

ENGINEERING DESIGN SEMINAR

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MAINTENANCE & INSPECTION

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INTRODUCTION

The purpose of this section is to provide information on nondestructive testing (NDT) methods commonly used in refinery applications.

VISUAL TESTING

Because of time constraints during shutdowns, visual internal inspection of the process equipment is of great importance in helping to select areas that may need mechanical repair or further NDT. The quality of the visual inspection data is restricted by the ability and willingness of the maintenance department to prepare (open and clean) a vessel for internal inspection. Flashlight, pit gauge, hammer, and weld inspection gauges are some tools that can be easily carried and used during a visual inspection of process equipment. Articles 9 and 28 of Section V of the ASME Code can be referenced for visual examination requirements and standards.

CALIPERS

Calipers are special tools for taking measurements that indicate accurate thicknesses of materials. Location of thickness measurements can be obtained only in equipment at opened areas. These measurements are accurate in recording data to base recommendations regarding corrosion rates.

TELEBRINELLER

The telebrineller consists of a kit containing the following:

- Magnifying scope with scale
- Bars with known hardness
- Bar holder with anvil

- A sphere
- A telebrineller computer

Not supplied with the kit is a hammer. The Known Hardness Bar is installed in the holder between the anvil and the test area. Hardness bars are chosen by the inspector, using his experience as to what hardness range he expects to find.

The area to be tested must be thoroughly descaled and have a very smooth surface. This can be done with a smooth file or grinding wheel. Care must be taken to avoid deep grooves which will be magnified during measurement with the scope. The sphere in the bar holder is then positioned on the test area and held firmly in place. The anvil is then struck with one straight blow of the hammer. The scope is then placed over the depression in the test area and the scale reading is obtained. The same is done to the test bar. The readings are then entered on the computer with the hardness number taken off the hardness scale. This will then be recorded as the Brinell Hardness Number, commonly referred to as BHN.

HARDNESS TESTING

Hardnesses are taken of steels and some alloys after welding, heat treatments and refinery fires to see if any changes have occurred. Excessive hardnesses can lead to premature cracking failures because of reduced ductility and toughness at the hard areas. In the field, hardnesses are generally measured in Brinell numbers by using the portable Telebrineller instrument or by using several of the digital readout hardness testers now available.

HAMMER TESTING

Hammer testing is done to find detrimental conditions due to corrosion, dead areas in metals, or plugged tubes. Hammer testing is only performed on piping when a unit has been shutdown, depressured and cleaned out. Hammer testing is **NEVER** performed on piping that is in service or under pressure. Brass, copper or stainless steel return bends in exchanger equipment should not be hammer tested.

ULTRASONICS

Refinery applications of ultrasonics are normally confined to the use of portable thickness meters and weld flaw detectors. The metal thickness measurement by ultrasonics uses sound travelling at a known velocity (different for each metal type—see Table 1) via a transducer, travels through a couplant into the steel and reflects at a metal to air, liquid, etc., interface, then reflects back to the transducer. The time it takes for a sound wave to travel through the steel and back is measured by the ultrasonic instrument where it is converted in the instrument. The thickness is read out on a digital display. Thickness measurements can also be obtained using an instrument equipped with a Cathode Ray Tube (CRT). When searching for laminations or other discontinuities oriented parallel to the test surface, an instrument equipped with a CRT is better suited for evaluation than a digital readout instrument.

Transducers commonly used for longitudinal wave (straight beam) testing in refineries range from 3/8–5/8 inch diameter, dual, 5.0 MHz for digital readout instruments to 1/2–1 inch diameter, single, 1–5 MHz for instruments with a CRT screen. Temperatures as high as 750–850 °F (399–454 °C) can be read accurately for thickness with transducers equipped with a heat block and when a high temperature couplant is used. For hot readings, a higher frequency transducer generally will not work as well as one with a lower (2.25 MHz) frequency. For readings on thin or pitted material, a dual transducer or one with a higher frequency will give easier attained results.

Shear wave (angle beam) ultrasonics for the detection of weld discontinuities is also commonly used. Sound is transmitted at either a 45°, 60°, or 70° angle from a normal perpendicular to the test piece surface. When a discontinuity is struck by a sound wave, the sound is reflected back to the transducer where the mechanical energy of the sound is turned to electrical energy that gives a back reflection signal of a certain amplitude on the CRT screen. The location of the back reflection on the calibrated screen will give the length of the sound travel. The amplitude of the back reflection is evaluated in relation to the Distance Amplitude Curve (DAC) that has been set on the screen. The location of the DAC on the screen is formed by setting the signal amplitudes from three known sized reflectors at known sound travel distances. Therefore, ultrasonic shear wave flaw detection is the comparison of signal amplitudes between known and found discontinuities. Generally, the flaws most detrimental to a weld's integrity will give

reflected signal amplitudes that far exceed the DAC curve on the CRT screen. Other more sophisticated techniques for sizing of flaws are currently used, but generally require more specialized equipment and operator experience than is commonly found. Those services are typically provided by specialist contractors from outside the refinery.

TABLE 1

Typical Sound Velocities in Various Materials (Longitudinal Wave)		
	In/s x 10 ²	m/s
Aluminum	2500	6300
Brass	1700	4300
Cadmium	1100	2800
Cast Iron	1800	4600
Copper	1800	4600
Epoxy Resin	1100	2800
Glass (Crown)	2200	5600
Glass (Window)	2700	6800
Gold	1300	3300
Inconel	2200	5600
Lead	850	2200
Magnesium	2300	5800
Manganese	1800	4600
Molybdenum	2500	6300
Neoprene	630	1600
Monel	2100	5300
Nickel	2200	5600
Nylon	1000	2500
Phenolic	560	1400
Platinum	1600	4100
Plexiglas	1100	2800
Polyethylene	700	1800
Polystyrene	930	2400
Polyurethane	700	1800
Porcelain	2200	5600
Rubber (Butyl)	730	1900
Rubber (Vulc.)	900	2300
Silver	1400	3600
Steel	2300	5800
Tin	1300	3300
Titanium	2400	6100
Tungsten	2100	5300
Zinc	1600	4100
Zircaloy 2	1900	4700

ASME Sections V and VIII are normally the reference codes for set up of the instrument and for acceptance criteria for vessels built under ASME Section VIII. Articles 4, 5, and 23 are the reference subsections in Section V. In addition, any inspection company doing ultrasonic inspection should have its own written procedures available for review by the Refinery Inspection Department.

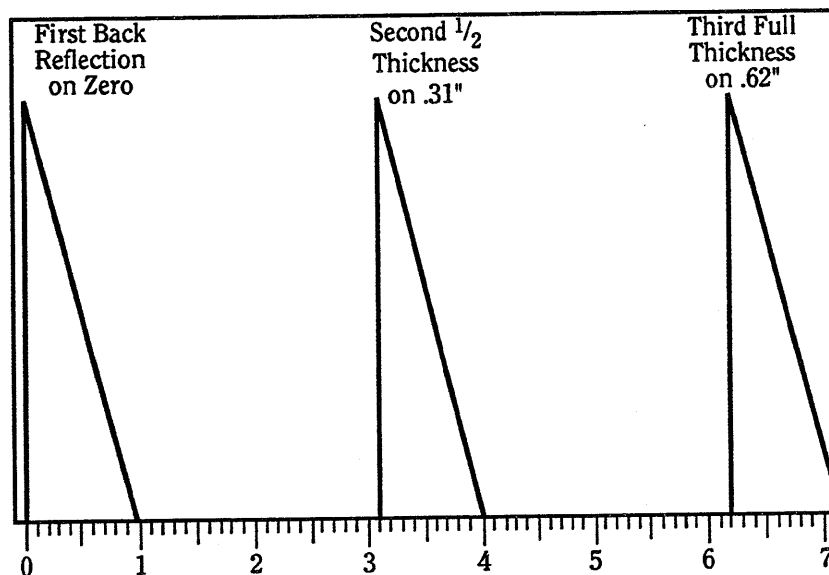
The following pages show some basic techniques for the use of ultrasonics in a refinery application. They are not formal procedures and are only included as examples of ways an ultrasonic instrument can be set up for testing. Articles 4, 5 and 23 of Section V of the ASME Code are normally used as references for set up of ultrasonic equipment. Appendix 12 of Section VIII of the ASME Code is the referencing section for acceptance criteria of vessels built under the ASME Code when using ultrasonics to test for weld defects.

INSTRUMENT CALIBRATION FOR THICKNESS TESTING

The calibration knob on the instrument spreads or pulls together the back reflections of the test block. The delay knob moves the back reflection back and forth on the Cathode Ray Tube (CRT) screen. To calibrate the instrument on the three spike method, line the first back reflection on zero line using a 0.50 inch test block, set the next back reflection of 0.25 inch. This represents 1/2 thickness. The third back reflection goes on 0.50 inch and represents full thickness. In reading the instrument, always match two back reflections to get the thickness. If thickness is 0.62 inch, the first back reflection will be moved to zero line with delay knob, the second is 0.31 inch (1/2 thickness), and the third is 0.62 inch (full thickness). With this system, error is brought to a minimum.

