"REVIEW/PREPARATION/APPROVAL OF WELDING PROCEDURE SPECIFICATION AND WELDER'S QUALIFICATION"

By

BHANU PRATAP SINGH

College of Engineering

University of Petroleum & Energy Studies

Dehradun

May, 2008

"REVIEW/PREPARATION/APPROVAL OF WELDING PROCEDURE SPECIFICATION AND WELDER'S QUALIFICATION"

A thesis submitted in partial fulfillment of the requirements for the Degree of

Master of Technology

(Pipeline Engineering)

By

BHANU PRATAP SINGH

Under the guidance of

Mr. R. P. SHRIWAS	**Mr. SUNIL KUMAR SHARMA**
SENIOR ADJUNCT PROFESSOR	**DEPUTY MANAGER**
U.P.E.S., DEHRADUN	**ADANI ENERGY LIMITED**

Approved By

Dr. B. P. Pandey

Dean

College of Engineering

University of Petroleum & Energy Studies

Dehradun

May, 2008

UNIVERSITY OF PETROLEUM & ENERGY STUDIES
(ISO 9001:2000 Certified)

CERTIFICATE

This is to certify that the work contained in this thesis titled "REVIEW/PREPARATION/APPROVAL OF WELDING PROCEDURE SPECIFICATION AND WELDER'S QUALIFICATION" has been carried out by Mr. BHANU PRATAP SINGH under my supervision and has not been submitted elsewhere for a degree.

Prof. R.P. SHRIWAS
Senior Adjunct Professor
University of Petroleum and
Energy Studies, Dehradun

Date: 23/5/2008

Corporate Office:
Hydrocarbons Education & Research Society
3rd Floor, PHD House,
4/2 Siri Institutional Area
August Kranti Marg, New Delhi - 110 016 India
Ph.: +91-11-41730151-53 Fax : +91-11-41730154

Main Campus:
Energy Acres,
PO Bidholi Via Prem Nagar,
Dehradun - 248 007 (Uttarakhand), India
Ph.: +91-135-2102690-91, 2694201/ 203/ 208
Fax: +91-135-2694204

Regional Centre (NCR) :
SCO, 9-12, Sector-14,
Gurgaon 122 007
(Haryana), India.
Ph: +91-124-4540 300
Fax: +91-124-4540 330

Regional Centre (Rajahmundry):
GIET, NH 5, Velugubanda,
Rajahmundry - 533 294,
East Godavari Dist., (Andhra Pradesh), India
Tel: +91-883-2484811/ 855
Fax: +91-883-2484822

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

This project report provide details of the welding of gas pipeline of 8" diameter that would supply natural gas for industrial purpose in the city of Potteries- Khurja, situated 100 K.M. away from national capital Delhi.

Every day countless kilometres of steel pipelines are installed worldwide for the most varied civil and industrial uses. They form real networks comparable to a system of road networks, which, although not so obvious, are definitely much more intricate and carry fluids that have become essential for us. To comply with technical specifications and fulfil the necessary safety requisites, special materials and welding processes that have evolved with the sector have been developed in recent years.

The main welding process used to install the pipelines is **manual welding with coated electrode**, which, thanks to its ease and versatility, is still the one most used. However, to limit costs and increase welding productivity, particularly on long routes, various constructors have adopted the semi-automatic or completely automatic **welding process with solid wire or wire flux coated with gaseous protection.**

Ample space has been dedicated to the operative practice and quality assessment, due to its considerable use still today. The presumption of this work is to be able to satisfy the most demanding technician and welder, but, in particular, to supply each user with useful information and a solid operative basis, as regards the processes and filler materials and the welding equipment.

ACKNOWLEDGEMENT

It has been an immense pleasure and truly enriching experience doing my major project at the Khurja Site of **Adani Energy Limited (AEL).** I take this opportunity to thank all those people who have made this experience a memorable one. Firstly, I would like to thank my guide **Mr. SUNIL KUMAR SHARMA (Deputy Manager)** who has been instrumental and a guiding force behind the completion of this project. He has been constantly eliciting insights and viewpoints on the subject matter.

I would also like to thank the complete Project Team especially **Mr. Amit Gupta, Mr. Vikas Gautam, Mr. Nitin Kumar** who were there throughout my stint at Adani Energy Limited, Khurja, for any help I needed.

I am also indebted to **Mr. RAJEEV CHAK (Assistant Vice President-CNG)** for giving me an opportunity to do my project work in the ADANI Group Company.

Several other people have been instrumental in the successful completion of this project. Finally, I would like to thank the staff at ADANI ENERGY LIMITED, Khurja who provided easy access material for reference and all those people who have helped in no single measure through their suggestions and comments.

BHANU PRATAP SINGH

ADANI ENERGY LIMITED:

ADANI GROUP is one of the fastest growing corporate houses in India with diversified business interests and a turnover of over Rs. 25000 Crore. The group is engaged in global trading, logistics, energy, port development, SEZ, power generation, edible oil refining and infrastructure development.

Adani Group has formed company ADANI ENERGY LIMITED (AEL) for developing the city gas distribution projects in various cities across INDIA. AEL having the experience of implementing the project shall hold at least 30% of the equity of Adani Energy Limited.

Adani Energy Limited as a part of Adani Group was incorporated in the year 2000 to develop Gas distribution project. AEL has got NOC from respective State Governments for setting up City Gas Distribution project & is in the advanced stages of planning & development in Faridabad, Noida, Lucknow, Jaipur, Udaipur, and Khurja.

City Gas Distribution System:

Natural gas is transported & supplied to the consumer's premises by using extensive pipeline network. The backbone of the distribution network is the Main Steel Pipeline that brings natural gas from source to the city. Steel pipeline is routed to reach all major demand centers. in the city. Along the steel network, CNG stations are located, where natural gas is compressed to 200-250 Bar for dispensing it to vehicles as a fuel. The pressure in the main steel pipeline is 19 to 26 Bar through "District Regulator Station" or DRS located at various locations on the steel pipeline network. From DRS, takes off the Medium Density Polyethylene Pipeline (MDPE) network. The MDPE network does the real task of carrying & distributing Natural Gas right up to the customer's premises. These pipes carry natural gas at a pressure of 4 Bar to 21 mBar to individual houses, commercial establishments & industrial units. The pressure regulator maintains the requisite pressure in the MDPE pipeline. The metering device installed in the customer's premises records the units of gas consumed by the user based on which invoicing is done.

