyond the breaking point. It is one of the most valuable destructive tests because it provides data on strength, ductility and soundness of base metal and weld metal.

ALL WELD METAL TENSION TEST

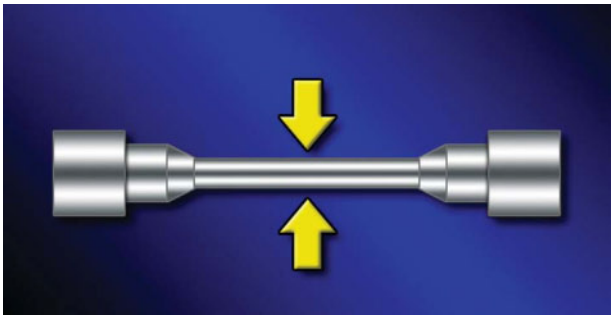
All weld metal and all base metal specimens are used to determine the strength and ductility properties of material.

These tests are commonly used to classify base metal and weld metal to national standards. For example, filler metals must meet minimum mechanical properties to be classified to the American Welding Society filler metal identification system.

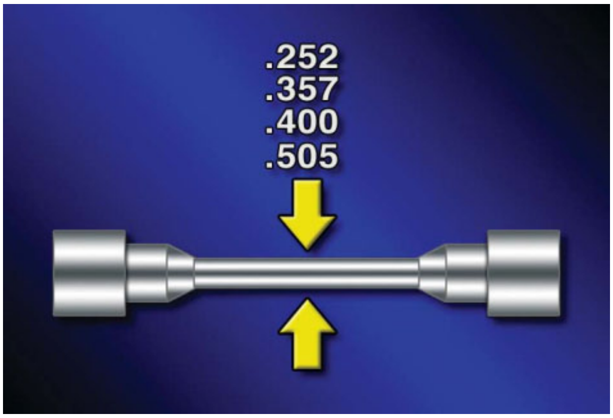
All weld metal specimens are machined from the center portion of a weld test coupon.

It must consist entirely of weld metal in the reduced section of the specimen.

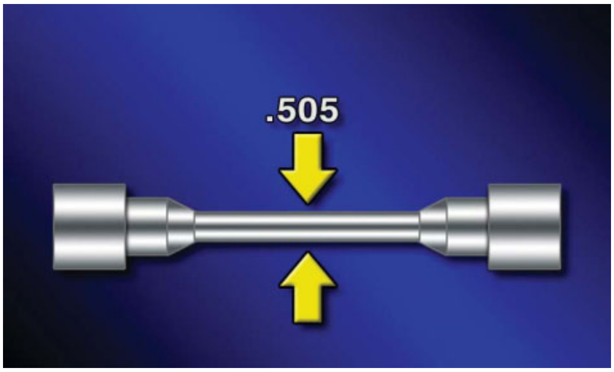
The ends of the specimen are shaped to fit the jaws of the testing equipment in use. Published codes provide requirements regarding preparation of test specimens which must be considered.



The reduced section of the specimen is normally tapered about .005-inch from the ends to the center. This allows the fracture to occur approximately in the center of the specimen where it is the thinnest.

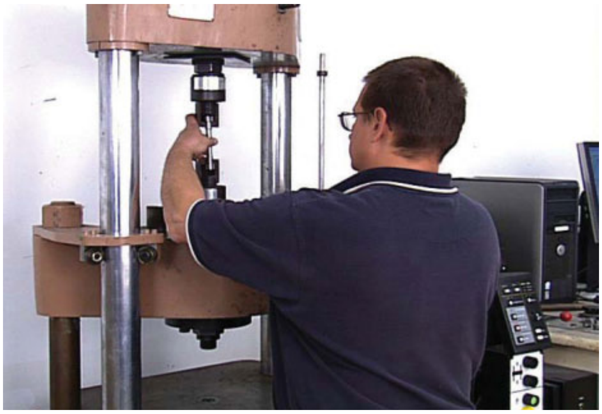


The diameter at the center of the tensile specimen will vary depending on material thickness and code requirements. The finished surface should be smooth enough to prevent premature failure. A rough surface could initiate a fracture in an undesirable location.

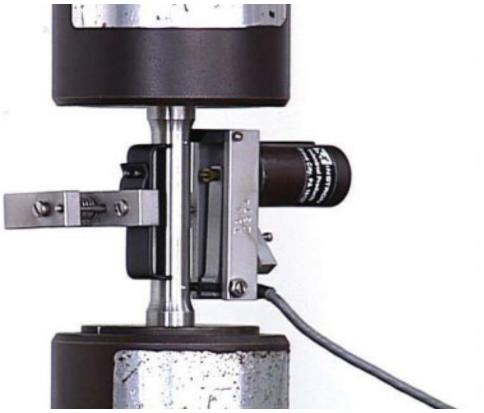


The procedure for testing all weld metal or base metal tensile specimens will be discussed first. It is essential that the applicable specification be reviewed to determine the exact procedure. A .505-inch specimen will be used for illustration.

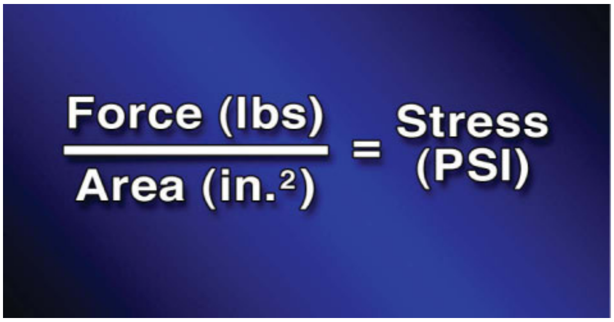
The five-o-five specimen is marked with a centerpunch at two points, two inches apart. This is known as gage length. The original gage length of two inches is recorded for use later to calculate ductility.



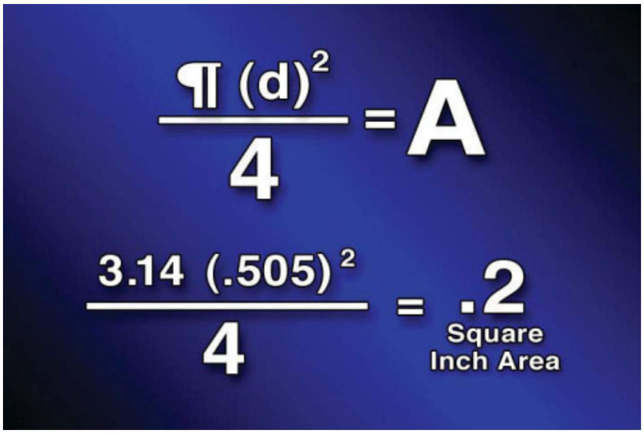
The specimen is secured in the jaws of the tension machine. A strain gage is attached to the specimen to detect changes in length when force is applied.



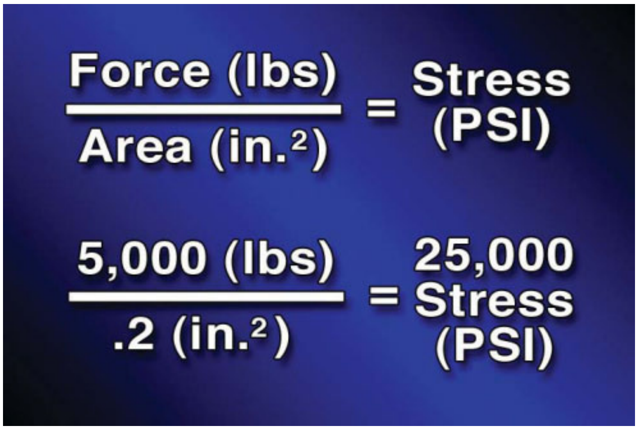
The equipment operator begins the pulling process by allowing the machine to apply pounds of force (load) to the specimen.



As the force is applied, stress develops in the specimen. The stress is equal to the force applied divided by the cross sectional area of the specimen.

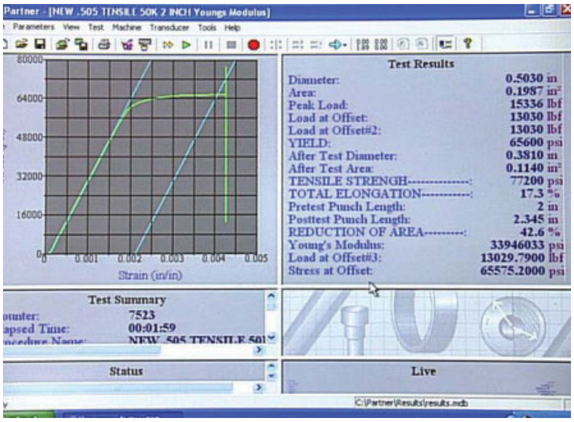


The area of a five-o-five diameter specimen is determined by squaring the diameter and then multiplying by Π or 3.14. This value is divided by four. The answer is .2 square inches.

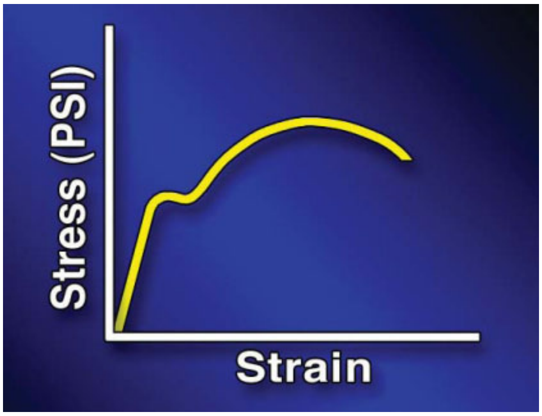


If the force applied to the specimen is five thousand pounds, the stress becomes 25,000 pounds per square inch (psi).

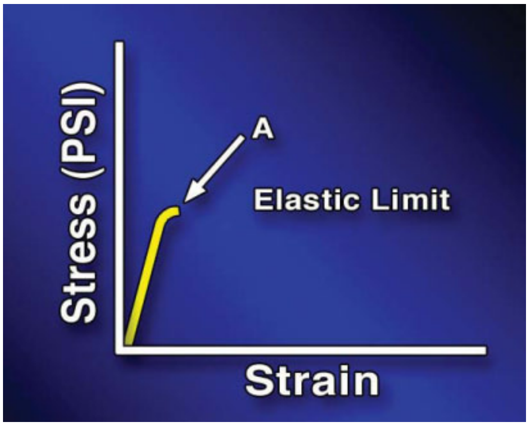
As the force is applied, the specimen begins to stretch or elongate. This is commonly referred to as strain. The units for strain are inch per inch. This is the amount of increase in length per inch of gage length.