Figure 1

3 Spike Method



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ULTRASONIC WELD INSPECTION

Ultrasonic weld inspection is almost always performed with the angle beam method. The sound is introduced into the metal adjacent to the weld where it travels between the surfaces until it crosses the weld. The distance from the weld which must be prepared for the introduction of the sound wave depends on the thickness of the material and the skip distance of the sound wave.

The heat affected zone of the weld should be completely examined by scanning with a straight beam transducer or search unit. This procedure is used to detect reflectors which might affect the interpretation of the angle beam results. This is only for finding something that will block the angle sound wave and not a base for rejection of the parent metal.

The reference specimens for longitudinal beam testing shall be a flat bottom hole, 1/16 inch in diameter for each 2 inches of metal thickness and extending to a depth of 1/2 inch minimum.

Longitudinal Beam Testing

A distance amplitude correction curve must be constructed when base material is over 2 inches in thickness. Using basic calibration block, position the search unit for maximum response from the basic calibration hole at 1/4 T. Adjust the signal amplitudes to 75 percent of full CRT screen. This will be the primary reference response. Without changing the gain control, position the search unit for maximum response from the calibration hole at 3/4 inch T and mark the amplitude on the CRT screen. Join the two points with a straight line and extend its length to cover the test range. This line is the basic reference line for determining the size of the flaw indications.

Calibration Procedure

This procedure shall be used once every 15 feet of weld examined and at least twice for each type of weld joint. (Check the instrument with test block.)

Evaluation of Indications

All indications which produce a response greater than the reference level shall be investigated to the extent that the operator can determine the shape, identity and location and evaluate them in terms of acceptance-rejection standard.

Acceptance-Rejection Standard

As per ASME Section VIII, Appendix 12:

- Discontinuities, such as cracks, lack of fusion and incomplete penetration, are unacceptable regardless of amplitude.
- Other imperfections are unacceptable if their size exceeds the limits shown in Appendix 12.
- If the weld joins two members having different thicknesses, the lesser of the two members governs.

Repairs

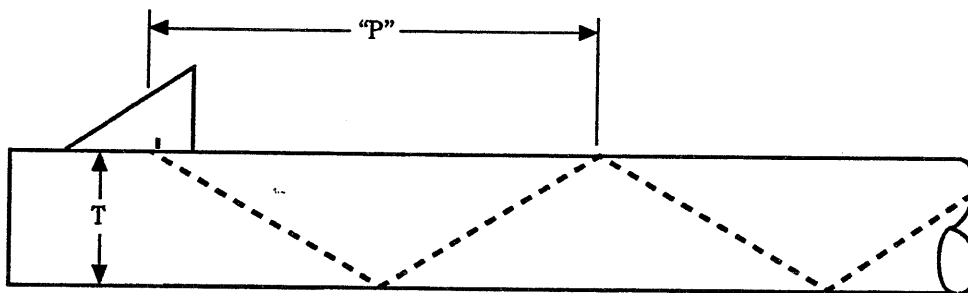
Repairs should be re-examined by the same procedure used for detection of the defect.

Weld Defect Location and Identification

When the angle transducer is used for the inspection of welds, the sound beam moves between the two surfaces of the metal as light is reflected between two mirrors.

Figure 2

Sound Beam Path



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Skip Distance

The distance "P" from the centerline of the sound beam leaving the transducer to the point where the central ray strikes the upper surface of the basic metal again is called the "skip distance." The skip distance is obtained by multiplying a mathematical factor C_p by the thickness of the metal being tested. Values of C_p for various angles of sound entry are as follows:

Angle	45°	60°	70°	80°
C_p	2	3.5	5.5	11.5

The length of the skip distance is required information if the location of defect is to be determined. The location is essential to the identification of the nature of the defect. Defects are not always completely identified by their position in the weld. Transducer movements can be used to aid in determining if the defect is a point defect or one of linear character.

Plotting Cards

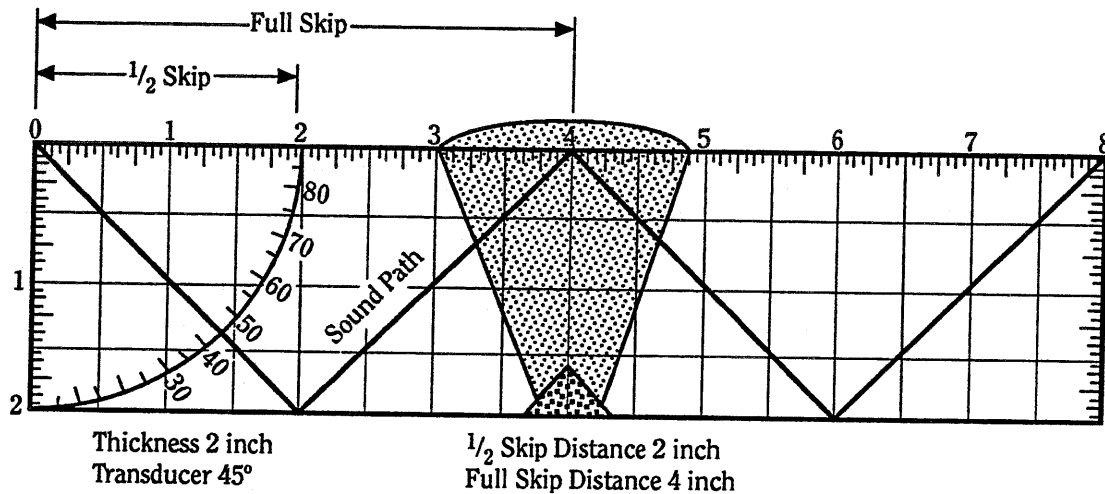
Plotting cards can be used to determine the location of the defects in the welds. The plots can be prepared on standard graph paper or on specially imprinted cards suitable for field use. The card is layed off with a horizontal and vertical graduated scale and a protractor across the left end. A small plastic slide on which the outline of the weld configuration can be drawn is used in conjunction with the plotting card. Before the plotting card can be prepared for use, the thickness of the basic metal and the type of weld profile should be obtained from the drawings or blueprints. The new ultrasonic instruments have become so electronically sophisticated they make the use of a plotting card almost obsolete. A scale drawing of the weldment will, however, aid an operator in "knowing" where the sound is in the specimen being tested.

Preparation of Plotting Cards

The thickness of the material is shown on the plotting card by the vertical scale. The horizontal scale is the half skip and full skip distances of the sound wave from the test side of the material (Figure 3). The thickness of the material is shown on the plotting card by drawing a horizontal line below the top scale at the proper distance to represent the thickness. Sound travel is a line drawn through point "0" at the top left corner and the angle on the arc of the protractor which corresponds to the transducer angle. This line intersects the line representing the bottom surface of the test metal at half skip distance of the sound wave. The line is then extended from half skip at the same angle to the top part of the test material for full skip distance of the sound wave.

Figure 3

Plotting Card



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ANGLE BEAM TESTING

Frequency

The nominal frequency shall be 2.25 MHz unless variables such as production material grain structure necessitate the use of lower frequencies in order to assure adequate penetration.

Beam Angle

The beam angle in the production material shall be a combination of 45°, 60° and 70°. ASME Code, Section V, requires the use of two of these.

Sound Travel Path or Skip Distances

Sound travel path shall be set on CRT in relation to the sound travel path on the plotting cards.

Distance-Amplitude Correction

Compensation for the distance travelled by the sound beam as it passes through the material will be done by use of curves.

Determination of Curves

Distance amplitude correction curves will be constructed by utilizing the responses from the basic calibration hole in the basic calibration test block, the primary reference response is 100 percent of the full CRT screen. The other responses covering the contemplated examination distance range and the corresponding responses are marked on the CRT screen.

The basic calibration holes are shown in the Table 2.

TABLE 2

Test Block Calibration Hole (All Dimensions in Inches)			
Thickness of Basic Metal	Block Thickness	Hole Location	Hole Diameter
Up to 1 incl.	3/4 or T	1/2 T	3/32
Over 1 through 2	1-1/2 or T	1/4 T	1/8
Over 2 through 4	3 or T	1/4 T	3/16
Over 4 through 6	5 or T	1/4 T	1/4

Note: For each increase in the thickness of 2 inches, or fraction thereof, the hole diameter shall increase 1/16 inch.