Benefits of Natural Gas (NG):

Natural Gas is an established clean & green fuel worldwide. Natural Gas is predominately being used as a fuel in most of the major cities of the world, namely, New Delhi, Mumbai, Ahemadabad, London, Paris, New York, Rome, Tokyo, Boston, Los Angeles, Barcelona, etc.

Natural Gas is being used for various domestic & commercial applications, such as, for cooking, water heating, space heating, and air conditioning and for various industrial requirements, such as, power generation, fuel for furnace, boilers, kilns, etc. CNG is also fast emerging as the preferred auto fuel al over the world.

These are various benefits associated with Natural Gas:

- Reliable supply
- Unmatched convenience
- Economical Benefits
- Safety
- Environment Friendly

CHAPTER-1

INTRODUCTION

1.1 INTRODUCTION

The development of oil and natural gas fields is continuously being promoted all over the world. Oil and natural gasses are transported through pipelines from the production fields to refineries and the hub bases for consumers.

In the construction of the transportation pipelines, the girth joints of pipes are increasingly welded using manual, semiautomatic or mechanized gas metal arc welding processes. However, traditional shielded metal arc welding (SMAW) continues as the dominant method. Welding includes the alignment and welding necessary for the construction and completion of the pipeline.

This report covers the arc welding of butt, and fillet welds in carbon and low-alloy steel piping used in the compression, pumping, and transmission of natural gas, fuel gases, carbon dioxide, and nitrogen and, where applicable, covers welding on distribution systems. It applies to both new construction and in-service welding. The welding may be done by a shielded metal-arc welding, submerged arc welding, gas metal-arc welding, flux-cored arc welding, or flash butt welding process or by a combination of these processes using a manual, semiautomatic, or automatic welding technique or a combination of these techniques. This report also covers the procedures for radiographic, magnetic particle, liquid penetrant, and ultrasonic testing as well as the acceptance standards to be applied to production welds tested to destruction or inspected by radiographic, magnetic particle, liquid penetrant, ultrasonic, and visual testing methods.

As long as oil and natural gases are produced, pipelines will be constructed for transmission of these fuels. In selecting appropriate welding procedures and welding consumables, crack resistibility, welding efficiency and weld joint characteristics should be carefully examined.

This project report includes the following:

- A description of the welding process.
- A proposal on the essential variables.
- A welding procedure specification.
- Weld inspection methods.
- Types of weld imperfections and their proposed acceptance limits.
- Repair procedures.

1.2 Brief Overview of Khurja City Gas Distribution Project

Total length of the pipeline for the project	30.2 KMs
Pipe Diameter	8" (219.16mm)
Pipe Grade	API 5L X42
Pipe Wall Thickness	6.4 mm
Total number of pipes required	2507
Total number of joints	2506

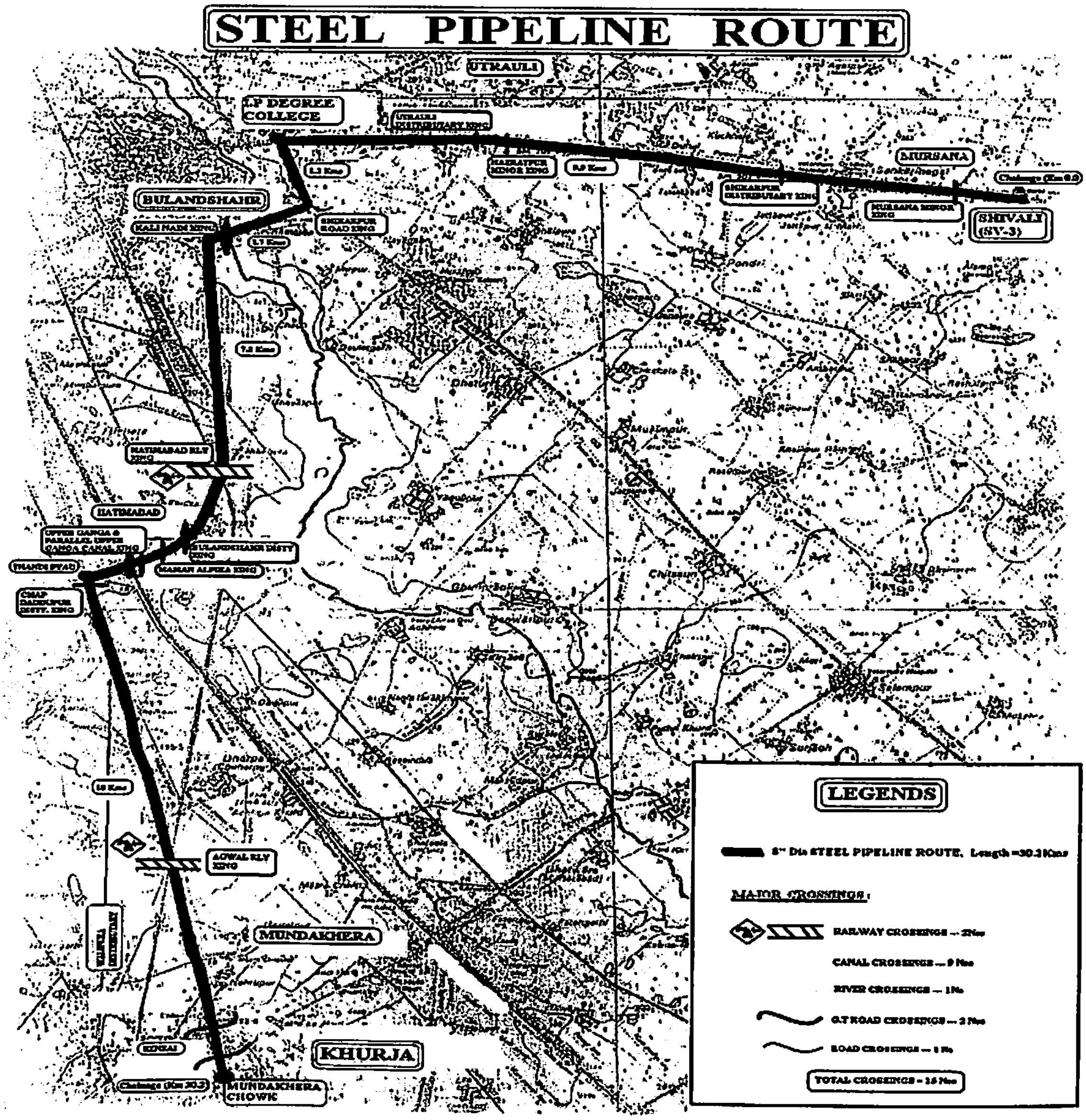


Fig.-1: Pipeline Route

CHAPTER-2

LITERATURE REVIEW

2.1 GENERAL INFORMATION

The main welding process used to weld pipelines is the manual metal arc (MMA) welding with coated electrodes. There are many reasons for this choice. The first is the most obvious: the manual electrode is the first product invented that is suitable for arc welding.