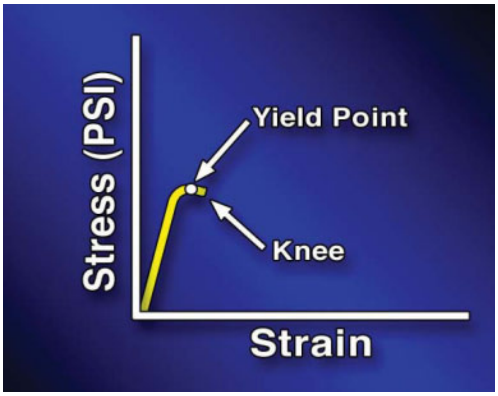
Some tensile equipment is designed with charts to plot the stress in relation to the strain. The gage attached to the specimen detects the elongation which is used by the equipment to plot the strain.



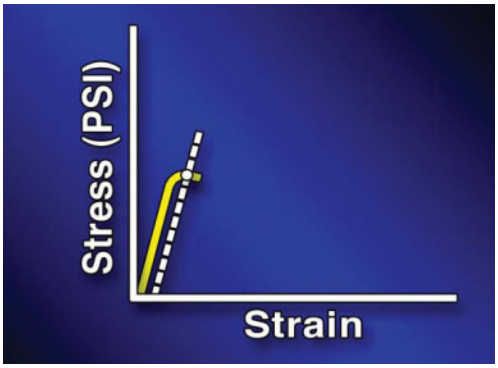
The curve which is plotted is called a stress-strain curve. In the lower part of the curve, the stress is proportional to the strain. Under these loading conditions, the material is an elastic state. This means if the load is removed, the material will return to its original length.



As the load continues to increase, the material eventually reaches its elastic limit at point A. At point A, the material begins to yield. When the material yields, it will permanently elongate, sometimes referred to as plastic deformation. Under these loading conditions, the material is in a plastic state. If the load is removed now, the material will not return to its original length.

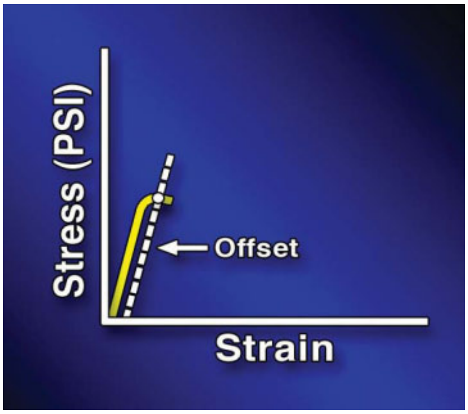


The point at which the material is permanently elongated is called the yield point. The yield point is defined as the load that causes a marked increase in strain without increase in stress.

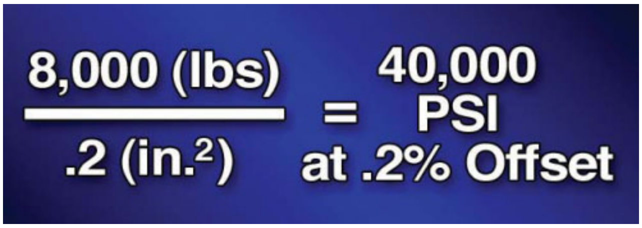


In many cases, the yield point is difficult to determine. Because of this, yield strength is more commonly used to describe the point of yielding, or permanent deformation.

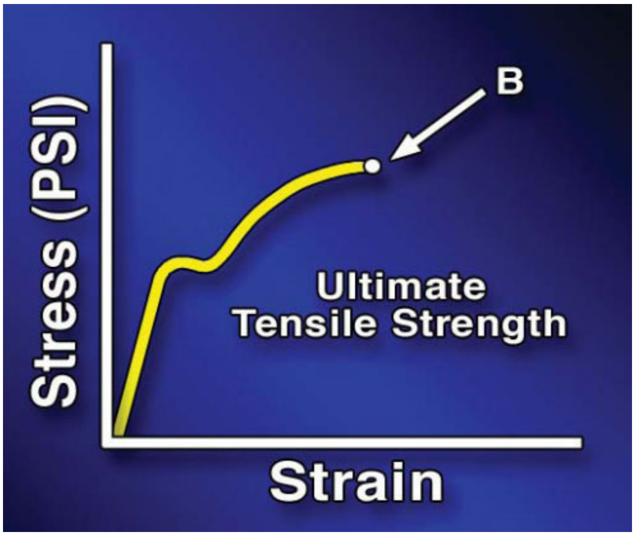
The yield strength is determined by drawing a straight line parallel to the straight portion of the curve.



This is described an as offset method since the distance between the lines is a percentage of the original gage length. The point at which the offset line crosses the original curve is the yield strength.

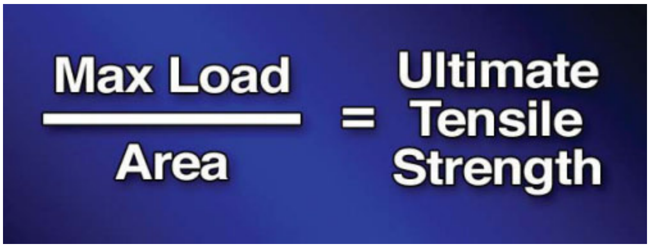


If the intersection occurred at a load of eight thousand pounds, we can divide the load by the cross sectional area to determine the yield strength. In this case, it is 40,000 pounds per square inch.



After the material has yielded, the strain gage is usually removed to prevent damage to the gage when the material ruptures.

As addition load is applied, it reaches a maximum value called the ultimate tensile strength. A noticeable reduction in area and increase in length will occur as the load is increased.

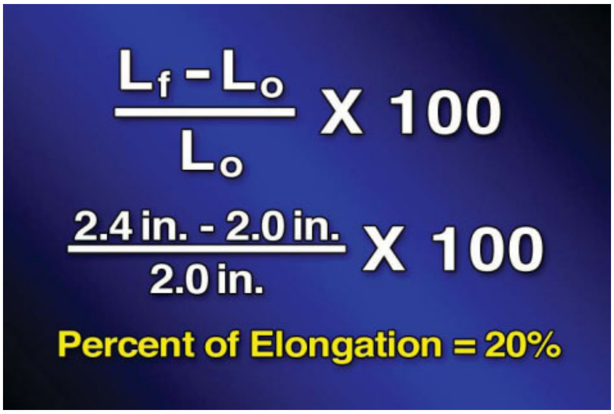


By dividing the maximum load by the original cross sectional area, the ultimate tensile strength can be calculated.

After the ultimate strength is achieved, the actual stress may decrease as the material fails. This is due to the significant reduction of area which occurs in the later stages of the test.

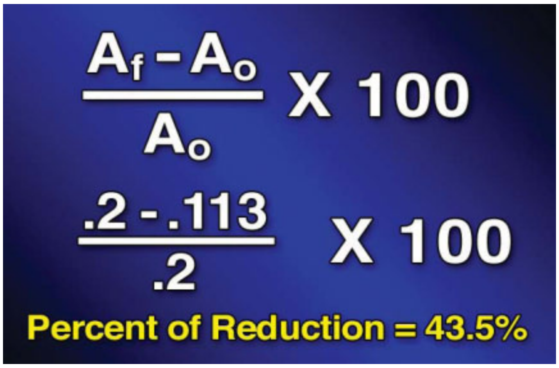
The broken specimen is used to calculate ductility through percent elongation and percent reduction of area.

The percent of elongation is determined by measuring the final length between the punch marks.

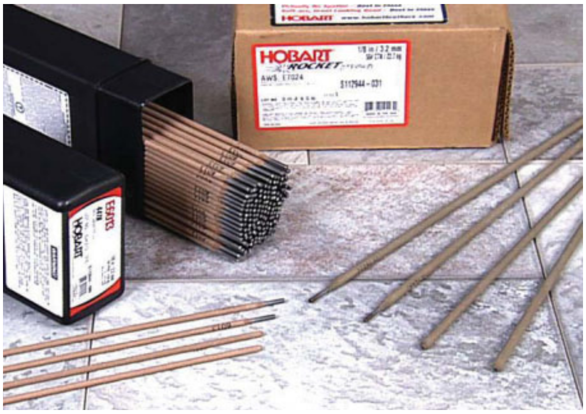


The difference between the final length and the original length is divided by the original length followed by multiplying by 100. A higher percentage indicates greater ductility.

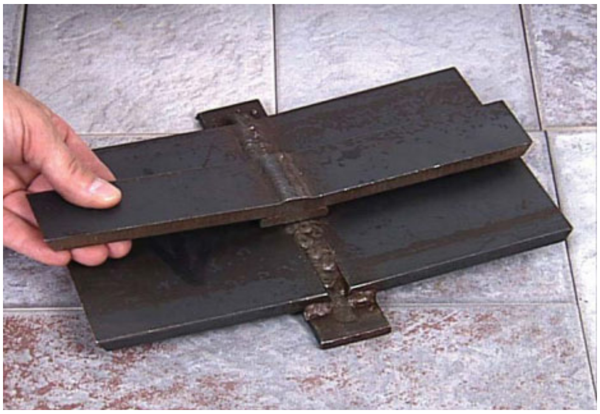
To measure reduction of area, measure the smallest cross section of the broken specimen. Calibrated micrometers or calipers are used to make the measurement.



The difference between the original and final area is divided by the original area and then the result is multiplied by 100. A higher percentage indicates greater ductility.



The all weld metal tensile test is most commonly used to specify and classify welding consumables. However some welding codes also require this test to qualify procedures with special processes such as electroslag and electrogas welding.



REDUCED SECTION TENSION TEST

These tests are commonly used by published welding codes to qualify welding procedures.

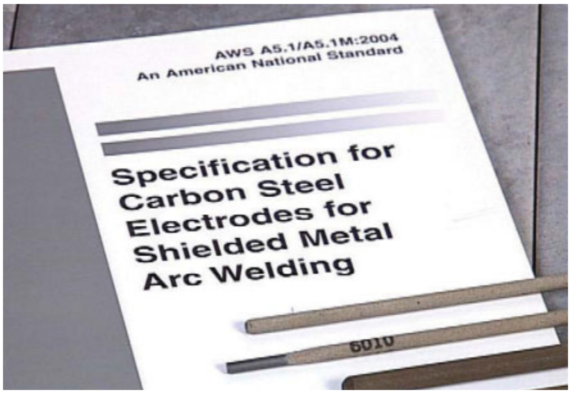
Usually the test specimens are removed from plate and pipe welds transverse to the direction of welding. The type, size and number of test specimens will depend on code requirements.

Once the specimens are removed, they are machined to the required dimension. The term reduced section is used since the middle of the specimen is thinner than the ends.

The reduced section tensile is placed in the tension machine and pulled to failure. The strain gage is normally not used to perform these tests.

Most codes require the ultimate tensile strength recorded in the test to be equal to or greater than the minimum of the specified tensile range of the base metal welded.

Full sections may be required on thin material or small diameter pipe where it becomes difficult to remove the test specimen.



It is important to review the applicable specification to determine the proper procedure and type of coupon based on the qualification to be performed. The tensile test is most often used to verify materials and procedures prior to production or construction, although it could be used on random sampling of production parts.