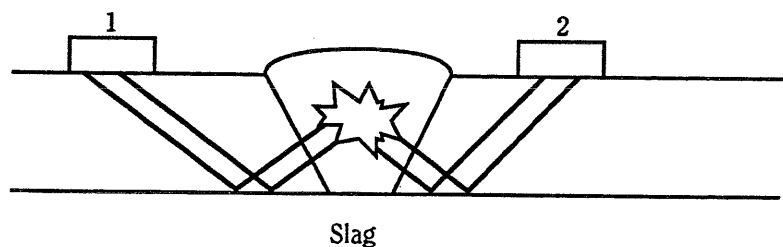
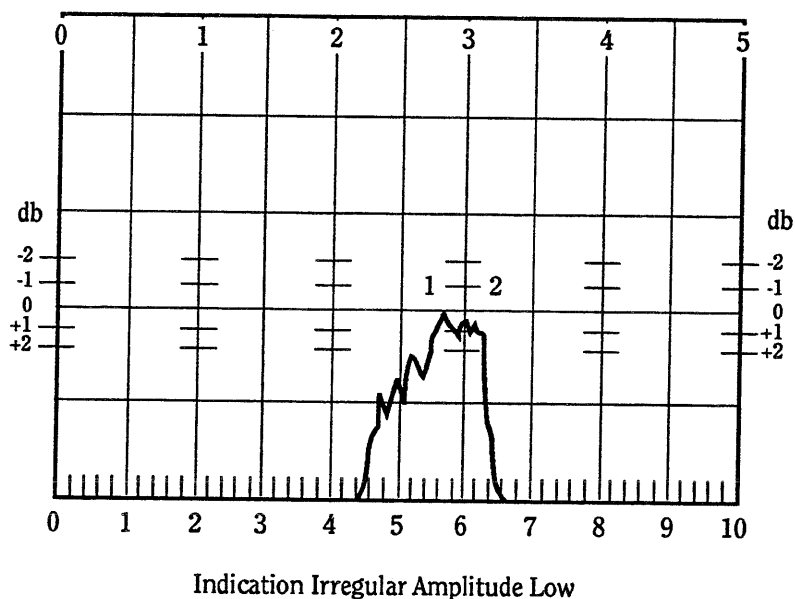
Plotting Card

Point 0 represents the transducer. Measurements are made from where the sound enters from the transducers to the center of the weld. The following conditions are shown in Figure 3: thickness, 2 inches; transducer, 45°; 1/2 skip distance, 2 inches; full skip distance, 4 inches. An indication on your screen at 3-1/4 inches would represent a

flaw in the fusion zone. One on the screen at 4 inch would be something in the cap pass.

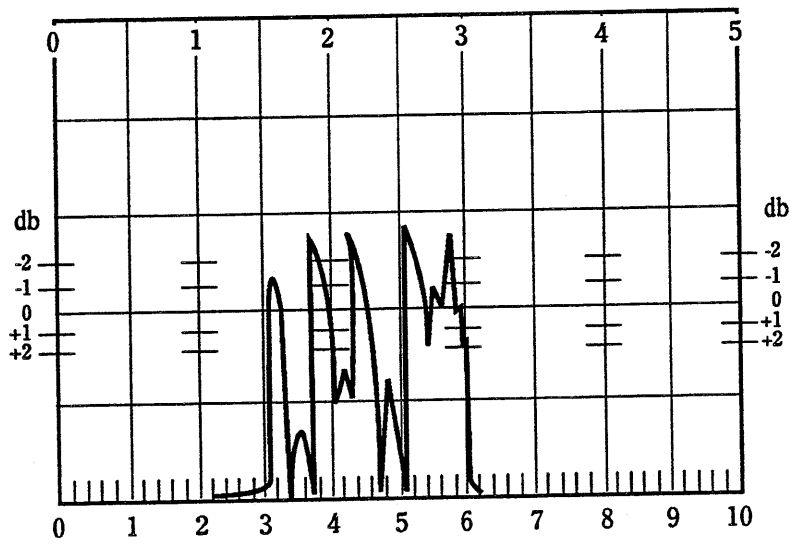
In moving the transducer up with the distance 2 inches from the center of the weld will give an indication on the screen at 2 inches half skip distance, indicating the flaw would be in the stringer pass. Most flaws can be identified from where they are found in the weld. Cracks, slag, porosity and gas pockets can be found anywhere in the weld, and identified by distinctive patterns on the CRT screen, and reactions of these patterns on movement of the transducers. Examples are shown in Figures 4, 5, and 6.

Figure 4

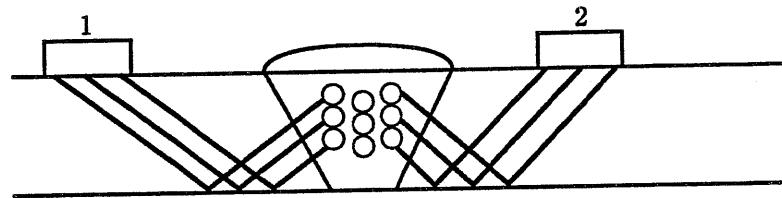


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Figure 5



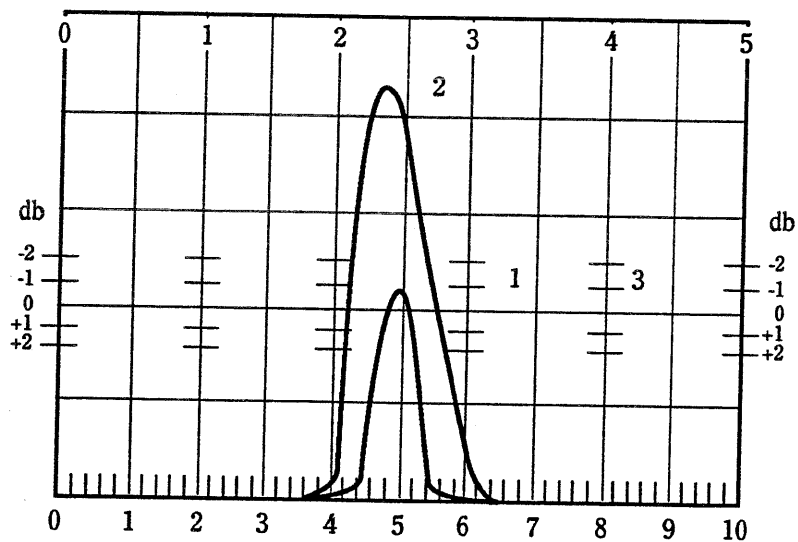
Multiple Spiked Echos
Echos Change as Probe is Moved



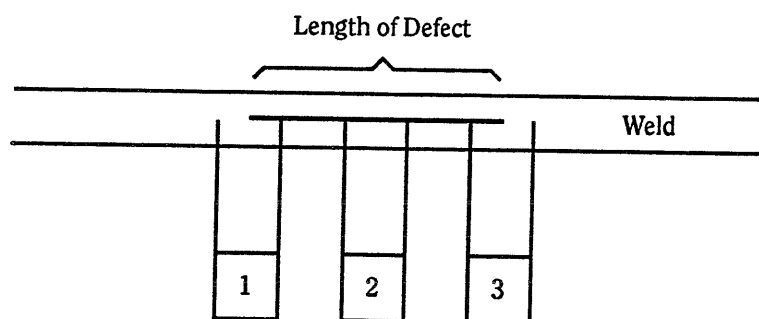
Grouped Porosity

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Figure 6



Amplitude of 1 & 3 are $\frac{1}{2}$ the Amplitude of 2,
but show in same place on CRT



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Dye Penetrant

Discontinuities open to the surface can be detected using the dye penetrant method of NDT. Articles 6 and 24 of Section V of the ASME Code are the reference subsections. Visible dye and fluorescent dye penetrants are the two portable methods commonly used in refineries. There are two types of visible red dye penetrants used, water soluble (good for rough surfaces) and solvent removable red dyes. Excess water soluble dye can be removed by a coarse water spray while excess solvent removable dye is removed by wiping the test area clean with a solvent dampened, lint-free cloth. Once the developer is sprayed over the test area, the indication will blot out and be shown red in stark contrast to the bright white developer. Fluorescent dye penetrant testing is performed like the visible dye method except that the test results are obtained by viewing the test piece under an ultraviolet light source (black light).

Dye Penetrant Testing Steps

- Clean the test piece

Vapor degreasing, detergent cleaning, steam cleaning, and solvent cleaning are several acceptable cleaning methods.

Sandblasting and wire brushing are two methods of cleaning that are not recommended.

- Apply the penetrant

Spraying, swabbing or brushing on are acceptable.

Dwell times are dependent on the material being tested and the type of discontinuity that is being tested for.

- Remove the penetrant

Use coarse water spray with water soluble penetrants.

Solvent dampened, lint-free cloth is used with solvent removable dyes.

- Apply developer

Allow time for the developer to dwell before interpreting the test.

Magnetic Particle Testing

When a magnetic field is induced in a test piece, a flux leakage field will be produced if a discontinuity exists. Iron particles will line up along the leakage field when sprayed over the test area. Primarily in refinery applications a yoke on AC power is used to detect cracks open to the surface. When a crack exists, it will show as a reddish line if red dry iron powder is used or as a fluorescent green line as viewed under ultra violet light if wet fluorescent particles are used as the discontinuity indicator. The magnetic field on either side of the yoke extends approximately 3 inches. Discontinuities will be detected that are perpendicular to the yoke up to 45° from the normal. Therefore, when testing, the magnetic field should be induced in two directions perpendicular to each other to assure that any discontinuity will be detected regardless of its orientation. Testing is performed on a clean test piece by contacting the yoke with the test piece and either spraying the dry powder or wet fluorescent particles over the magnetized area. Evaluation is performed with the magnetic field being continually induced. Articles 7 and 25 are the reference subsections of Section V of the ASME Code.