However, still today, when more sophisticated materials and more productive and less expensive techniques are at the users' disposal, manual welding remains a favoured process to weld pipes. Its easy use, capacity to reach positions of difficult accessibility, the simplicity of the necessary generators (or the fact of being able to use motor generators; network power is not always available on installation sites), the fact that protective gases (difficult to find in certain countries, in particular third world countries), necessary in welding with solid or cored wires, are not required, all these and others are the reasons for this choice.

Some classes of cellulosic and basic electrodes have been specially designed to meet the requirements of the grade of steel used to manufacture the pipeline and the safety specifications laid down by standards, but also to equip the user i.e. welders with versatile products created for this specific purpose.

2.1.1 Welding Procedure:

A suitable welding procedure is usually determined by productivity and quality requirements rather than the need to control distortion. Nevertheless, the welding process, technique and sequence do influence the distortion level.

2.1.2 Weld Distortion:

Distortion in a weld results from the expansion and contraction of the weld metal and adjacent base metal during the heating and cooling cycle of the welding process. Doing all welding on one side of a part will cause much more distortion than if the welds are alternated from one side to the other. During this heating and cooling cycle, many factors affect shrinkage of the metal and lead to distortion, such as physical and mechanical properties that change as heat is applied. For example, as the temperature of the weld area increases yield strength, elasticity, and thermal conductivity of the steel plate decrease, while thermal expansion and specific heat increase. These changes, in turn, affect heat flow and uniformity of heat distribution.

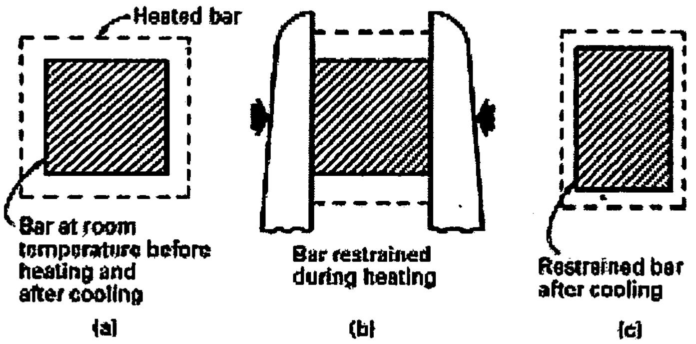


Fig.-2: Weld Distortion

If a steel bar is uniformly heated while unrestrained, as in (a), it will expand in all directions and return to its original dimensions on cooling. If restrained, as in (b), during heating, it can expand only in the vertical direction - become thicker. On cooling, the deformed bar contracts uniformly, as shown in (c), and, thus, is permanently deformed. This is a simplified explanation of basic cause of distortion in welding assemblies.

2.1.3 Welding Process:

General rules for selecting a welding process to prevent angular distortion are:

- Deposit the weld metal as quickly as possible
- Use the least number of runs to fill the joint

Unfortunately, selecting a suitable welding process based on these rules may increase longitudinal shrinkage resulting in bowing and buckling.

In manual welding, MIG, a high deposition rate process, is preferred to MMA. Weld metal should be deposited using the largest diameter electrode (MMA), or the highest current level (MIG), without causing lack-of-fusion imperfections. As heating is much slower and more diffuse, gas welding normally produces more angular distortion than the arc processes.

Mechanized techniques combining high deposition rates and high welding speeds have the greatest potential for preventing distortion. As the distortion is more consistent, simple techniques such as presetting are more effective in controlling angular distortion.

2.1.4 Welding Technique:

General rules for preventing distortion are:

- Keep the weld (fillet) to the minimum specified size
- Use balanced welding about the neutral axis
- Keep the time between runs to a minimum

2.1.5 Welding Sequence:

The sequence, or direction, of welding is important and should be towards the free end of the joint. For long welds, the whole of the weld is not completed in one direction. Short runs, for example using the back-step or skip welding technique, are very effective in distortion control.

- Back-step welding involves depositing short adjacent weld lengths in the opposite direction to the general progression.
- Skip welding is laying short weld lengths in a predetermined, evenly spaced, sequence along the seam. Weld lengths and the spaces between them are generally equal to the natural run-out length of one electrode. The direction of deposit for each electrode is the same, but it is not necessary for the welding direction to be opposite to the direction of general progression.

2.1.6 Best Practice:

The following fabrication techniques are used to control distortion:

- Using tack welds to set up and maintain the joint gap
- Identical components welded back to back so welding can be balanced about the neutral axis
- Attachment of longitudinal stiffeners to prevent longitudinal bowing in butt welds of thin plate structures
- Where there is choice of welding procedure, process and technique should aim to deposit the weld metal as quickly as possible; MIG in preference to MMA or gas welding and mechanized rather than manual welding

- In long runs, the whole weld should not be completed in one direction; back-step or skip welding techniques should be used.

2.2 Pipe Welding:

Welding is the simplest and easiest way to join sections of pipe. The need for complicated joint designs and special threading equipment is eliminated. Welded pipe has reduced flow restrictions compared to mechanical connections and the overall installation costs are less. The most popular method for welding pipe is the shielded metal-arc process; however, gas shielded arc methods have made big inroads as a result of new advances in welding technology.

Pipe welding has become recognized as a profession in itself. Even though many of the skills are comparable to other types of welding, pipe welders develop skills that are unique only to pipe welding. Because of the hazardous materials that most pipelines carry, pipe welders are required to pass specific tests before they can be certified.