TOPIC 2
REVIEW QUESTIONS

1. Determine the following mechanical properties using the information and equations shown below:

Ultimate Tensile Strength = ______________________________

Yield Strength = ______________________________

% Elongation = ______________________________

% Reduction of Area = ______________________________

EQUATIONS

$$\text{Area} = \frac{\Pi (d)^2}{4}$$

$$\text{Stress} = \frac{\text{Load}}{\text{Area}}$$

$$\text{\% Elongation} = \frac{Lf - Lo}{Lo} \times 100$$

$$\text{\% Reduction of Area} = \frac{Ao - Af}{Ao} \times 100$$

INFORMATION

Diameter = .505 inches
Maximum Load = 18,400 pounds
Load at Yield = 13,200 pounds
Original Length = 2 inches
Final Length = 2.25 inches
Final Diameter - .405 inches
 = 3.14

TOPIC 3

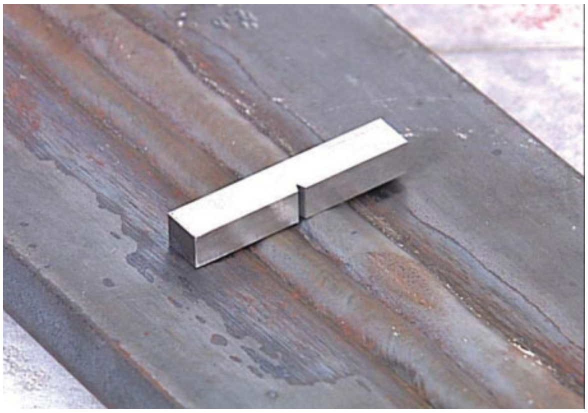
IMPACT TESTING

OBJECTIVE

To know the procedure used to perform impact tests and the results derived from the test.

INTRODUCTION

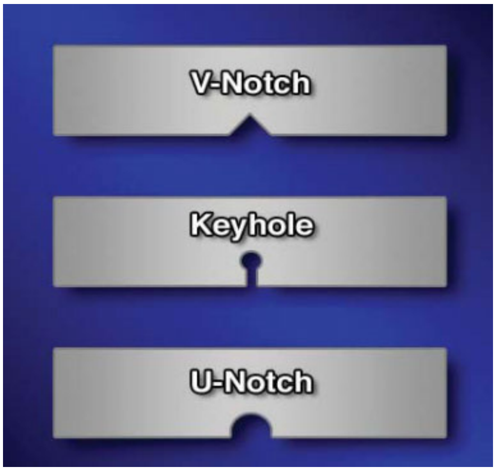
The basic principle of the impact test is to determine the behavior of a material once it has been struck with a sudden blow. The test provides data to measure the toughness of a material at varying temperatures. Base and filler metals are evaluated to determine their ability to provide toughness through impact testing.



CHARPY V-NOTCH PREPARATION

The most common form of impact test is the Charpy v-notch test. The test specimen is prepared with a precisely machined notch.

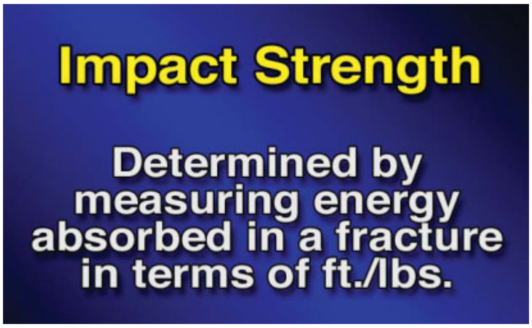
When weld joints require impact tests, a series of specimens are removed transverse to the weld axis. Normally, five, seven or more are required to determine impact properties. The dimensions of the specimens are important to the accuracy of the test. The dimensions are based on the quality specification and the testing procedure.



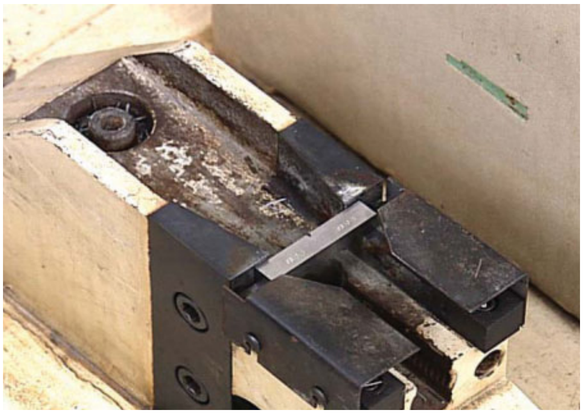
There are three common types of notched specimens used with the Charpy test which include the V-notch, the keyhole notch and the U-notch. The V-notch is the most common. The notch is precisely machined to insure reliability of the results.

The required numbers of specimens are stamped for identification. Both ends should be stamped so the broken specimens can be matched and evaluated.

The test begins by cooling the specimens. Methanol and liquid nitrogen are sometimes used in a refrigerated bath to cool the specimens.

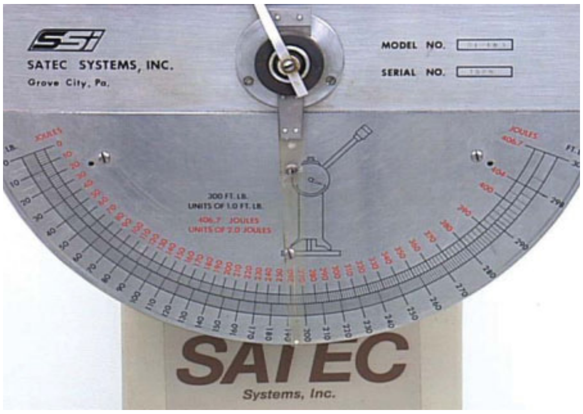


The impact strength of a metal is determined by measuring the energy absorbed in the fracture in terms of foot pounds. The Charpy impact machine provides the impact force with a free-falling pendulum. The amount of energy depends on the weight of the pendulum and the distance it travels to apply the load.

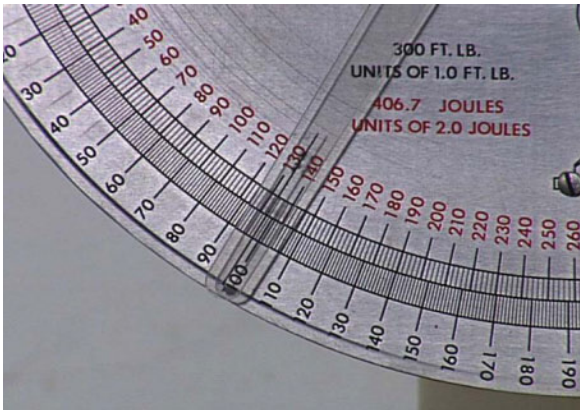


The test specimen is placed at the support fixture against the anvil at the base of the machine. The specimen is supported at both ends and positioned with the notch centered on the opposite side of the pendulum strike.

The pendulum is released from a fixed standard height and allowed to swing downward and strike the specimen. As the pendulum falls, it builds up energy.



A gage located on the test equipment starts at three hundred foot pounds. The needle will travel clockwise and stop at the top of the pendulum swing.

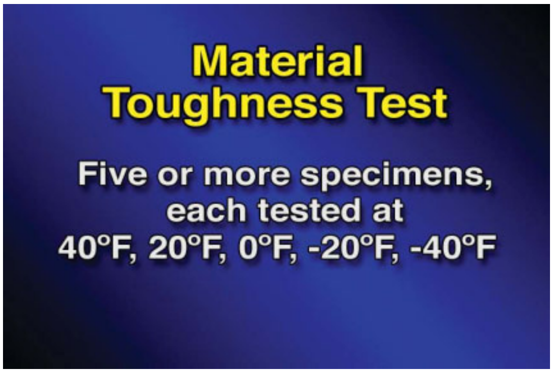


When the pendulum strikes the specimen, it slows down because the specimen absorbs some of the three hundred foot pounds. This prevents the pendulum from making a full swing. At the completion of the swing, the needle will register the amount of absorbed energy.

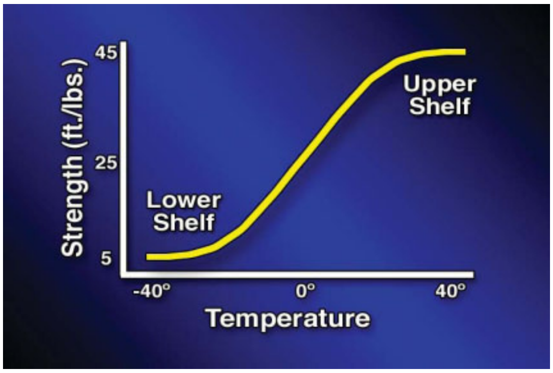
CHARPY V-NOTCH RESULTS

Some quality specifications may require a series of five or more specimens to be cooled to -20° F. Once the temperature is achieved, all of the specimens are broken.

The material meets the necessary toughness requirements if all specimens are capable of sustaining the minimum acceptable foot pounds of energy.

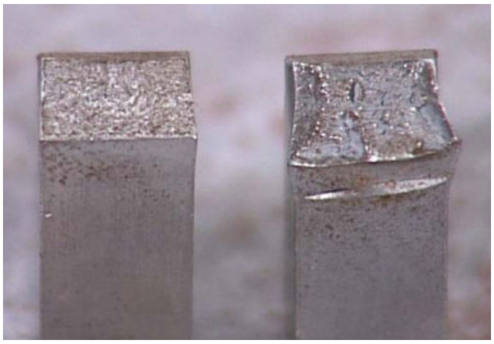


Another procedure which is sometimes employed consists of preparing a series of specimens to be tested at various temperatures. Groups of five or more test specimens may be tested at each temperature.



The results of the specimens tested are averaged to obtain a foot pound value at each temperature. The results can be plotted on an energy transition curve. The curves developed for carbon steel show an upper shelf and a lower shelf. The lower shelf indicates that toughness properties are lost in this temperature range. At lower temperatures, steels normally become brittle or lose toughness properties.

A measure of ductility is also possible. This is the degree of lateral expansion of the fracture surface, sometimes called Mils Lateral Expansion. More expansion on the side adjacent to the notch after testing indicates the material has greater ductility.

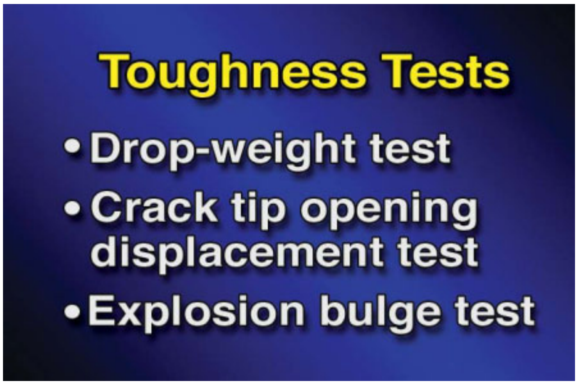


The fractured surface of the impact specimen can also be evaluated at either ductile or brittle. Some standards require that 50% or more of the fractured surface must appear ductile.