Radiography

Either gamma or x-rays can be used, but x-rays are rarely used in refineries due to the much greater portability of gamma ray sources. Essentially, a permanent picture is taken of the test piece. The test piece is exposed to radiation, generally from an iridium¹⁹² source. The test film is taped to the opposite side of the test piece from the source. Discontinuities generally show up as darkened lines, holes, etc. Tungsten

inclusions from the TIG welding procedure will be bright white on the film. Articles 2 and 22 are the referencing subsections of Section V of the ASME Code.

Acoustic Emission

Acoustic emission testing is becoming more accepted in the industry. Acoustic emission tests seek out noise from active discontinuities either during a pressure up or cool down phase of operation. It is a highly specialized field which requires specially skilled, experienced personnel. Articles 11 and 12 are the reference subsections of Section V of the ASME Code.

Alloy Analyzing

Alloy analyzers are very useful tools in establishing the percentage of alloying elements (chromium, molybdenum, etc.) in flanges, piping, plate, etc. Alloy analysis is especially useful during new construction or unit revamps. It is not uncommon to find materials to be low in chromium, for example, from what has been stamped on a new flange or stenciled on a piece of pipe.

INSPECTION OF NEW CONSTRUCTION

The inspection of new construction is performed at the vendor's facility and also on the job site. Shop inspection will insure that the prefabrication item for a project complies with the project specifications and that dimensions are within tolerance.

Shop Inspection

To inspect fabricated equipment properly, the inspector needs to be familiar with the provisions of the purchase order, written specifications, drawings and the codes applicable to the item being inspected. The code for pressure vessels is usually ASME; for piping, the American National Standard Code for Pressure Piping (ANSI). Occasionally, there may be state or local codes applicable to the installation site.

All plate is marked by the steel mill with a heat and slab number. Pipe and forgings bear only heat numbers. By taking these numbers from the material used and examining the corresponding mill test report, verification of materials is obtained.

After plates are cut, the edges can be examined for any defect that may become exposed and for proper beveling for conformance with the approved welding procedure. Each piece cut from the plate should be permanently marked with the heat and slab number of the plate from which it was cut.

It is desirable to observe the equipment from time to time during assembly and welding to be sure that proper fit-ups are being obtained and that approved welding procedures are being followed.

When fabrication is complete, an internal and external examination should be made for any visible weld repair that might be required. At the same time, the vessel dimensions should be checked.

If a complete radiography test is required, it should be examined as soon as it is completed. Any other NDT that is required should be witnessed by the inspector.

If postweld heat treatment is required, it should be checked that an adequate number of thermocouples are used and that these are properly placed. The recording chart should be examined after postweld heat treatment is complete.

If a hydrostatic test or air test is required, these should be witnessed also. If any leaks are found, the defective area should be examined after the defect is removed and before any repair welding is done. Any non-destructive testing and/or postweld heat treatment that is required should be performed prior to retesting.

Field Inspection

All equipment should be examined for shipping damage at the time it is received on the job site and the details of any repairs required be noted at this time.

The inspector should be familiar with all applicable codes and specifications pertinent to the project and to ascertain that these are complied with. He should observe the same points as the shop inspector of the field assembly welding and testing.

During construction, it is advisable to make the necessary inspection drawings and obtain thickness measurements of the equipment. This is recommended because of mill tolerances. This tolerance is minus 0.01 inch with no maximum excessive thickness for vessel plates, and plus or minus 12-1/2 percent of the nominal wall thickness for pipe. A 0.50 inch nominal wall pipe could be between 0.4375 inches and 0.5625 inches thick and still comply with standard manufacturing specifications. From this, erroneous conclusions could be reached at the first inspection of a unit if the actual thickness were not recorded at the time of construction.

ON-STREAM INSPECTION

On-stream inspection can contribute greatly in shortening downtime. On-stream testing helps in planning and enables any questionable piping and other equipment which needs to be replaced to be fabricated before a shutdown. Ultrasonic testing equipment can check hot lines up to 850 °F (454 °C) and sometimes at higher temperatures. Radiography can be used to check piping for erosion, corrosion and scaling while the unit is on-stream. Transfer lines can be checked for scale, which will enable the refinery to be prepared prior to shutdown to clean these lines. In many cases, it is not necessary to remove insulation for radiography pictures. It is important to know which lines need to be cleaned prior to shutdown.

One of the best ways to facilitate the above is to utilize on-stream inspection techniques. These techniques, done by either ultrasonic means or radiography, are most applicable to the piping in the refinery. During a turnaround, planning usually does not include sufficient time for preparation and thorough inspection of the piping systems. Normally, after all other equipment has been opened, cleaned and inspected, the inspector finds

time to start checking the piping system. The proper inspection of all piping during a turnaround can be carried out only if a sufficiently manned inspection crew is available. To overcome this need for sufficiently manned groups during turnaround, it is advisable that a thorough piping inspection be made prior to the turnaround.

Sometime prior to a scheduled turnaround, a thorough thickness check should be made of all critical process piping (within temperature limitations) in each unit. This would require fewer personnel to be used, both inspectors and maintenance people, during a shutdown. A program of making holes in insulation and moving ladders can be done with limited personnel on a normal working day basis. Also, ladders are more readily available and can be placed where required. Scaffolding can be erected without interfering with other work normally taking place during a turnaround.

A far larger number of checkpoints can be made when the inspectors and maintenance personnel are only concerned with piping. During the on-stream piping inspection, other important conditions can be noted and, in many cases, rectified prior to the turnaround. These include:

- Thin piping can be scheduled for replacement with most of the fabrication completed before shutdown of the unit.
- Leaking flanges and valves can be identified and scheduled for repairs.
- Inoperative valves can be scheduled for replacement or reworking.
- Repair or replacement of poor insulation can be either completed immediately or scheduled for the turnaround. Since it may require scaffolding to check some piping, the scaffolding can be used to complete repairs of the insulation at the same time.

The use of "on-stream piping inspection" is, therefore, strongly recommended and its advantages are obvious. If only one important line can be scheduled for replacement during normal turnaround time, this will generally more than pay for the time and expense of the inspectors.

SHOP VS. FIELD INSPECTION OF A VESSEL

Shop Inspections

– Dimensional Tolerances Per UOP Specifications

Plumbness:

< 6.35 mm in any 6096 mm (20 feet) to a maximum of 19.05 mm over the entire length of the vessel.

Maximum Permissible Offset:

Longitudinal joint = 6.35 mm

Circumferential joint = 12.7 mm

Out of Roundness: as prescribed by the code

Overall Length of the Vessel (does not include skirt):

= to ± 12.7 mm (1/2 inch) or
0.4 mm (1/64 inch) per 304.8 mm (12 inches)
to a maximum of 19.05 mm (3/4 inch)

Skirt Length: = ± 6.35 mm (1/4 inch)

– Nozzles

Elevation: ± 9.5 mm (3/8 inch)

Orientation: ± 6.35 mm (1/4 inch)

Projection: ± 3.17 mm (1/8 inch)

Flange Face Deflection:

Horizontal – $1/2^\circ$ or 0.8 mm (1/32 inch)

Vertical – $1/2^\circ$ or 0.8 mm (1/32 inch)

Material PMI should be checked.

Heat treatment charts should be reviewed.

Welding procedures should be reviewed.

Hydrotest should be witnessed.

Paperwork should be conformed.

Asme Section VIII Usually the Reference Code

Field Inspections Should Include Answers to the Following:

– Lining

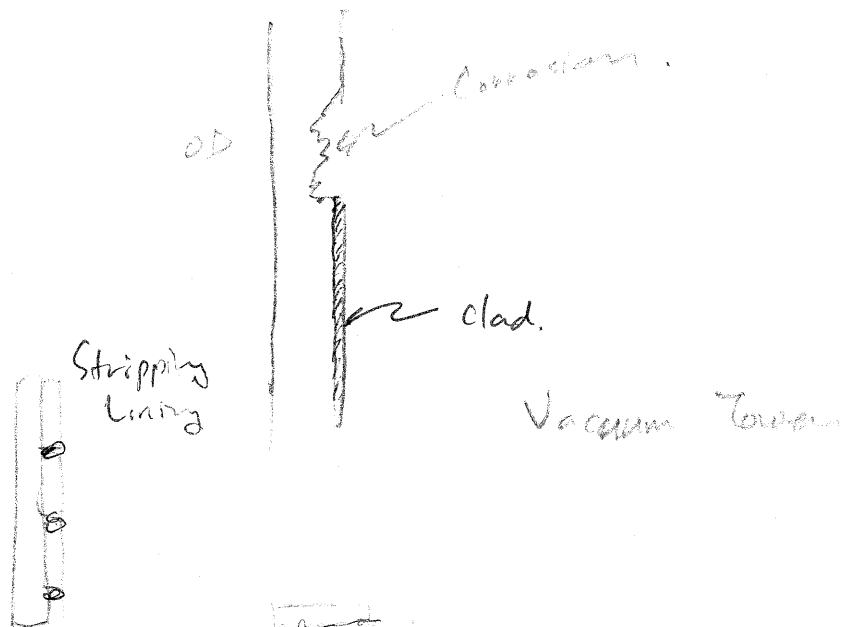
Type?