2.3 Pipe Welding Positions:

There are four positions used in pipe welding. They are known as the horizontal rolled position (1G), the horizontal fixed position (5G), pipe inclined fixed (6G), and the vertical position (2G). These terms refer to the position of the pipe and not to the weld

2.4 Types of Joint:

2.4.1 Butt Joint:

Details of butt joint shown in Fig.-3 are as following:

1. Root gap: separation between the edges to be welded at the root of the joint
2. Root face: surface of the joint preparation perpendicular to the surface of the plate
3. Bevel surface: oblique surface of the joint preparation
4. Bevel angle: angle between the bevelled surface and a plane perpendicular to the plate
5. Included angle: total angle between the two bevel surfaces
6. Seam width: effective width of the joint (distance between the bevels plus depth of penetration). The width of the calking iron seam and groove iron is the same thing
7. Thickness of the plate

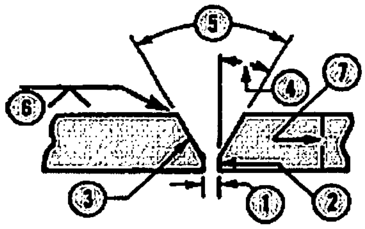


Fig.-3: Butt Joint

2.4.2 Fillet Joint:

Details of fillet joint shown in Fig.-4 are as following:

1. Throat thickness: distance between seam root and surface measured on the bisector of the angle
2. Leg length: distance between seam root and edge
3. Joint root: point in which the bottom of the seam intersects the surface of the base metal
4. Joint edge: junction point between seam surface and base metal surface
5. Joint surface: external surface of the seam
6. Fusion depth: depth reached by the fusion bath from the surface of the base metal
7. Seam width: distance between the joint edges

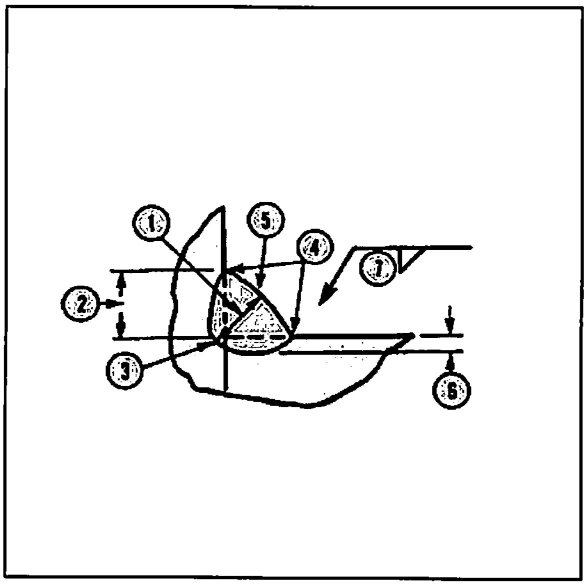


Fig.-4: Fillet Joint

2.5 Filler Material:

Welding electrodes are used as a filler material to fill the gap between pipe faces. There are many different types of electrodes used in the shielded metal arc welding (SMAW) process. Arc welding electrodes are identified using the A.W.S, (American Welding Society) numbering system and are made in sizes from 1/16" to 5/16". An example would be a welding rod identified as a 1/8" E6010 electrode.

In general, all electrodes are classified into five main groups:

1. Mild steel
2. High-carbon steel
3. Special alloy steel
4. Cast iron
5. Non-ferrous

The widest range of arc welding is done with electrodes in the mild steel group. Electrodes are manufactured for use in specific positions and for many different types of metal. They also are specially designed to use with ac or dc welding machines.

2.5.1 Types of Electrodes:

Electrodes are classified as ***either bare or shielded.*** The original bare electrodes were exactly as their name implied—bare. Today, they have a light covering, but even with this improvement they are rarely used because of their limitations. They are difficult to weld with, produce brittle welds, and have low strength. Just about all welding is done with shielded electrodes.

The shielded electrode has a heavy coating of several chemicals, such as **cellulose, Titania sodium, low- hydrogen sodium, or iron powder.** Each of the chemicals in the coating serves a particular function in the welding process. In general, their main purposes are to **induce easier arc starting, stabilize the arc, improve weld appearance and penetration, reduce spatter, and protect the molten metal from oxidation or contamination by the surrounding atmosphere.** As molten metal is deposited in the welding process, it attracts oxygen and nitrogen. Since the arc stream takes place in the atmosphere, oxidation occurs while the metal passes from the electrode to the work. When this happens, the strength and ductility of the weld are reduced as well as the resistance to corrosion. The coating on the electrode prevents oxidation from taking place. As the electrode melts, the heavy coating releases an inert gas around the molten metal that excludes the atmosphere from the weld. The burning residue of the coating forms a slag over the deposited metal that slows down the cooling rate and produces a more ductile weld. Some coatings include powdered iron that is converted to steel by the intense heat of the arc as it flows into the weld deposit.

2.5.2 Electrode Identification:

Electrodes are often referred to by a manufacturer's trade name. The American Welding Society (AWS) and the American Society for Testing and Materials (ASTM) have set up certain requirements for electrodes to assure some degree of uniformity in manufacturing electrodes. Thus different manufacturer's electrodes that are within the classification established by the AWS and ASTM should have the same welding characteristics. (See fig.-5).

All mild steel and low-alloy electrodes are classified with a 4 or 5 digit number prefixed by "E."

Prefix "E" = Electrode

First two (or three) digits = Tensile strength (psi) (stress relieved or as welded)

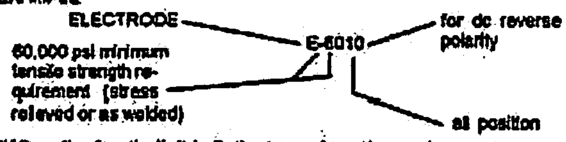
Third (or fourth) digit = Position of welding

1 = all positions (flat, horizontal, vertical, overhead)

2 = horizontal and flat positions only

FOURTH DIGIT	TYPE OF COATING	WELDING CURRENT
1	cellulose potassium	ac or dc Reverse or Straight
2	titania sodium	ac or dc Straight
3	titania potassium	ac or dc Straight or Reverse
4	iron powder titania	ac or dc Straight or Reverse
5	low hydrogen sodium	dc Reverse
6	low hydrogen potassium	dc or dc Reverse
7	iron powder iron oxide	ac or dc
8	iron powder low hydrogen	dc Reverse or Straight or ac
0*	see reference below	

EXAMPLE



*When the fourth digit is 0, the type of coating and current to use are determined by the third digit. For example, E-6010 indicates a cellulose sodium coating and operates on dc reverse, while E-6020 has an iron oxide coating and operates on ac or dc.

Fig.-5: Explanation of AWS classification numbers

In this classification, each type of electrode is assigned a specific symbol, such as E-6010, E-7010, and E-8010. The prefix E identifies the electrode for electric arc welding. The first two digits in the symbol designate the minimum allowable tensile strength in thousands of pounds per square inch of the deposited weld metal. For example, the 60-series electrodes have a minimum tensile strength of 60,000 pounds per square inch, while the 70-series electrodes have strength of 70,000 pounds per square inch.

The third digit of the symbol indicates the joint position for which the electrode is designed. Two numbers are used for this purpose: 1 and 2. Number 1 designates an electrode that can be used for welding in any position. Number 2 represents an electrode restricted for welding in the horizontal and flat positions only.