PROCEDURES AND STANDARDS

- **American Welding Society**
- **American Society for Testing and Materials**
- **American Society of Mechanical Engineers**
- **Military Specifications**

The Charpy impact test is commonly used to certify welding filler metals and to qualify welding procedures. The procedure for conducting the test, number and type of specimens and standards of acceptability may be specified by code.



OTHER IMPACT TESTS

Other types of tests are used to measure toughness properties. Although not as common as the Charpy test, may be specified by some quality specifications.

TOPIC 3

REVIEW QUESTIONS

1. A carbon steel brittle fractured surface will have a:

A. silver grainy appearance
B. torn surface
C. significant amount of lateral expansion
D. dull gray appearance

2. The Charpy impact test is commonly used to:

A. certify filler metals
B. certify base metals
C. qualify procedures for special processes
D. all of the above

3. Besides the Charpy impact test, what other tests are used to meaure toughness?

A. Drop-weight test
B. Crack tip opening displacement test
C. Explosion bulge test
D. All of the above

4. The toughness properties of a material are very sensitive to:

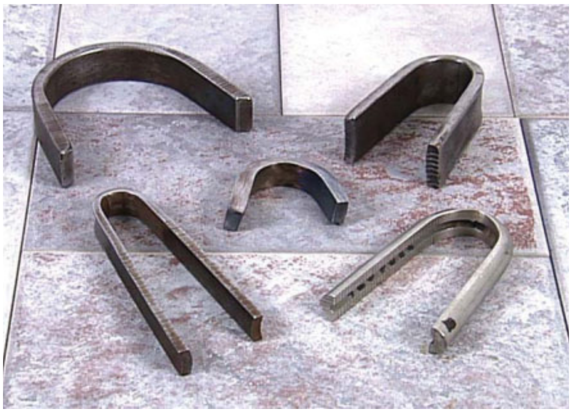
A. temperature
B. notch placement
C. amount of loading
D. all of the above

TOPIC 4

GUIDED BEND TESTING

OBJECTIVE

To know the procedure used to perform guided bend tests and the results derived from the test.



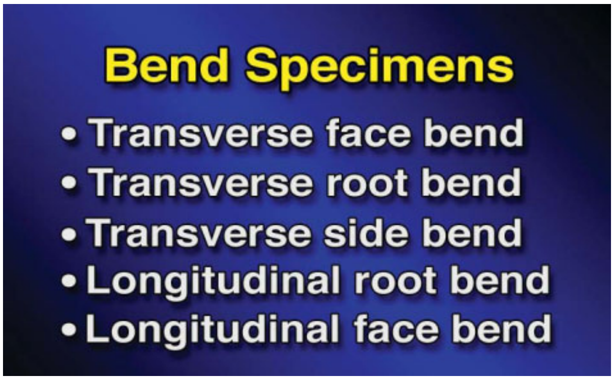
INTRODUCTION

The basic principle of the guided bend test is to determine the soundness and ductility of weld metal by bending a specimen into a U-shape and then evaluating the bent surface.

The guided bend test is perhaps one of the most popular destructive testing methods due to its simplicity and comparatively low cost.

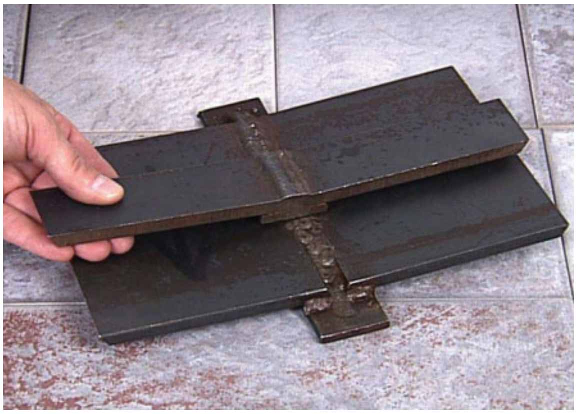
Because it provides a tension and a compression load on a weld specimen, this test is helpful for determining if weld metal and base metal are thoroughly fused.

It is used to provide evidence that a welding procedure will produce quality welds with minimum discontinuities. It is also used to determine the welder's ability to deposit sound welds on plate or pipe.

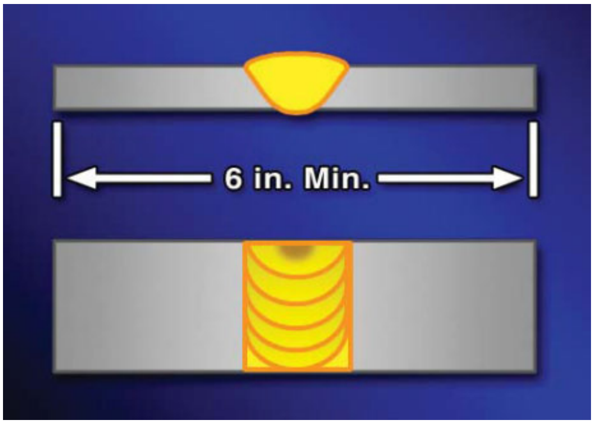


GUIDED BEND TEST PROCEDURES

There are five types of bend specimens, each of which is evaluated in much the same way.

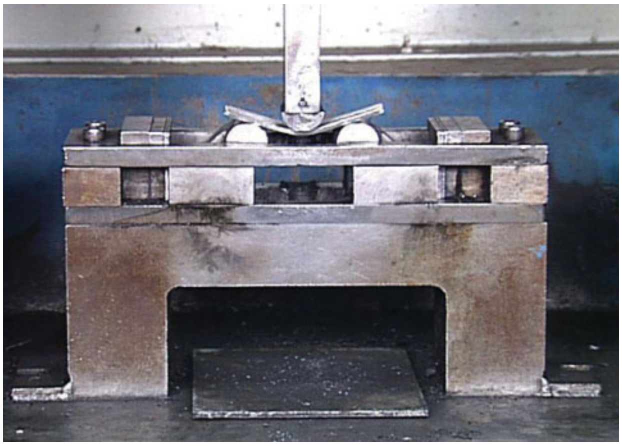


The transverse face and root bend specimens are removed perpendicular to the weld axis. The actual number and location of the specimen will depend on the applicable specification or code.



Generally, the length is a minimum of six inches. The width of the specimen is normally no more than four times the test material thickness. The thickness for the transverse face and root bend is equal to the test material thickness and generally does not exceed three-eighths inch.

Before bending, the weld reinforcement is removed. Care must be taken to avoid removing material below the surface of the specimen. The grinding or machining should be parallel to the longitudinal axis of the specimen.

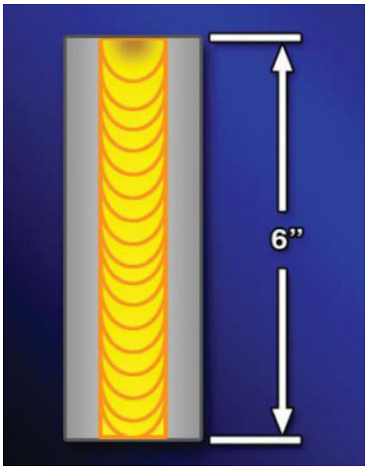


The transverse face bend is positioned in the bend fixture so that the face surface becomes the convex surface of the bend specimen. For a root bend, the root surface becomes convex.

The transverse side bend test is generally used on material greater than three-eighths inch thick.

The specimen is bent so that one of the side surfaces becomes the convex surface.

The longitudinal root and face bend are prepared down the weld axis.

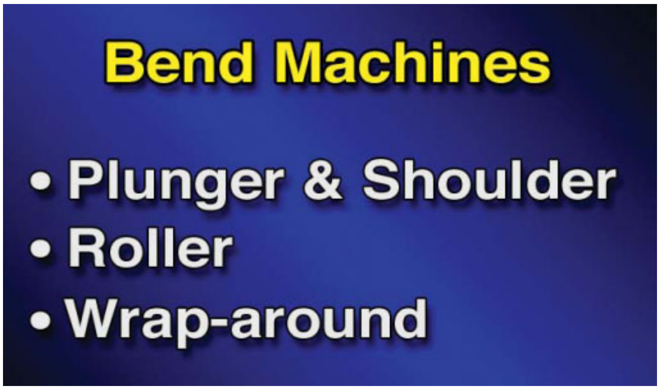


The length is approximately six inches and the width is approximately the width of the weld plus five-eighths inch. The thickness is equal to the plate thickness up to a maximum of three-eighths inch.

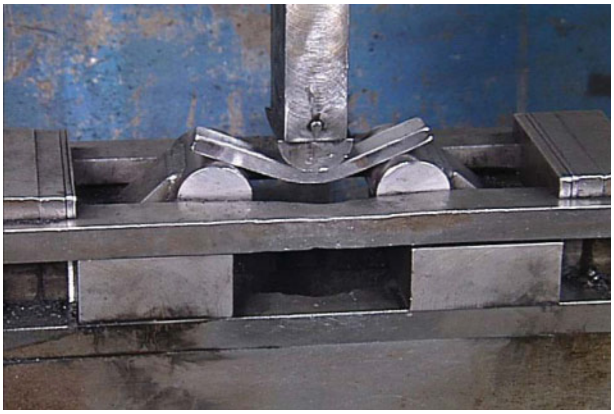
The longitudinal face bend is bent so that the face surface becomes the convex surface of the bent specimen. The root would be tested in a similar manner.

THE CODE LISTS:
TYPE
NUMBER
LOCATION
DIMENSIONS

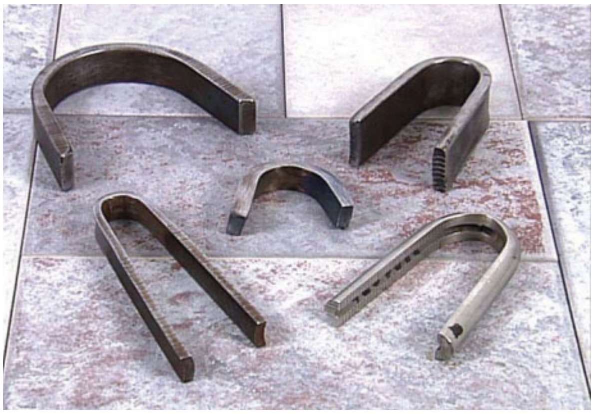
The requirements are detailed in the testing procedure or applicable code.