Where?

Corroded?

Bulged?

Eroded?



– Unlined Areas of the Vessel

Corrosion?

Appearance?

How much?

Where?

How deep?

Erosion?

Where?

How deep?

– Weld Seams

What service?

Cracked?

Corroded?

Further NDT needed?

– Bulges or Distortions

Deflected?

How much?

Where?

How big?

– **Internal Equipment**

Trays?

Distributors?

Vortex Breaker?

Demister pad?

Cyclones?

Air grid?

– **Insulation**

Missing?

What is the condition of it?

Metal jacket condition?

– **Ladders and Platforms**

Are they useable?

Are there kick plates?

Is the bolting secure?

– **Supports**

Fireproofed skirt?

Condition?

Base metal condition?

Steel saddles?

Concrete saddle?

– **Nozzles**

Thickness?

Corroded?

Liner leakage?

Welds cracked?

Flange gasket surface condition?

Bolting?

Inspect to the API-510 or National Board Inspection Code.

Both reference the ASME Code.

WELDING ELECTRODES (Welding Rods)

Welding rods are classified by The Welding Society to give a standard to the manufacture of the manual rods. The letters and numbers are designated as follows:

- (E-6010-A1 is used as an example)
- E – The prefix "E" designates arc welding electrode.
- E-60XX – The first two digits of the four digit numbers indicate the tensile strength of the electrode; (60 means 60,000 psi tensile strength.)
- E-XX1X – The next to the last digit indicates the position the rod will weld; positions are as follows: 1 – All positions; 2 – Flat and horizontal positions; 3 – Flat position only.
- E-XX10 – The last two digits combined together designate the type of coating on the electrode to best perform in the position as stated.
- E-XXXX-A1 – The suffix number (A1) designates the approximate alloy in the weld deposit. Examples are:

A1	1/2 percent Mo
B1	1/2 percent Cr – 1/2 percent Mo
B2	1–1/4 percent Cr – 1/2 percent Mo
B3	2–1/4 percent Cr – 1 percent Mo
C1	2–1/2 percent Ni
C2	3–1/2 percent Ni
C3	1 percent Ni, 0.35 percent Mo, 15 percent Cr
D1 & D2	0.25–0.45 percent Mo
G	0.50 percent min. Ni, 30 percent min. Cr, 0.20 percent Mo, or 10 percent min. V (Only one element is required for use of this suffix)

GENERAL INFORMATION

Preheating for Welding

By using a preheat procedure when welding, there is a strong tendency to reduce the hardness of the metal in the fusion zone. Heated metal will cool slower after welding, thereby reducing the chance for cracking to occur. Preheating must be done by exacting means or its effectiveness is minimal. Heating only the weld area is insufficient. A large area of the metal should be heated prior to welding so cooling of weld area will be slow.

Compatible Weld Electrodes

For most alloy welds, it is best to use a compatible electrode — where the principal alloying elements are of the same composition as the metals to be joined by welding. Use of compatible electrodes generally requires a preheat and post heat treatment, especially in the low chromium groups, specifically 2-1/4 Cr-1, 5 Cr-1/2 Mo, etc. This is not usually true of the stainless steel group, with the exception of the straight chromium stainless steels, 11-13 percent Cr.

Spot Welding

Spot welding is a form of resistance welding. Joining of the two metals is done by pressure after the electric charge brings the metal up to the correct temperature for fusion. Filler metal is not required — the metals merely being joined by "melting into each other".

Seldom would you find a spot weld being made in the field. Special treatment is required, and the normal maintenance contractor is not equipped to do this.

Reinforcement of a Weld

Any weld metal deposited above the surface of the base material is considered as weld reinforcement. The fabrication codes specify the limitations for this.

Root Pass of a Weld

The most important pass of a weld. The root is as the name implies — it must be first and all other passes then follow. The root must be free of slag and cracks before welding of succeeding passes.

The root pass has 100 percent penetration when making a butt weld. Allowing anything less than 100 percent penetration will, in effect, create a "notch" in the underside of the root weld. This "notch", or stress riser, can be a place where cracking may start.

Full Annealing

Full annealing is the process of softening metal in a temperature range above the transformation range. The metal is raised to a temperature to allow rearrangement, held at this temperature usually between 1500–2000 °F (815–1093 °C), depending on the material, for a specified time, and then cooled slowly in the furnace. Normalizing is almost the same, except the metal is allowed to cool in still air.

The transformation range is the temperature interval within which austenite forms while ferrous alloys are being heated. It is also the temperature interval within which austenite transforms to ferrite while ferrous alloys are being cooled. Therefore, each metal has a critical temperature where transformation will occur. Stress relief is below the transformation range, and annealing is generally above (full anneal is always above).

Stress Relief

Reducing residual stress in a metal object is done by heating the object to a suitable temperature below the transformation range and holding for a specified length of time.

The Coefficient of Expansion

Each metal has its own coefficient of expansion and, therefore, each metal will grow in size at a unique rate for each degree of temperature rise.

As applied to the welding of metals, two widely separated coefficients of expansion will cause cracking of the metal in the area of the weld.

No method can be employed to restrain metals from growing during the temperature rise. Therefore, the weakest member (usually the one under greatest stress) will fracture when the weldment is subjected to cyclic temperatures.

Qualification Welding Procedures and Welding Operators

Before any welding is performed, it is required that a Weld Procedure Specification (WPS) be written. A test plate is made following this procedure and specimens removed from this are subjected to destructive tests (tensile and bend) to prove the adequacy of the procedure. This is the procedure qualification record (PQR). See Section IX of the ASME code for specifics relating to the WPS and PQR's.

After the procedure is qualified and approved, each welder that is to use this must make a test plate following the WPS. If the test results are satisfactory, the welder is deemed qualified to use this procedure. See Section IX of the ASME code for the specifics of the Welder Procedure Qualification testing.

Filler Metals

The following information is taken from an American Welding Society Committee Report, AWS D10.8-16, titled "Welding of Chromium-Molybdenum Steel Piping", Sections 3, 5, 6, and 7.

The following factors are among those considered in the selection of the proper filler metal. They should not be considered as requirements but as general guides for selection.

- The strength of the weld metal should be equal at least to that of the minimum requirements of the limiting base metal.
- It is desirable that the coefficient of expansion of the weld metal be equal or intermediate to the two base metals, particularly if their degree of dissimilarity is great.
- Where corrosion is a factor to be considered, the weld should be similar to the base metals, thus to avoid development of significant corrosion cells.
- For high-temperature service, it is advisable that the weld metal should not produce or permit the following:

Extensive diffusion across the weld interface such as carbon migration.

Vast differences in resistance to the environment, such as oxidation and stress or plastic deformation as a result of different high-temperature properties, such as creep.

- In selecting a ferritic filler metal, the weld metal with the lowest tendency to quench harden, and which meets the above qualifications and gives satisfactory performance, is the best one to select.

The composition of deposited weld metal is not designed to be identical to base metal. However, for the joining of similar metals, it should be of the same general composition as shown in Table 3. Where dissimilar metals are being welded, the possible filler metal compositions are: a match with the lower alloy composition, the higher alloy, an intermediate grade, or composition different from any of these three.

It is a consensus that where both base metals are ferritic, the fourth possibility mentioned (that of an entirely different alloy) should not be used, especially for service at elevated temperatures or in corrosive environments. Consistent with the factors listed previously, this fourth possibility should be considered only where one of the base metals is an austenitic steel.

Where only ferritic materials are being joined, good service results have been achieved with all of the three remaining possible kinds of ferritic filler metal compositions. However, the majority of users now select the lower or an intermediate filler metal. Furthermore, this approach is consistent with the five factors given above. Accordingly, Table 3 follows this approach. In some cases, alternative choices are given in the table as essentially equivalent.

Where one of the materials in a dissimilar joint is austenitic stainless steel, the filler metal selection will vary according to the service to which the joint will be subjected. A distinction has been made in the table for service below or above 800°F (427°C), for this is roughly the temperature above which the diffusion rates of many alloying elements, especially carbon, begin to increase substantially. Consideration must then be given to the selection of a filler metal which will minimize such diffusion.

Another consideration for higher temperature service, particularly where cyclic stress is involved, is the need for a weld metal which can best bridge the significant differences in coefficient of expansion and thermal conductivity between austenitic and ferritic steels.