The fourth digit of the symbol represents special characteristics of the electrode, such as weld quality, type of current, and amount of penetration. The numbers range from 0 through 8. Since the welding position is dependent on the manufacturer's characteristics of the coating, the third and fourth numbers are often identified together.

2.5.3 Electrode Selection:

Select the electrode that is best suited for the position and type of welding to be done. For the root pass of a multilayer weld, you need an electrode large enough yet not exceeding 3/16 inch, that ensures complete fusion and penetration without undercutting and slag inclusions. Make certain the welding current is within the range recommended by the manufacturers of the welding machines and electrodes.

Several factors are critical when choose an electrode for welding. The welding position is particularly significant. Table shows the recommended current types and welding positions for the most common electrodes.

As a rule of thumb, you should never use an electrode that has a diameter larger than the thickness of the metal that you are welding. Some operators prefer larger electrodes because they permit faster travel, but this takes a lot of expedience to produce certified welds.

Position and the type of joint are also factors in determining the size of the electrode. For example, in a thick-metal section with a narrow vee, a small-diameter electrode is always used to run the frost weld or root pass. This is done to ensure full penetration at the root of the weld. Successive passes are then made with larger electrodes.

Deposit rate and joint preparation are also important in the selection of an electrode. Electrodes for welding mild steel can be classified as fast freeze; fill freeze, and fast fill.

FAST-FREEZE electrodes produce a snappy, deep penetrating arc and fast-freezing deposits. They are commonly called reverse-polarity electrodes, even though some can be used on ac. These electrodes have little slag and produce flat beads. They are widely used for all-position welding for both fabrication and repair work.

FILL-FREEZE electrodes have a moderately forceful arc and a deposit rate between those of the fast-freeze and fast-fill electrodes. They are commonly called the straight-polarity electrodes, even though they may be used on ac. These electrodes have complete slag coverage and weld deposits with distinct, even ripples. They are the general-purpose electrode for a production shop and are also widely used for repair work. They can be used in all positions, but fast-freeze electrodes are still preferred for vertical and overhead welding.

Table-1: Electrode Selection Guide

Type	AWS Class	Current Type	Welding Position	Weld Results
Mild Steel	E6010 E6011	DCR DCR, AC	F, V, OH, H F, V, OH, H	Fast freeze, deep penetrating, flat beads, all- purpose welding
	E6012 E6013 E6014	DCS, AC DCR, DCS, AC DCS, AC	F, V, OH, H F, V, OH, H F, V, OH, H	Fill-freeze, low penetration, for poor fit-up, good bead contour, minimum spatter
	E6020 E6024	DCR, DCS, AC DCR, DCS, AC	F, H F, H	Fast-fill, high deposition, deep groove welds, single pass
	E6027	DCR, DCS, AC	F, H	Iron powder, high deposition, deep penetration
	57014	DCR, DCS, AC	F, V, OH, H	Iron powder, low penetration, high speed
	E7024	DCR, DCS, AC	F, H	Iron powder, high deposition, single and multiple pass
Low Hydrogen	E6015 E6016 E6018 E7016 E7018 E7028	DCR DCR, AC DCR, AC DCR, AC DCR, AC DCR, AC	F, V, OH, H F, V, OH, H F, V, OH, H F, V, OH, H F, V, OH, H F, H	Welding of high-sulphur and high-carbon steels that tend to develop porosity and crack under weld deposit
Stainless Steel	E308-15, 16	DC, AC	F, V, OH, H	Welding stainless steel 301, 302, 303 304, 308
	E309-15, 16	DC, AC	F, V, OH, H	Welding 309 alloy at elevated temperature application and dissimilar metals
	E310-15, 16	DC, AC	F, V, OH, H	Welding type 310 and 314 stainless steel where high corrosion and elevated temperatures are required
	E316-15, 16	DC, AC	F, V, OH, H	Welding type 316 stainless steel and welds of highest quality. Contains less carbon to minimize carbon transfer in the weld. Type 316 reduces pitting corrosion
	E347-15, 16	DC, AC	F, V, OH, H	For welding all grades of stainless steels
Low Alloy	E7011-A1 E7020-A1	DCR, AC DCR, DCS, AC	F, V, OH, H F 2	For welding carbon moly steels
	E8018-C3	DCR, AC	F, V, OH, H	For low alloy, high-tensile strength
	E10013-G	DCS, AC	F, V, OH, H	For low alloy, high-tensile steels

DCR—Direct Current Reverse Polarity
DCS—Direct Current Straight Polarity
AC—Alternating Current
F—flat, V—vertical, OH—overhead, H—horizontal

Among the FAST-FILL electrodes are the heavy- coated, iron powder electrodes with a soft arc and fast deposit rate. These electrodes have a heavy slag and produce exceptionally smooth weld deposits. They are generally used for production welding where the work is positioned for flat welding.

Another group of electrodes are the low-hydrogen types that were developed for welding high-sulfur and high-carbon steel. These electrodes produce X-ray quality deposits by reducing the absorption of hydrogen that causes porosity and cracks under the weld bead.

Welding stainless steel requires an electrode containing chromium and nickel. All stainless steels have low-thermal conductivity that causes electrode over- heating and improper arc action when high currents are used. In the base metal, it causes large temperature differentials between the weld and the rest of the work, which warps the plate. A basic rule in welding stainless steel is to avoid high currents and high heat. Another reason for keeping the weld cool is to avoid carbon corrosion.

The basic rule in selecting electrodes is to pick one that is similar in composition to the base metal.

2.6 Current Types:

SMAW is performed using either AC or DC current. Since DC current flows in one direction, DC current can be DC straight, (electrode negative) or DC reversed (electrode positive). With DC reversed, (DC+ OR DCRP) the weld penetration will be deep. DC straight (DC- OR DCSP) the weld will have a faster melts off and deposit rate. The weld will have medium penetration.

AC current changes its polarity 120 times a second by it and cannot be changed as can DC current.