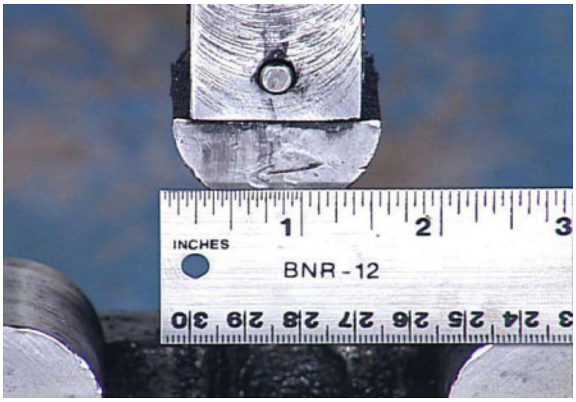
There are basically three types of guided bend machines. The conventional plunger and shoulder machine consists of a plunger which applies the bending load and a set of shoulders which act as a die, forming the prescribed bend specimen.



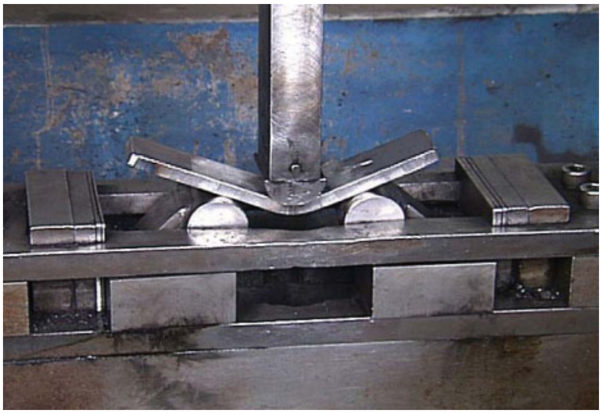
The roller machine works in much the same way. However, the shoulders have rollers attached to minimize resistance during bending.



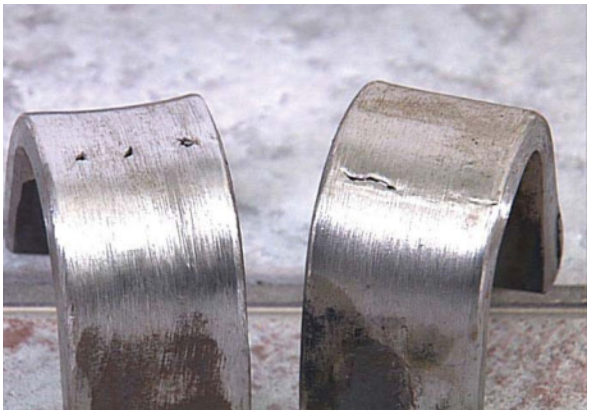
The wrap-around machine is much different. It holds one end of the bend specimen and then forces the other end around a prescribed size die to shape the specimen into a U.



Regardless of the type used, the machine must be set up to provide the required radius on the specimen. The required radius will differ with each code so care must be taken to insure proper set-up.



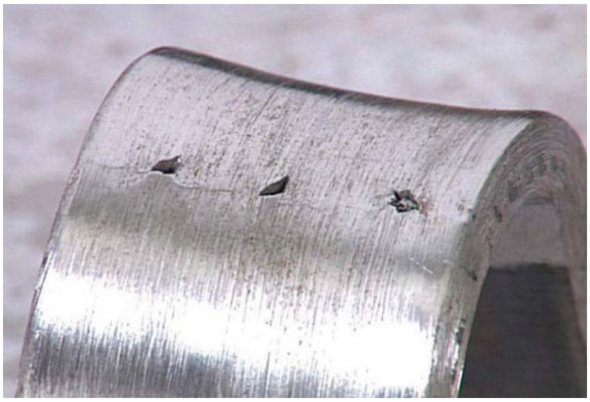
The specimen is placed in the bend fixture with the weld in the center. This insures the weld is in the center of the bend. Activate the plunger and bend the specimen.



GUIDED BEND TEST RESULTS

Once all the required specimens have been bent, the evaluation process begins. The standards of acceptability will differ with each code, so care must be taken to insure the proper code is used.

Discontinuities exposed on the convex surface of the specimen are evaluated. Some codes allow evaluation of discontinuities on the sides of the specimen as well.



Any discontinuities greater than the allowable code limits are considered unacceptable. For example, the maximum discontinuity size could be one-eighth inch measured in any direction.

TOPIC 4

REVIEW QUESTIONS

1. Name at least four types of guided bend tests:

2. List four discontinuities which can be determined by the guided bend test:

3. Which type of bend test is most often used on thicker metals?

4. What are the three types of bend equipment?

TOPIC 5

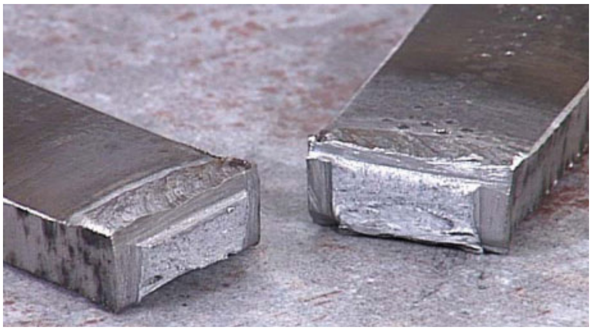
NICK BREAK TESTING

OBJECTIVE

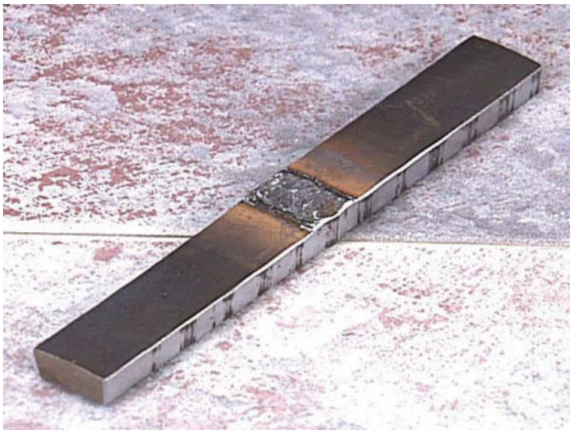
To know the procedure used to perform nick break tests and the results derived from the test.

INTRODUCTION

This destructive test is a simple but effective method of determining the soundness of weld metal. It is commonly used to qualify procedures and welders by some codes. For example, the American Petroleum Institute code for transmission pipelines sometimes requires the nick break for qualification.



The basic principle of this test is to visually inspect a fractured surface for weld metal soundness. Discontinuities such as porosity, slag entrapment, lack of fusion, or other welding problems are evaluated.



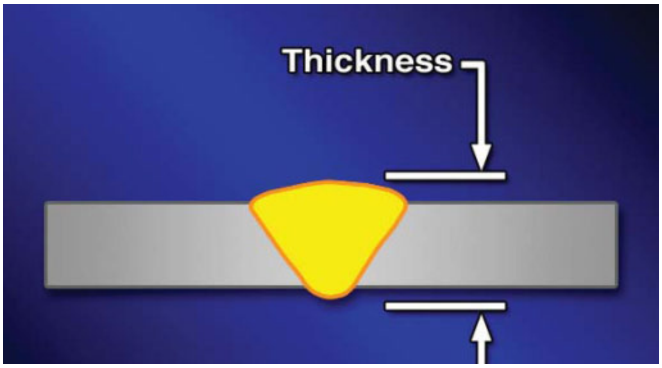
NICK BREAK TEST PROCEDURES

The nick break test consists of preparing a weld metal specimen from a butt joint, much like those prepared for the guided bend test.

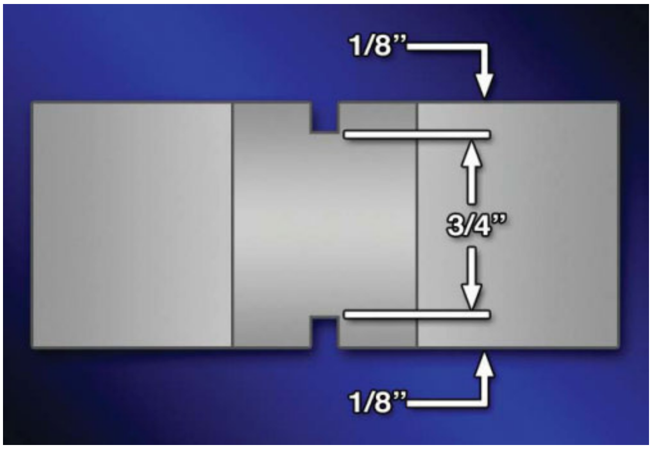
Special attention must be given to the dimensions required. Published welding codes or company standards will dictate the number and type of specimens, if required.

There are two types of specimens: the end notched specimen and the all-around notched specimen. The end-notched specimen is the more common. The all-around notched specimen is considered optional by some codes.

The location from which the specimens are taken is generally the same as for guided bend specimens. However, when both are required from the same test coupon, they are taken side by side, as in the case of certain pipe qualifications.

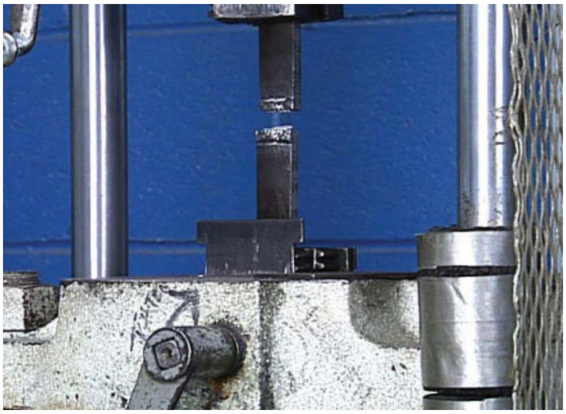


The dimensions of the nick break specimen depend largely on the thickness of the test material and the governing specification.

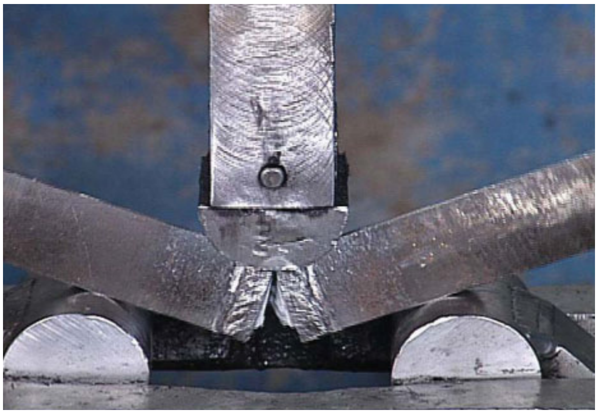


All codes agree that the notch is prepared in the center of the weld. However, the depth of the notch can differ from one code to the next. The notch is prepared by any suitable means. Generally, the notch depth is approximately one-eighth inch. The portion between the two notches is the area of fracture and is normally required to be a minimum of three-quarters inch.

Weld reinforcement is generally not removed so that the entire throat of the weld can be inspected. However, this would not be true with the all-around notch specimen since the notch has removed a portion of the reinforcement.