It is generally best in shielded metal-arc welding to use electrodes with low-hydrogen for welding chromium-molybdenum steels. The moisture content of low-hydrogen electrodes must be minimized by dry storage until the time of use. The composition of backing rings or backing filler metals (consumable inserts) usually is similar to that of the electrode, although lower alloy compositions have been used satisfactorily.

Table 3 is not necessarily complete, as other materials may well be proven acceptable by procedure qualification and service tests. However, if the proper base metal has been selected for the service requirements and good welding procedures are followed, these filler metals should give welds with good service performance.

TABLE 3

FILLER METALS FOR VARIOUS BASE-METAL COMBINATIONS											
	C-Steel	C-Mo	1/2 Cr 1/2 Mo	1 Cr 1/2 Mo	1-1/4 Cr 1/2 Mo	2 Cr 1/2 Mo	2-1/4 Cr 1 Mo	5 Cr 1/2 Mo	7 Cr 1/2 Mo	9 Cr 1 Mo	18-8 Stainless
C-Steel	—	A	A	A	A, B	B, C	B, C	C, D	C, D	C, D	G
C-Mo	A	B	B	B	B	B, C	B, C	C, D	C, D	C, D	G
1/2 Cr-1/2 Mo	A	B	C	C	C	C	C	C, D	C, D	C, D	G
1 Cr-1/2 Mo	A	B	C	C	C	C	C	C, D	C, D	C, D	G
1-1/4 Cr-1/2 Mo	A, B	B	C	C	C	C	C	C, D	C, D	C, D	G
2 Cr-1/2 Mo	B, C	B, C	C	C	C	D	D	D	D	D	G
2-1/4 Cr-1 Mo	B, C	B, C	C	C	C	D	D	D	D	D	G
5 Cr-1/2 Mo	C, D	C, D	C, D	C, D	C, D	C, D	D	E	E	E	G
7 Cr-1/2 Mo	C, D	C, D	C, D	C, D	C, D	D	D	E	F	F	G
9 Cr-1 Mo	C, D	C, D	C, D	C, D	C, D	D	D	E	F	F	G
18-8 Stainless	G	G	G	G	G	G	G	G	G	G	—

Filler Metals

- A. Carbon steel (such as E7016 or E7018)
- B. Carbon - 1/2 Mo (such as E7016-A1 or E7018-A1)
- C. 1-1/4 Cr - 1/2 Mo (such as E8016-B2 or E8018-B2)
- D. 2-1/4 Cr - 1 Mo (such as E9016-B3 or E9018-B3)
- E. 5 Cr - 1/2 Mo (such as E502-15)
- F. 9 Cr - 1 Mo

- G. For cyclic service and wherever postheating is to be used:
75 Nickel - 16 Chromium - 7 Iron

For noncyclic service above 800 °F (427 °C):
 75 Nickel - 16 Chromium - 7 Iron (preferred)
 25 Chromium - 20 Nickel (Type 310) (alternate)
 25 Chromium - 12 Nickel (Type 309) (alternate)

For noncyclic service below 800 °F (427 °C):
 25 Chromium - 12 Nickel (Type 309),
 25 Chromium - 20 Nickel (Type 310),
 29 Chromium - 9 Nickel (Type 312) or
 75 Nickel - 16 Chromium - 7 Iron

Preheating

Preheating is almost always specified for the welding of chromium-molybdenum steels, even when preheating is not required for weld metal. Table 4 gives general preheat and interpass temperatures.

It is claimed that temperatures lower than those given in the table are acceptable and desirable for the deposition of the root pass with gas tungsten-arc welding on the lower chromium alloys. The lower temperature permits better control of the shape of the first pass, with less likelihood of excessive melt-through. It appears that the slower rate of travel with this process, compared to manual shielded metal-arc welding, produces adequate local preheating in the area of the weld. Lower preheating temperatures are sometimes used in the case of tack welds where excessive warpage might result from the preheating temperatures in the table. When welding takes place in confined areas, it is sometimes necessary to use lower temperatures for the sake of the welder. All such deviations from the table should be in accordance with any applicable code and should be verified by both procedure qualification tests and service experience.

In making a dissimilar joint with an austenitic stainless steel, these steels are not generally preheated and the interpass temperature is kept as low as practicable. For such materials, it is best that they are not cooled too slowly. In such joints, preheating is applied only to the chromium-molybdenum side if possible. The method of applying heat should be such that the temperature around the joint is uniform. The rate of heating is best limited to that which will not permit temperature differences across the wall thickness to exceed 150 °F (66 °C), in order not to produce high stresses from differential expansion. On the other hand, there is no advantage to heating rates appreciably slower than those required to meet this limitation.

If heat enters the base metals only through the surfaces, as in a furnace or with resistance of gas heating, the rate of heating will have to be fairly low to meet this requirement. Torch heating may produce not only high temperature gradients through a thick wall but also around the circumference, unless care is taken to heat at the proper rate and uniformly around the joint. If heat is produced under the surface layers of the base metal, as with low-frequency induction heating, the same limitations on maximum temperature differences prevail but much higher heating rates are permissible.

TABLE 4

PREHEAT AND INTERPASS TEMPERATURE FOR VARIOUS BASE-METAL COMBINATIONS											
	C-Steel	C-Mo	1/2 Cr 1/2 Mo	1 Cr 1/2 Mo	1-1/4 Cr 1/2 Mo	2 Cr 1/2 Mo	2-1/4 Cr 1 Mo	5 Cr 1/2 Mo	7 Cr 1/2 Mo	9 Cr 1 Mo	18-8 Stainless
C-Steel	—	B	C	C	C	C	C	D	D	D	A
C-Mo	B	B	C	C	C	C	C	D	D	D	A
1/2 Cr-1/2 Mo	C	C	C	C	C	C	C	D	D	D	E
1 Cr-1/2 Mo	C	C	C	C	C	C	C	D	D	D	E
1-1/4 Cr-1/2 Mo	C	C	C	C	C	C	C	D	D	D	E
2 Cr-1/2 Mo	C	C	C	C	C	C	C	D	D	D	E
2-1/4 Cr-1 Mo	C	C	C	C	C	C	C	D	D	D	E
5 Cr-1/2 Mo	D	D	D	D	D	D	D	D	D	D	E
7 Cr-1/2 Mo	D	D	D	D	D	D	D	D	D	D	E
9 Cr-1 Mo	D	D	D	D	D	D	D	D	D	D	E
18-8 Stainless	A	A	E	E	E	E	E	E	E	E	—

- A. No preheating except that, when atmospheric temperatures are below 70 °F (21 °C), the weld joint should be preheated to 100 °F (38 °C).
- B. For butt welds, 200–400 °F (93–204 °C) minimum. May be lowered to 100 °F (38 °C) minimum if the wall thickness is under 3/8 inches and the carbon content is below 0.20 pct. For fillet welds, no preheating required for any (throat) thickness except that, when atmospheric temperatures are below 70 °F (21 °C), the weld joint should be preheated to 100 °F (38 °C).
- C. 300–600 °F (149–316 °C) minimum. May be lowered to 200 °F (93 °C) minimum if the wall thickness is under 3/4 inches.
- D. 400–700 °F (204–371 °C) minimum. May be lowered to 300 °F (149 °C) minimum if the wall thickness is under 3/4 inches.
- E. 200–500 °F (93–260 °C) minimum. For chromium–molybdenum material only.

Interruption of Preheating-Postheating Cycle

Where preheating and postheating are employed in a welding procedure, there is sometimes a question as to whether or not the weldment may be allowed to cool to room temperature before the application of the heat treatment, whether before or after the completion of the welding.

The effects of interrupting the heating cycle are both metallurgical and mechanical in nature. Metallurgical effects involve microstructural changes, while mechanical effects involve thermal contraction of the weldment which may produce localized distortion or high residual stress. Accordingly, the heat cycle which gives the greatest assurance of successful welding is one in which there is no interruption of preheating during welding and the postweld heat treatment follows immediately.

However, there are operational and economic reasons for not carrying out this continuous process that make the interrupted procedure almost mandatory in some cases and quite common in most welding procedures. It is difficult to make general rules as to when such interruptions are permissible, because there are many factors which must be considered. The following factors are among those to be considered.

TEMPERATURE OF THE AIR

As the temperature of the air decreases, it becomes better practice not to interrupt the heating cycle. This factor becomes important in cold weather at unheated construction sites.

MOISTURE AND OTHER HYDROGEN FORMING CONSISTITUENTS

Hydrogen can be introduced into the arc from either water vapor or materials in the coverings of certain types of electrodes. If dissolved in the metal, hydrogen may produce high stresses or even cause cracking. It is safer, therefore, to interrupt when using low-hydrogen electrodes, provided they are not permitted to absorb moisture. They may be less desirable than electrodes with other types of coverings if they are permitted to absorb moisture.