2.7 Electrode Polarity:

Polarity is the direction of the current flow in a circuit, as shown in figure. In **straight polarity**, the electrode is negative and the work piece positive; the electrons flow from the electrode to the work piece. In **reverse polarity**, the electrode is positive and the work- piece negative; the electrons flow from the work piece to the electrode. To help you remember the difference, think of straight polarity as a SENator and reverse polarity as a REPresentative. Use only the first three letters of each key word. SEN stands for **Straight Electrode Negative;** REP for **Reverse Electrode Positive.**

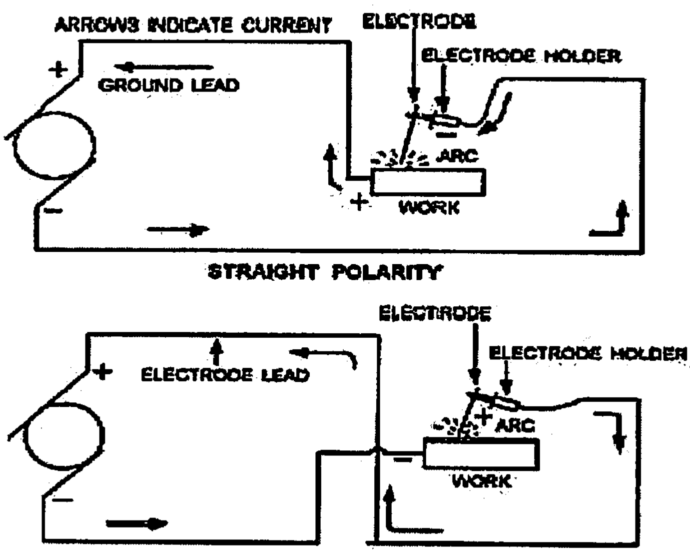


Fig.-6: Straight and reverse polarity in electric welding

Polarity affects the amount of heat going into the base metal. By changing polarity, you can direct the amount of heat to where it is needed. When you use straight polarity, the majority of the heat is directed toward the work piece. When you use reverse polarity, the heat is concentrated on the electrode. In some welding situations, it is desirable to have more heat on the work piece because of its size and the need for more heat to melt the base metal than the electrode; therefore, when making large heavy deposits, you should use STRAIGHT POLARITY.

In general, straight polarity is used for all mild steel, bare, or lightly coated electrodes. With these types of electrodes, the majority of heat is developed at the positive side of the current, the work piece. However, when heavy-coated electrodes are used, the gases given off in the arc may alter the heat conditions so the opposite is true and the greatest heat is produced on the negative side. Electrode coatings affect the heat conditions differently. One type of heavy coating may provide the most desirable heat balance with straight polarity, while another type of coating on the same electrode may provide a more desirable heat balance with reverse polarity.

Reverse polarity is used in the welding of nonferrous metals, such as aluminium, bronze, Monel, and nickel. Reverse polarity is also used with some types of electrodes for making vertical and overhead welds.

One disadvantage of direct current welding is **"arc blow"**. As stated earlier, arc blow causes the arc to wander while you are welding in corners on heavy metal or when using large-coated electrodes. Direct current flowing through the electrode, workpiece, and ground clamp generates a magnetic field around each of these units. This field can cause the arc to deviate from the intended path. The arc is usually deflected forward or backward along the line of travel and may cause excessive spatter and incomplete fusion. It also has the tendency to pull atmospheric gases into the arc, resulting in porosity.

Arc blow can often be corrected by one of the following methods: by changing the position of the ground clamp, by welding away from the ground clamp, or by changing the position of the work piece.

2.8 Starting the Arc:

Two basic methods are used for starting the arc: the STRIKING or BRUSHING method (fig.-7) and the TAPPING method (fig.-8). In either method, short-circuiting the welding current between the electrode and the work surface starts the arc. The surge of high current causes the end of the electrode and a small spot on the base metal beneath the electrode to melt instantly. In the STRIKING or BRUSHING method, the electrode is brought down to the work with a lateral motion similar to striking a match. As soon as the electrode touches the work surface, it must be raised to establish the arc (fig.-7). The arc length or gap between the end of the electrode and the work should be equal to the diameter of the electrode. When the proper arc length is obtained, it produces a sharp, crackling sound.

In the TAPPING method, you hold the electrode in a vertical position to the surface of the work. Tapping starts the arc or bouncing it on the work surface and then raising it to a distance equal to the diameter of the electrode (fig.-8). When the proper length of arc is established, a sharp, crackling sound is heard.

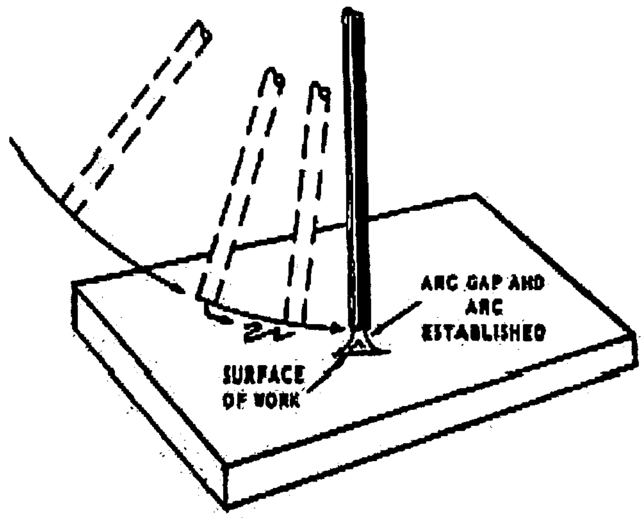


Fig.-7: Striking or brushing method of starting the arc

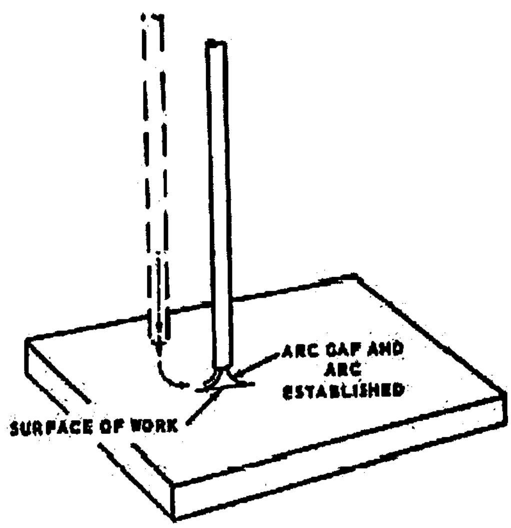


Fig.-8: Tapping method of starting the arc

When the electrode is withdrawn too slowly with either of the starting methods described above, it will stick or freeze to the plate or base metal. If this occurs, you can usually free the electrode by a quick sideways wrist motion to snap the end of the electrode from the plate. If this method fails, immediately release the electrode from the holder or shutoff the welding machine. Use alight blow with a chipping hammer or a chisel to free the electrode from the base metal.