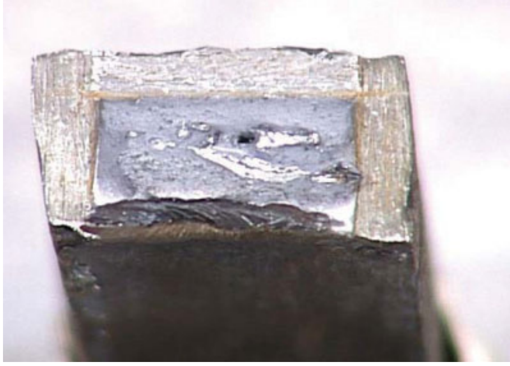


Any suitable means of breaking the specimen is acceptable. However, proper attention to safety must always be considered when conducting the test. The specimens can be pulled in a tension test machine until broken.



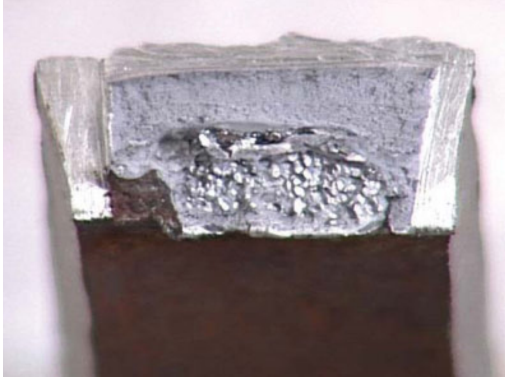
The specimen can also be subjected to a bending load or one end of the specimens could be fixed and the opposite end struck with a hammer to cause the break.

NICK BREAK TEST RESULTS

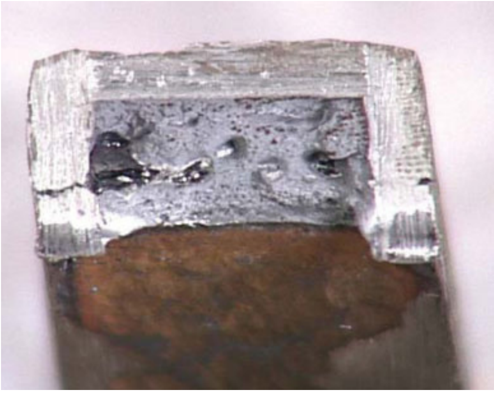


The specimen is then examined for discontinuities that might cause poor soundness.

Lack of fusion could appear as a silvery line in the weld metal which could open during testing.



Porosity appears as round depressions on the fractured surfaces. Some codes allow no more than six gas pockets per square inch of weld metal, with the largest gas pocket no greater than on-sixteenth inch.



Slag inclusions appear as a non-metallic, glass-like substance on the fractured surfaces. The applicable quality specification will provide dimensions on the amount of acceptable slag inclusions.

COUPON TEST REPORT

Date ______ Test No. ______
Location ______
State ______ Weld Position: Roll ❑ Fixed ❑
Welder ______ Mark ______
Welding time ______ Time of day ______
Mean temperature ______ Wind break used ______
Weather conditions ______
Voltage ______ Amperage ______
Welding machine type ______ Welding machine size ______
Filler metal ______
Reinforcement size ______
Pipe type and grade ______
Wall thickness ______ Outside diameter ______

	1	2	3	4	5	6	7
Coupon stenciled							
Original specimen dimensions							
Original specimen area							
Maximum load							
Tensile strength							
Fracture location							

❑ Procedure ❑ Qualifying test ❑ Qualified
❑ Welder ❑ Line test ❑ Disqualified

Maximum tensile ______ Minimum tensile ______ Average tensile ______
Remarks on tensile-strength tests ______
1. ______
2. ______
3. ______
4. ______

Remarks on bend tests ______
1. ______
2. ______
3. ______
4. ______

Remarks on nick-break tests ______
1. ______
2. ______
3. ______
4. ______

Test made at ______ Date ______
Tested by ______ Supervised by ______

Note: Use back for additional remarks. This form can be used to report either a procedure qualification test or a welder qualification test.

Once the test specimens are evaluated, the results are recorded on the applicable form. This could be a procedure qualification record or welder qualification report.

TOPIC 5

REVIEW QUESTIONS

1. Name four discontinuities which could appear on the fractured surface of a nick break test specimen:

____

____

____

____

2. The nick break test is commonly used to:

A. certify filler metals
B. determine weld strength
C. determine impact strength
D. qualify procedures and welders

3. The nick break specimen contains:

A. a keyhole notch
B. a v-notch
C. a rectangular notch
D. a U-shaped notch

4. The nick break test most often used on:

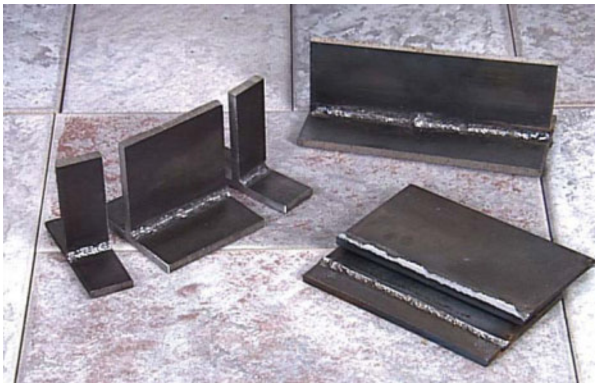
A. a groove weld
B. a fillet weld
C. an edge weld
D. a flange weld

TOPIC 6

FILLET WELD BREAK TESTING

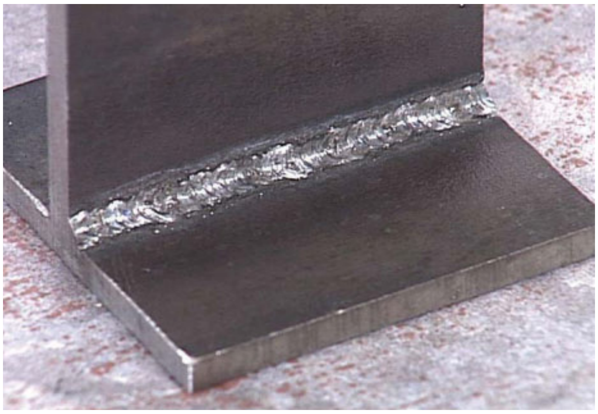
OBJECTIVE

To know the procedure used to perform fillet weld break tests and the results derived from the test.



INTRODUCTION

This destructive test is similar to the nick break test. The fillet weld break test consists of depositing a fillet welding of a specific size and then applying force to bend or break the specimen. The face of the weld and the fractured surface are evaluated for weld soundness.



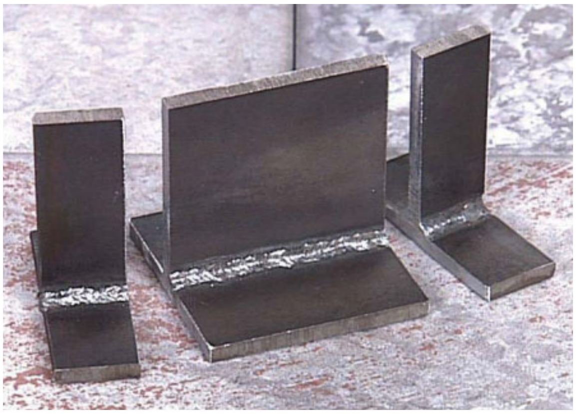
The fillet weld break test is used to qualify procedures, welders and welding operators for producing fillet welds on plate and pipe. It is especially common for the qualification of tack welders.

The governing code or quality specification must be considered to obtain accurate test information.

FILLET WELD BREAK TEST PROCEDURES

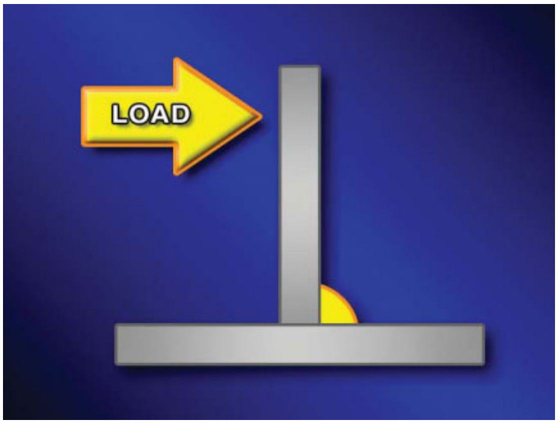
When plates are to be joined by fillet welds, the t-joint is most often used to perform the break test. Single pass fillet welds are tested using this method due to the difficulty in breaking large multipass welds. The length, width and thickness of the test plate and the fillet weld size depend upon the code requirements and the design of the weldment.

The preparation for the t-joint test consists of depositing the proper size fillet weld according to the welding procedure. Some codes may require a weld restart in the center of the bead.

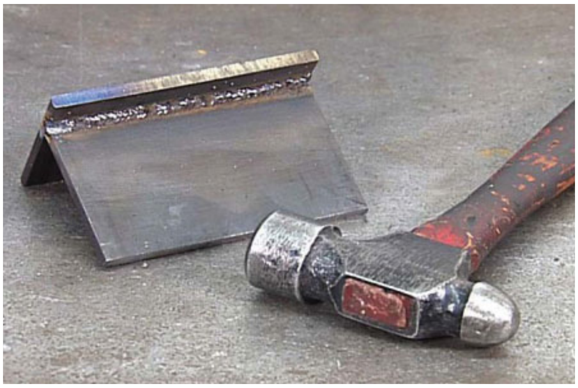


One inch from each end may be removed prior to break testing. This is especially common when macro etch specimens are also required.

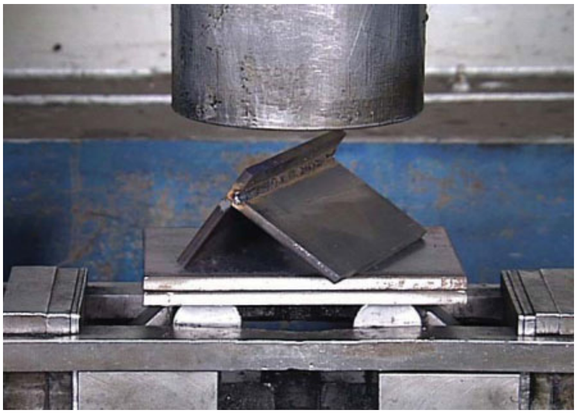
The specimen is visually inspected for cracks, overlap, undercut and other discontinuities.



To break the weld, the root must be in tension. Generally, any suitable means of loading the specimen is acceptable although safety must be considered.



The specimen can be bent or broken using a hammer; or a press could be used to apply a bending load.



The load is increased or repeated until the specimen breaks. However, if the specimen bends without breaking, it usually passes the test.