JOINT RESTRAINT AND SUPPORT DURING FABRICATION

There is more residual stress in a weld between highly restrained members, such as a closure joint in a pipe line with "cold spring", and interruptions are less advisable in such cases. The same is true if the weld may be subjected to high bending moments when partially completed. In welding of the materials considered herein, proper support of the piping deserves careful consideration.

HARDENABILITY OF BASE MATERIALS

The chromium-molybdenum alloys being considered here do not produce an especially high level of hardness, principally because their carbon contents are low. However, if the carbon content is on the high side, especially when the chromium content exceeds 2.5 percent, the hardenability increases significantly, and greater restrictions are set on interruptions in the heating cycle.

MASS OF THE BASE METAL

An increase in the mass of the base metal increases both the restraint on the weld and the cooling rate from welding temperatures of both the heat-affected base metal and the weld metal. Accordingly, the weld area is subjected to higher stresses when it is apt to be less ductile.

For a given weld, however, the greater the percentage of the weld which has been completed, the more nearly the strength and rigidity of the joint approach that of the pipe, and the lower are the unit stresses in the weld. It is for this reason that interruption is generally not permitted until some minimum amount of weld or a given fraction of the wall thickness has been deposited.

Wherever interruptions are permitted, the weldment must be cooled slowly and uniformly, and no welding should proceed until the preheat temperature has been re-established in the weld area.

Based on industrial experience, certain general suggestions can be made with regard to the problem of interrupted heat cycles in the welding of the chromium-molybdenum steels included here. However, it must be emphasized that such general suggestions should be interpreted in the light of the factors mentioned above and the specific job conditions. They should not be applied indiscriminately:

- In any case where an interrupted procedure is followed in piping materials whose wall thickness is less than 1 inch, the weld deposit prior to interruption should never be less than 1/3 the wall thickness or two layers, whichever is greater. For very thick pipe, the requirement of 1/3 the wall thickness may be greater than necessary, and a minimum weld thickness, such as 3/4 inch, may be specified instead.
- The heat cycle may be safely interrupted for the nominal chromium-molybdenum grades containing less than 2.5 percent chromium, provided they are welded under controlled procedures using low-hydrogen electrodes and under normal conditions of fabrication and erection.
- The heat cycle may be safely interrupted for the nominal chromium-molybdenum grades containing less than 2.5 percent chromium, in wall thicknesses under 1 inch, provided they are welded under controlled procedures using low-hydrogen electrodes and under normal conditions of fabrication and erection.

In wall thicknesses above 1 inch, these grades should be completely welded and postheating started without interruption. Alternatively, the weld joint should be given a short time tempering treatment at 1200–1300 °F (649–705 °C) before interruption of the cycle.

Post Weld Heat Treating (PWHT)

The method of heating should be such as to give uniform heating around the circumference. The rate of heating of a weldment to the postheat temperature is limited by the same requirement of maintaining a maximum temperature differential through the wall thickness of 150 °F (66 °C), discussed in the section on preheating. The maximum rate of cooling from the postheat temperature is also determined by the same factor.

There is no advantage to heating or cooling at a rate appreciably slower than that which would maintain this maximum temperature differential through the wall thickness. If the entire weldment is not heated, the band of metal heated to the specified temperature should be equal to at least three times the width of the weld and the temperature should diminish gradually outward from the weld.

If socket-type joints are postheated (ANSI/ASME B31.3 should be referenced), care should be taken to heat a wide area of metal, such an entire band around the pipe or tube. Otherwise, local expansion and then permanent upsetting may leave the heated area with higher and more extensive stresses than those present in the as-welded structure.

In general, postheating becomes more necessary as the diameter and wall thickness and/or the hardenability of the materials increase for the reasons given in Interruption of Preheating-Postheating Cycle. Therefore, with the less hardenable materials, postheating is generally required only above a certain minimum diameter and wall thickness, while the more hardenable materials may be postheated regardless of physical dimensions. An important exception to this rule occurs in joints to be used in acid or caustic service; these are usually postheated. The requirements for preheating given in Table 4 are still applicable regardless of whether or not postheating is specified.

Many welds in austenitic stainless steels are not postheated. This is also true for most dissimilar welds involving ferritic and austenitic steels, except where the ferritic base metal is of a nominal chromium content of 5 percent or higher and the wall thickness exceeds a minimum, such as 1/2 inch. In such cases, the probable higher level and increased hardenability of the ferritic material usually leads to a requirement that the joint be postheated.

Table 5 summarizes the postheat temperatures for the combinations of materials included in the scope of this discussion. It must be acknowledged that weldments have given excellent service performance with postheat temperatures somewhat different than those in the table. This is not to imply that they are necessarily unsatisfactory. Rather, they represent what should be good practice for the great majority of situations.

TABLE 5

POSTHEAT TEMPERATURES FOR VARIOUS BASE-METAL COMBINATIONS											
	C-Steel	C-Mo	1/2 Cr 1/2 Mo	1 Cr 1/2 Mo	1-1/4 Cr 1/2 Mo	2 Cr 1/2 Mo	2-1/4 Cr 1 Mo	5 Cr 1/2 Mo	7 Cr 1/2 Mo	9 Cr 1 Mo	18-8 Stainless
C-Steel	—	B	C	C	D	D	D	E	E	E	A
C-Mo	B	B	C	C	D	D	D	E	E	E	A
1/2 Cr-1/2 Mo	C	C	C	C	D	D	D	E	E	E	A
1 Cr-1/2 Mo	C	C	C	C	D	D	D	E	E	E	A
1-1/4 Cr-1/2 Mo	D		D	D	D	D	D	E	E	E	A
2 Cr-1/2 Mo	D	D	D	D	D	D	D	E	E	E	A
2-1/4 Cr-1 Mo	D	D	D	D	D	D	D	E	E	E	A
5 Cr-1/2 Mo	E	E	E	E	E	E	E	E	E	E	F
7 Cr-1/2 Mo	E	E	E	E	E	E	E	E	E	E	F
9 Cr-1 Mo	E	E	E	E	E	E	E	E	E	E	F
18-8 Stainless	A	A	A	A	A	A	A	F	F	F	—

A. Postheating not usually required.

B. Postheating required where carbon content exceeds 0.20 pct or with sections over 1/2 inch wall thickness. Heat to 1150–1250 °F (621–677 °C) for one hour per inch of wall thickness. No postheating required for socket-type joints.

C. 1200–1300 °F (649–704 °C) for one hour per inch of thickness.

D. 1275–1350 °F (691–732 °C) for one hour per inch of thickness.

E. 1300–1375 °F (704–746 °C) for one hour per inch of thickness. Cool to preheat temperature or below before applying postheating.

F. Not required for sections up to 1/2 inch wall thickness. Sections over 1/2 inch wall thickness heated to 1300–1375 °F (704–746 °C) for one hour per inch of thickness.

Killed Carbon Steel and Post Weld Heat Treating Requirements

The following general guidelines are being used for determining killed steel and PWHT requirements for process equipment.

Killed carbon steel is specified for the following services to minimize the possibility (or extent) of hydrogen blistering and hydrogen embrittlement.

- Hydrogen Service — Where hydrogen is a major component in the vapor phase of the process stream at 50 psia. (Partial pressure is based on operating pressure.)
- Hydrogen Sulfide (H_2S) — Where H_2S is present with an aqueous phase.
- Hydrofluoric Acid (HF) and Boron Trifluoride (BF_3) — Process stream containing any amount of HF or BF_3 acids.
- Alkanolamine (Amines) — Monoethanolamine (MEA) and diethanolamine (DEA) in solutions of about 5–20 wt percent.

Killed steel is also used for equipment designed at temperatures greater than 900 °F (482 °C) since the ASME Boiler and Pressure Vessel Code does not list design allowable stresses for plain carbon steel over 900 °F (482 °C).

Post weld heat treatment (PWHT) regardless of Code requirements is specified for killed carbon steel and carbon steel under the following environmental conditions:

- Hydrogen Sulfide (H_2S) — Where H_2S is present with an aqueous phase.
- Hydrofluoric Acid and Boron Trifluoride — Process streams containing any amount of HF acid or BF_3 .

- Caustic (NaOH) — Refer to the Caustic Soda Service Chart, Figure 8. Use operating temperature and concentration for NaOH (weight percent) to determine if PWHT is required.
- Amines — In MEA or DEA service.