2.9 Setting the Current:

The amount of current used during a welding operation depends primarily upon the diameter of the electrode. As a rule, higher currents and larger diameter electrodes are better for welding in the flat position than the vertical or overhead position. Manufacturers of electrodes usually specify a current range for each type and size of electrode; this information is normally found on the face of the electrode container.

When the current is too high, the electrode melts faster and the molten puddle will be excessively large and irregular. High current also leaves a groove in the base metal along both sides of the weld. This is called undercutting, and an example is shown in fig. -9 view C. With current that is too low, there is not enough heat to melt the base metal and the molten pool will be too small. The result is poor fusion and a irregular shaped deposit that piles up, as shown in fig, -9, view B. This piling up of molten metal is called overlap. The molten metal from the electrode lays on the work with- out penetrating the base metal. Both undercutting and overlapping results in poor welds, as shown in fig.-10. When the electrode, current, and polarity are correct, a good arc produces a sharp, crackling sound. When any of these conditions are incorrect, the arc produces a steady, hissing sound, such as steam escaping.

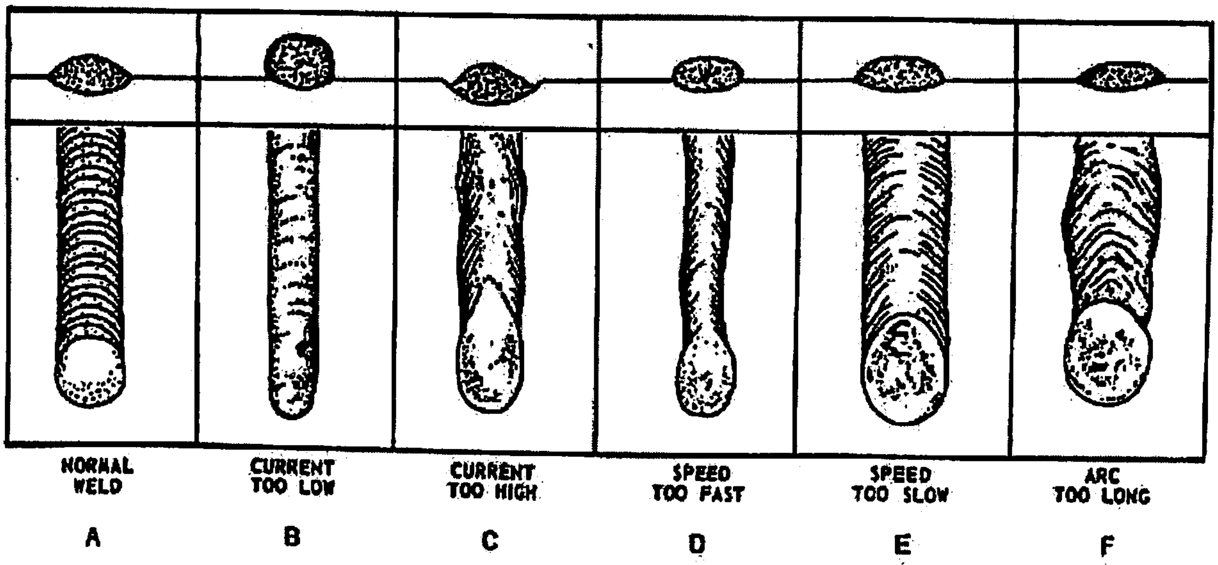


Fig.-9: Comparison of welds

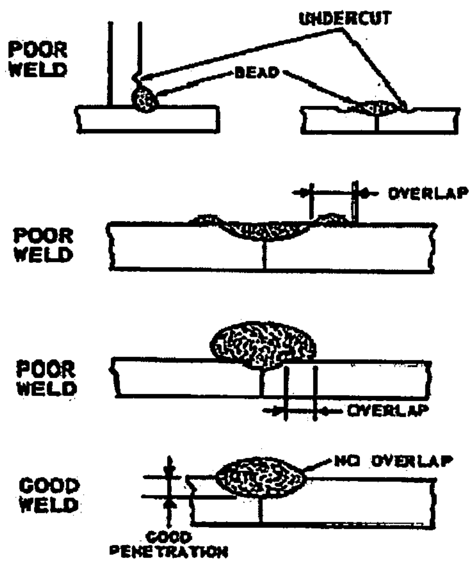


Fig.-10: Undercuts and overlaps in welding

2.10 Length of Arc:

When an arc is too long, the metal melts off the electrode in large globules and the arc may break frequently. This produces a wide, spattered, and irregular deposit with insufficient fusion between the base metal and the weld (fig.9, view F). When an arc is too short, it fails to generate enough heat to melt the base metal properly, causes the electrode to stick frequently to the base metal, and produces uneven deposits with irregular ripples. The recommended length of the arc is equal to the diameter of the bare end of the electrode, as shown in fig. The length of the arc depends upon the type of electrode and the type of welding being done; therefore, for smaller diameter electrodes, a shorter arc is necessary than for larger electrodes. Remember: the length of the arc should be about equal to the diameter of the bare electrode except when welding in the vertical or over- head position. In either position, a shorter arc is desirable because it gives better control of the molten puddle and prevents atmospherical impurities from entering the weld.

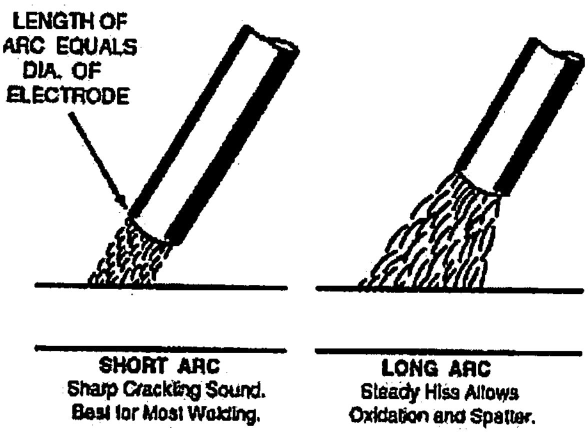


Fig.-11: Setting the length of an arc

2.11 Electrode Positioning Angles:

The angle at which welder holds the electrode, greatly affects the shape of the weld bead. Two angles are indicated: **the feed angle and the work angle.**

The feed angle is called *"TO BE PUSHED"* when the electrode points in the feed direction. This is also called electrode angle.

The work angle is called *"TO BE PULLED"* when the electrode points in opposite direction to the feed. Work angle is especially important in multiple-pass fillet welding. Normally, a small variance of the work angle will not affect the appearance or quality of a weld; however, when undercuts occur in the vertical section of a fillet weld, the angle of the arc should be lowered and the electrode directed more toward the vertical section. The work angle is given in relation to a reference plane or work plane.