FILLET WELD BREAK TEST RESULTS

The broken surfaces are visually inspected for discontinuities such as cracks, lack of fusion, inclusions and porosity.

Complete fusion to the root of the joint should be evident. Lack of fusion will normally appear as unmelted base metal with a clear edge.

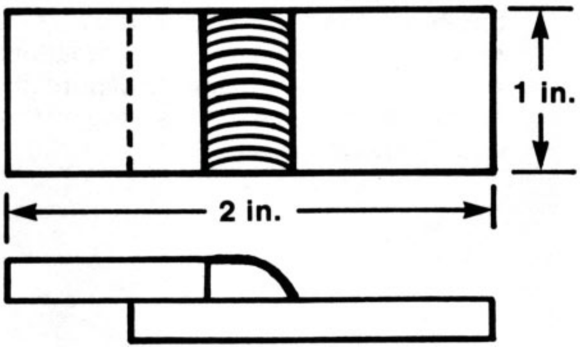
Porosity appears as a round discontinuity on the fractured surface. The discontinuities may have a silver color from oxidation. The maximum size or diameter of porosity and a total size is usually stated by the quality specification.

Slag inclusions will normally appear as nonmetallic material along the weld or with the weld metal. Similar to porosity, a maximum size and total length may be indicated.

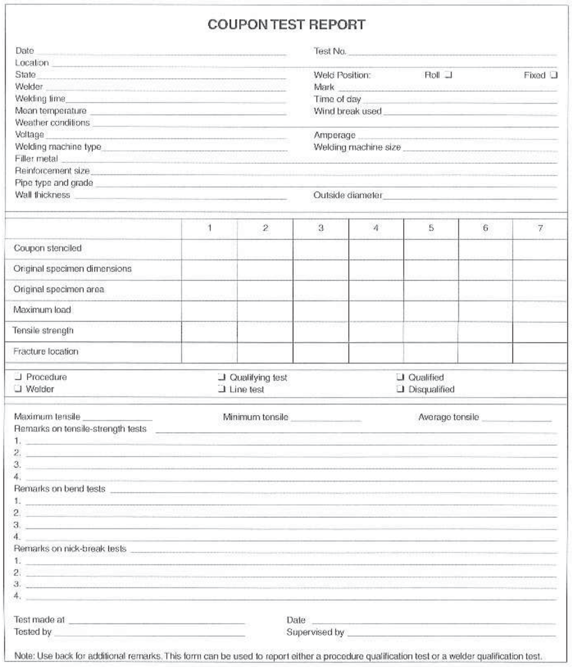
FILLET WELD BREAK TEST PIPE

Fillet welds on pipe connections can also be tested. Specimens may be removed from socket welds or t-connections.

The preparation of pipe specimens consists of welding the prescribed pipe per procedure and then removing the required number of specimens from the required location on the pipe.



Generally the size of the pipe weld test specimen is at least two inches long and one inch wide. However, the size will vary based on the quality specification. The specimens are prepared, broken and examined.



COUPON TEST REPORT

Date ______ Test No. ______
Location ______
State ______ Weld Position: Roll ❑ Fixed ❑
Welder ______ Mark ______
Welding time ______ Time of day ______
Mean temperature ______ Wind break used ______
Weather conditions ______
Voltage ______ Amperage ______
Welding machine type ______ Welding machine size ______
Filler metal ______
Reinforcement size ______
Pipe type and grade ______
Wall thickness ______ Outside diameter ______

	1	2	3	4	5	6	7
Coupon stenciled							
Original specimen dimensions							
Original specimen area							
Maximum load							
Tensile strength							
Fracture location							

❑ Procedure ❑ Qualifying test ❑ Qualified
❑ Welder ❑ Line test ❑ Disqualified

Maximum tensile ______ Minimum tensile ______ Average tensile ______
Remarks on tensile-strength tests ______
1. ______
2. ______
3. ______
4. ______
Remarks on bend tests ______
1. ______
2. ______
3. ______
4. ______
Remarks on nick-break tests ______
1. ______
2. ______
3. ______
4. ______

Test made at ______ Date ______
Tested by ______ Supervised by ______

Note: Use back for additional remarks. This form can be used to report either a procedure qualification test or a welder qualification test.

REPORTING

The results of the tests are placed on the appropriate form. This could be a procedure qualification record, a welder qualification report or a quality control production report.

TOPIC 6

REVIEW QUESTIONS

1. Name three uses of the fillet weld break test:

____

____

____

2. Usually single pass fillet welds are visually inspected prior to break testing. What discontinuities are inspected visually?

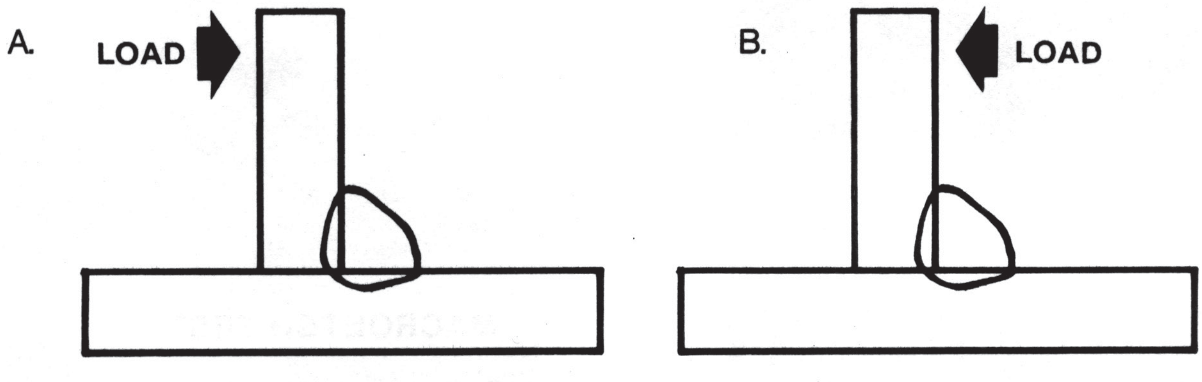
____

____

____

____

3. Place the letter in the blank provided to indicate which illustration shows the correct method of loading the fillet weld in the break test. ______________



4. What discontinuities are inspected on the fractured surface of the fillet weld break test?

______________________ ______________________

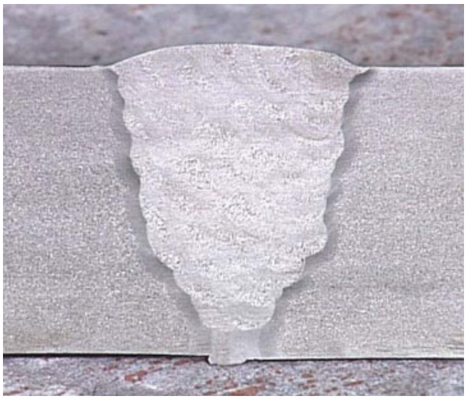
______________________ ______________________

TOPIC 7

ETCH TESTING

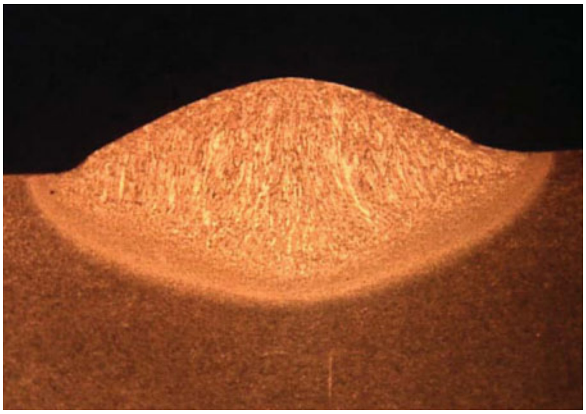
OBJECTIVE

To know the procedures used to perform etch tests and the results derived from the test.

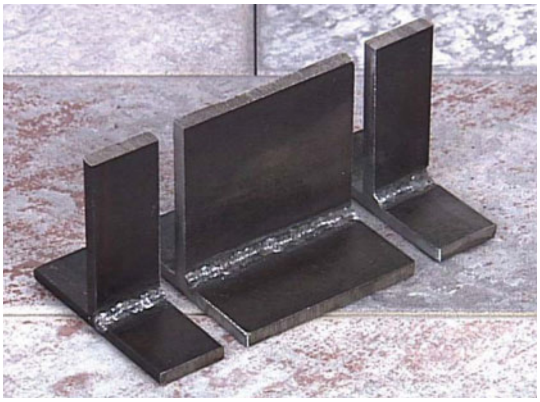


INTRODUCTION

The etch test consists of cutting a specimen transverse to the weld axis, applying an etching solution and inspecting the exposed surface. This form of destructive testing is an excellent method of determining the soundness of weld metal and the metallurgical structure produced by the weld.



The test outlines or defines the weld structure in relation to the base metal. The etched surface provides a contrast between the weld, heat affected zone and base metal. This form of testing is commonly referred to as metallographic examination.

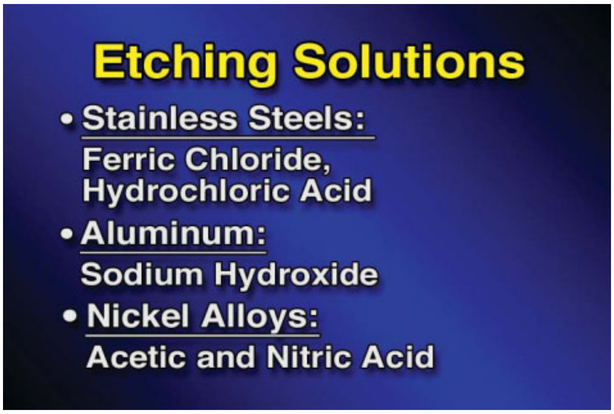


MACROETCH TEST

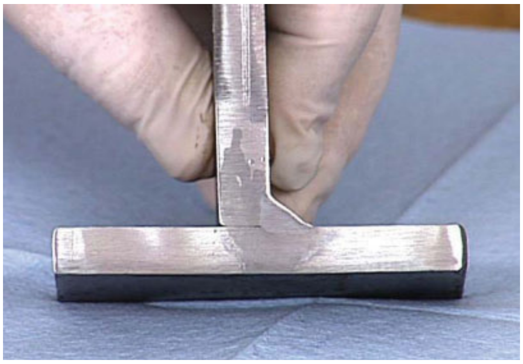
The macroetch test is commonly used to qualify fillet weld procedures and welders.

In this test, the coupon is cut transverse to the weld axis in one or more locations.