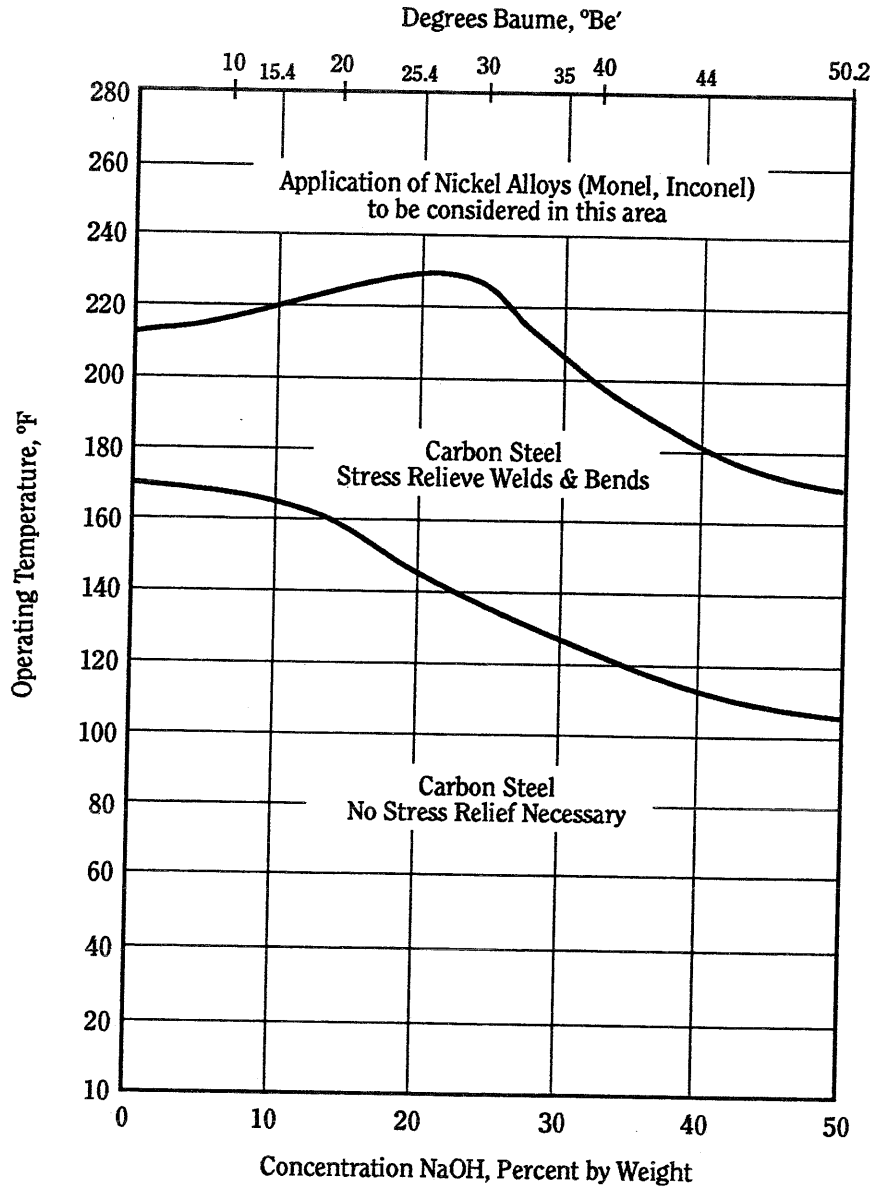
As mentioned above, these guidelines are general and thus there will be exceptions and additions (or deletions at times) to them.

Table 6

Typical Brinell Hardness Range for Various Materials		
	Minimum	Maximum
C-1/2	136	225
1-1/4 Chrome, 1/2 Mo	149	225
2-1/4 Chrome, 1 Mo	160	241
5 Chrome, 1/2 Mo	131	241
7 Chrome, 1/2 Mo	150	241
9 Chrome, 1/2 Mo	175	241
11-13 Chrome	179	241
18-8 SS	130	
Carbon Steel	140	200

Figure 7

Caustic Soda Service Chart



EDS-R00-2308

FIELD INSPECTION OF PROCESS VESSELS

Questions to Answer in a Report

UOP

INSPECTION REPORT PROCESS UNIT

LICENSEE	LOCATION	DATE
VESSEL SERVICE: PRESSURE VESSEL		
CONDITION	1. LINING 2. UNLINED AREAS 3. WELD SEAMS	4. BULGES-DISTORTIONS 5. INTERNAL EQUIPMENT 6. INSULATION 7. LADDERS & PLATFORMS 8. SUPPORT 9. NOZZLES

1. LINING

TYPE?

WHERE?

CORROSION?

EROSION?

BULGED?

UOP

INSPECTION REPORT PROCESS UNIT

LICENSEE		LOCATION	DATE
VESSEL SERVICE: PRESSURE VESSEL			
CONDITION	1. LINING 2. UNLINED AREAS 3. WELD SEAMS	4. BULGES-DISTORTIONS 5. INTERNAL EQUIPMENT 6. INSULATION	7. LADDERS & PLATFORMS 8. SUPPORT 9. NOZZLES

2. UNLINED AREAS

CORROSION?

WHERE?

APPEARANCE?

HOW DEEP?

AREA OF CORROSION?

EROSION?

WHERE?

HOW DEEP?

Mechanical Damage

**UOP
INSPECTION REPORT PROCESS UNIT**

LICENSEE		LOCATION	DATE
VESSEL SERVICE: PRESSURE VESSEL			
CONDITION	1. LINING 2. UNLINED AREAS 3. WELD SEAMS	4. BULGES-DISTORTIONS 5. INTERNAL EQUIPMENT 6. INSULATION	7. LADDERS & PLATFORMS 8. SUPPORT 9. NOZZLES

3. WELD SEAMS

WHAT SERVICE?

VISUAL FOR CORROSION

VISUAL FOR CRACKING

FURTHER NDT NEEDED?

NDT: Not Destructive Testing

640'c PWHF.
1100'f > Heat treatment

UOP

INSPECTION REPORT PROCESS UNIT

LICENSEE		LOCATION	DATE
VESSEL SERVICE: PRESSURE VESSEL			
CONDITION	1. LINING	4. BULGES-DISTORTIONS	7. LADDERS & PLATFORMS
	2. UNLINED AREAS	5. INTERNAL EQUIPMENT	8. SUPPORT
	3. WELD SEAMS	6. INSULATION	9. NOZZLES

4. BULGES-DISTORTIONS

DEFLECTED HOW MUCH?

WHERE?

HOW LARGE AN AREA?

**UOP
INSPECTION REPORT PROCESS UNIT**

LICENSEE		LOCATION	DATE
VESSEL SERVICE: PRESSURE VESSEL			
CONDITION	1. LINING 2. UNLINED AREAS 3. WELD SEAMS	4. BULGES-DISTORTIONS 5. INTERNAL EQUIPMENT 6. INSULATION	7. LADDERS & PLATFORMS 8. SUPPORT 9. NOZZLES

5. INTERNAL EQUIPMENT

TRAYS?

DISTRIBUTORS?

VORTEX BREAKERS?

DEMISTER PAD?

CYCLONES?

AIR GRID?

ETC.

**UOP
INSPECTION REPORT PROCESS UNIT**

LICENSEE		LOCATION	DATE
VESSEL SERVICE: PRESSURE VESSEL			
CONDITION	1. LINING 2. UNLINED AREAS 3. WELD SEAMS	4. BULGES-DISTORTIONS 5. INTERNAL EQUIPMENT 6. INSULATION	7. LADDERS & PLATFORMS 8. SUPPORT 9. NOZZLES

6. INSULATION

MISSING?

METAL JACKET CONDITION?

*API 570 . Piping Inspection Code
1st Ed. 1983.*

*Agreement to determine regional thickness
of piping*

UOP

INSPECTION REPORT PROCESS UNIT

LICENSEE		LOCATION	DATE
VESSEL SERVICE: PRESSURE VESSEL			
CONDITION	1. LINING	4. BULGES-DISTORTIONS	7. LADDERS & PLATFORMS
	2. UNLINED AREAS	5. INTERNAL EQUIPMENT	8. SUPPORT
	3. WELD SEAMS	6. INSULATION	9. NOZZLES

7. LADDERS AND PLATFORMS

ARE THEY USEABLE?

ARE THERE TOE PLATES?

IS THE BOLTING SECURE?

UOP

INSPECTION REPORT PROCESS UNIT

LICENSEE		LOCATION	DATE
VESSEL SERVICE: PRESSURE VESSEL			
CONDITION	1. LINING 2. UNLINED AREAS 3. WELD SEAMS	4. BULGES-DISTORTIONS 5. INTERNAL EQUIPMENT 6. INSULATION	7. LADDERS & PLATFORMS 8. SUPPORT 9. NOZZLES

8. SUPPORT

FIREPROOFED SKIRT

STEEL SADDLES

CONCRETE SADDLES

UOP

INSPECTION REPORT PROCESS UNIT

LICENSEE		LOCATION	DATE
VESSEL SERVICE: PRESSURE VESSEL			
CONDITION	1. LINING 2. UNLINED AREAS 3. WELD SEAMS	4. BULGES-DISTORTIONS 5. INTERNAL EQUIPMENT 6. INSULATION	7. LADDERS & PLATFORMS 8. SUPPORT 9. NOZZLES

9. NOZZLES

THICKNESS?

CORROSION?

LINER LEAKAGE?

WELDS CRACKED?

FLANGE GASKET SURFACE

BOLTING