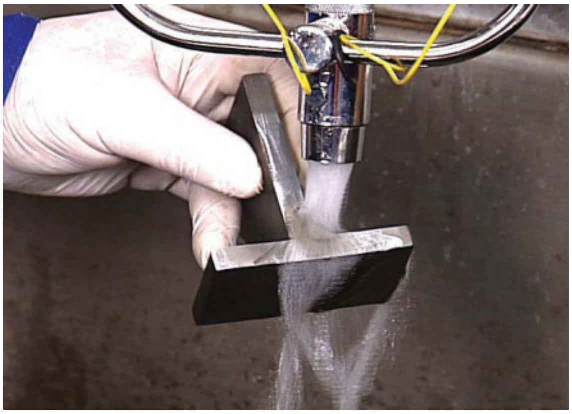
The weld specimens are ground smooth. In the case of carbon steel, the surface can be etched with a solution of one part ammonium persulphate and nine parts water or a solution of diluted hydrochloric acid.



Safety precautions must be considered when working with etchants such as hydrochloric acid. Some acids can cause serious burns through contact with the skin. The type of etchant will depend on the metal.



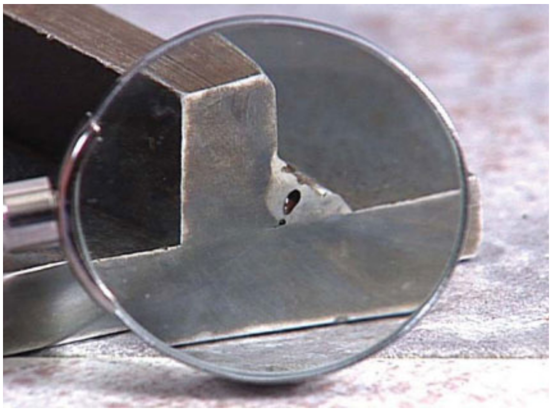
The etchant is normally applied at room temperature using a cotton swab or similar applicator. Etching begins the instant the solution is applied. However, it may be necessary to continue rubbing the surface until there is a clear definition of the weld structure.



After the surface is completely etched, it is washed in clean water and dried. When handling the specimen, the tester must be careful not to touch the etched surface. The etched surface can be preserved by applying a thin coat of clear lacquer.

The macrospecimen is inspected by looking at the etched surface without magnification or with magnification less than ten X.

The X means the number of times larger the area appears under a magnifying lens. Ten X means that the area will appear ten times larger than normal.



The etched surface is examined to determine weld soundness. Discontinuities such as cracks, porosity, incomplete fusion, slag inclusions and lack of penetration are evaluated.

The number of weld passes is also visible which helps determine where the problems occur and how the procedure can be modified to solve them.

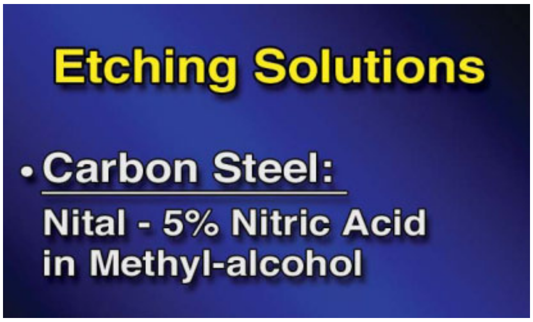
Published welding codes provide a standard of acceptability for evaluation of macroetch specimens to qualify welding procedures and welders.

The results are recorded on qualification reports or the quality control documents.

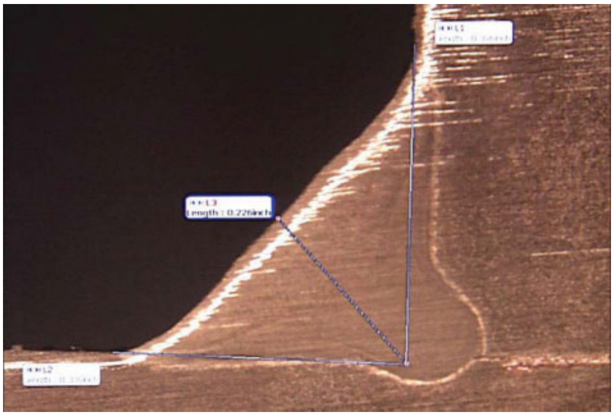
MICROETCH TEST

The microspecimen is inspected by examining the etched surface through a microscope with a magnification greater than ten X.

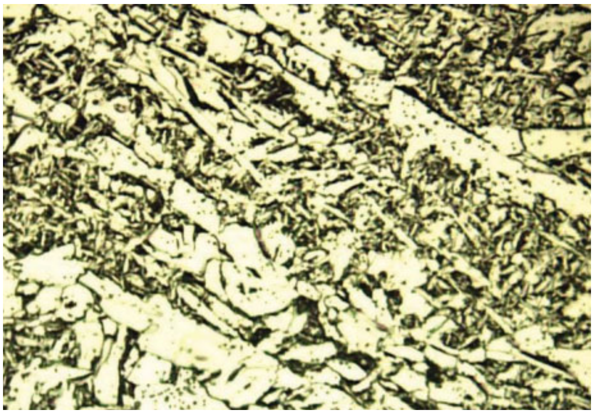
The microspecimen is prepared similar to the macrospecimen. However the surface is carefully ground and polished to a mirror-like finish to remove all scratches.



A metallographic etching solution is applied to the surface. Nital solution is commonly used on carbon steel which consists of 5% nitric acid in methyl alcohol.



The etched surface is then viewed through a microscope at high magnifications. Usually a picture (micrograph) is produced. The metallurgical structure of the weld metal, fusion zone and heat affected zone are analyzed for characteristics such as grain size, carbon content, and ferrite content.



Few codes require this detailed an examination. However, it is helpful in evaluating solutions to welding problems on ferrous and nonferrous metals.

The microexamination requires a trained metallographer with skill in metal preparation, knowledge of the test procedure and necessary experience to interpret results.

TOPIC 7

REVIEW QUESTIONS

1. Explain the difference between macroetch test and microetch test.

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2. List the steps required to perform macroetch examination in the proper order in the space provided.

Grind macrospecimen ____________________

Inspect macrospecimen ____________________

Apply lacquer ____________________

Cut macrospecimen ____________________

Wash macrospecimen ____________________

Apply etchant to macrospecimen ____________________

3. What is the primary use of macroetch testing?

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4. What is the primary use of microetch testing?

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GLOSSARY OF WELDING TERMS

All–Weld Metal Test Specimen – A test specimen with the reduced section composed wholly of weld metal.

Axis of a Weld – A line through the length of a weld, perpendicular to and at the geometric center of its cross section.

Base Metal Test Specimen – A test specimen composed wholly of base metal.

Complete Fusion – Fusion which has occurred over the entire base material surfaces intended for welding and between all layers and weld beads.

Complete Joint Penetration – Joint penetration in which the weld metal completely fills the groove and is fused to the base metal throughout its total thickness.

Crack – A fracture type discontinuity characterized by a sharp tip and high ratio of length and width to opening displacement.

Defect – A discontinuity or discontinuities that, by nature or accumulated effect, render a part or product unable to meet minimum applicable acceptance standards or specifications. This term designates rejectability.

Depth of Fusion – The distance that fusion extends into the base metal or previous pass from the surface melted during welding.

Discontinuity – An interruption of the typical structure of a material, such as a lack of homogeneity in its mechanical, metallurgical, or physical characteristics. A discontinuity is not necessarily a defect.

Electrogas Welding (EGW) – An arc welding process which produces coalescence of metals by heating them with an arc between a continuous filler metal (consumable) electrode and the work. Molding shoe(s) are used to confine the molten weld metal for vertical position welding. The electrodes may be either flux cored or solid. Shielding may or may not be obtained from an externally supplied gas or mixture.

Electroslag Welding (ESW) – A welding process producing coalescence of metals with molten slag which melts the filler metal and the surfaces of the work to be welded. The molten weld pool is shielded by this slag which moves along the full cross section of the joint as welding progresses. The process is initiated by an arc which heats the slag. The arc is then extinguished and the conductive slag is maintained in a molten condition by its resistance to electric current passing between the electrode and the work.

Ferrite Number – An arbitrary, standardized value designating the ferrite content of an austenitic stainless steel weld metal. It should be used in place of percent ferrite or volume percent ferrite on a direct one-to-one replacement basis. See the latest edition of AWS A4.2 *Standard Procedure for Calibrating Magnetic Instruments to Measure the Delta Ferrite Content of Austenitic and Duplex Ferritic-Austenitic Stainless Steel Weld Metal.*

Fusion Zone – The area of base metal melted as determined on the cross section of a weld.

Heat-Affected Zone – That portion of the base metal which has not been melted, but whose mechanical properties or microstructure have been altered by the heat of welding, brazing, soldering or cutting.

Joint Penetration – The minimum depth a groove or flange weld extends from its face into a joint, exclusive of reinforcement. Joint penetration may include root penetration.

Leg of Fillet Weld – The shortest distance from the root of the joint to the toe of the fillet weld.

Overlap – In fusion welding, the protrusion of weld metal beyond the weld toe or weld root; In resistance seam welding, the portion of the preceding weld nugget remelted by the succeeding weld.

Peel Test – A destructive method of inspection which mechanically separates a lap joint by peeling.

Porosity – Cavity-type discontinuities formed by gas entrapment during solidification.

Procedure Qualification – The demonstration that welds made by a specific procedure can meet prescribed standards.

Procedure Qualification Record (PQR) – A record of welding variables used to produce an acceptable test weldment and the results of tests conducted on the weldment to qualify a welding procedure specification.

Reinforcement of Weld – Weld metal in excess of the quantity required to fill a joint.

Size of Weld:

Groove Weld – The joint penetration (depth of bevel plus the root penetration when specified.)

Fillet Weld – For equal leg fillet welds, the leg lengths of the largest isosceles right triangle which can be inscribed within the fillet weld cross section. For unequal leg fillet welds, the leg lengths of the largest right triangle which can be inscribed within the fillet weld cross section.

Note: When one member makes an angle with the other member greater than 105 degrees, the leg length (size) is of less significance than the effective throat, which is the controlling factor for the strength of a weld.

Slag inclusion – A discontinuity consisting of slag entrapped in weld metal or at the weld interface.

Spatter – The metal particles expelled during welding and which do not form a part of the weld.

Tack Weld – A weld made to hold parts of a weldment in proper alignment until the final welds are made.

Undercut – A groove melted into the base metal adjacent to the toe or root of a weld and left unfilled by weld metal.

Underfill – A depression on the face of the weld or root surface extending below the surface of the adjacent base metal.

Weldability – The capacity of a material to be welded under the fabrication conditions imposed into a specific, suitably designed structure and to perform satisfactorily in the intended service.

Welder – One who performs a manual or semiautomatic welding operation.

Welder Performance Qualification – The demonstration of a welder's ability to produce welds meeting prescribed standards.

Welding Operator – One who operates machine or automatic welding equipment.

Welding Procedure – The detailed methods and practices including all welding procedure specifications involved in the production of a weldment.

Welding Procedure Specification (WPS) – A document providing in detail the required variables for a specific application to assure repeatability by properly trained welders and welding operators.

Based on Standard Welding Terms and Definitions, AWS 3.0. American Welding Society.