The fig.-12 illustrates the definition method of the angles. Taking the clock face as reference, 1 minute corresponds to 6°.

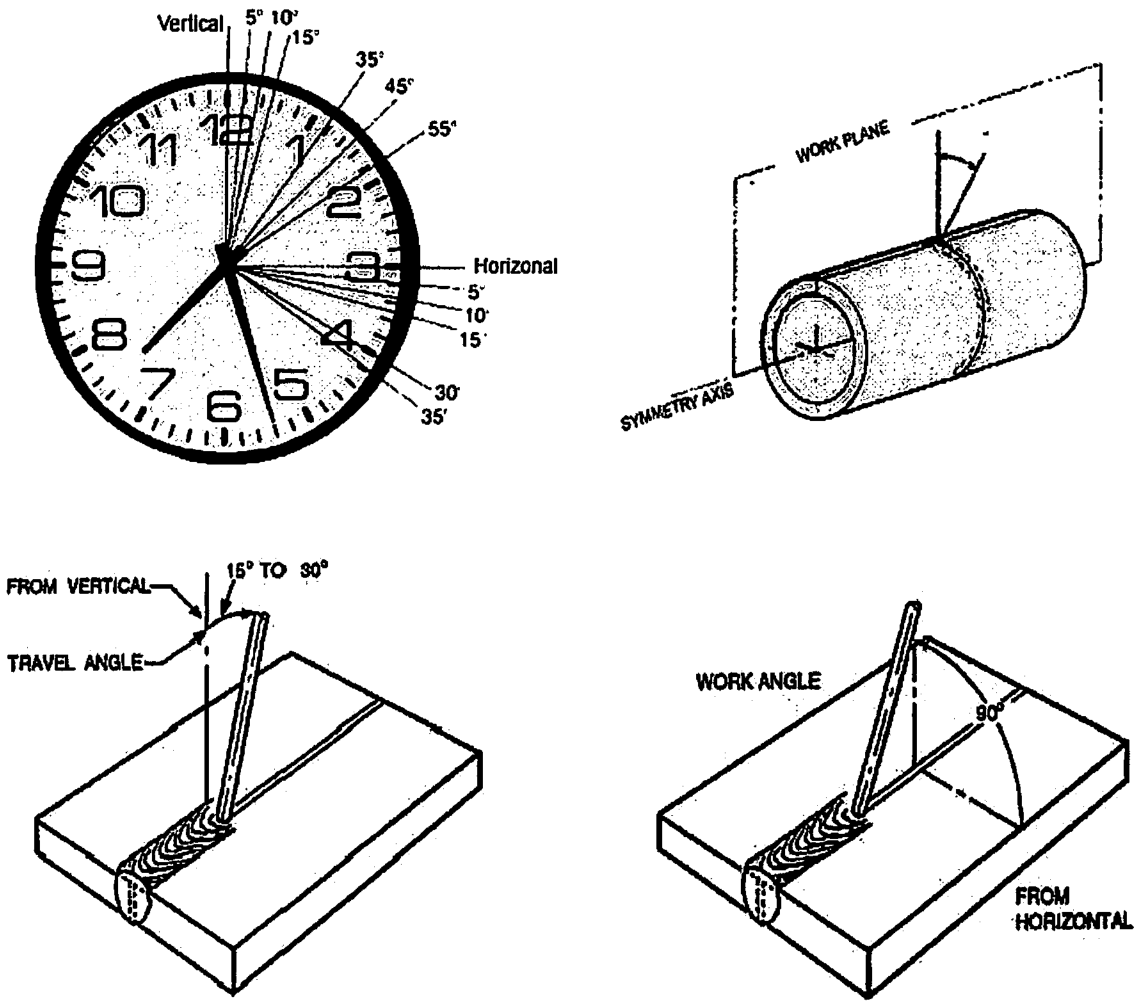


Fig.-12: Electrode Positioning Angles

2.12 Travel Speed:

Travel speed is the rate at which the electrode travels along a weld seam. The maximum speed of welding depends on the skill of the operator, the position of the weld, the type of electrode, and the required joint penetration. Normally, when the travel speed is too fast, the molten pool cools too quickly; locking in impurities and causing the weld bead to be narrow with pointed ripples, as shown in fig.9, view D. On the other hand, if the travel speed is too slow, the metal deposit piles up excessively and the weld is high and wide, as shown in fig.9, view E. In most cases, the limiting factor is the highest speed that produces a satisfactory surface appearance of a normal weld, as shown in fig.-9, view A.

2.13 Reestablishing the Arc:

When it becomes necessary to re-establish the arc (as in a long weld that requires the use of more than one electrode); the crater must first be cleaned before striking the arc. Strike the tip of the new electrode at the forward (cold) end of the crater and establish an arc. Move the arc backward over the crater, and then move forward again and continue the weld. This procedure fills the crater and prevents porosity and slag inclusions.

2.14 Peening:

Peening is a procedure that involves lightly hammering a weld as it cools. This process aids in relieving built-up stresses and preventing surface cracking in the joint area; however, peening should be done with care because excess hammering can work harden and increase stresses in the weld. This condition leads to weld embrittlement and early failure. Some welds are covered by specific codes that prohibit peening so you should check the weld specification before peening.

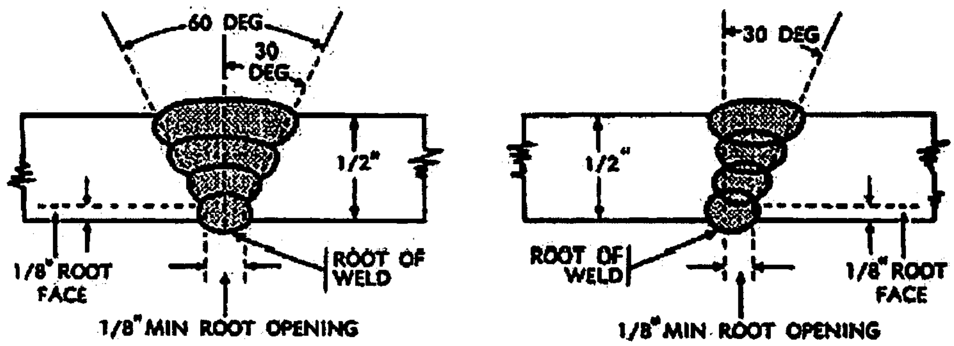


Fig.-13: Butt welds with multipass beads

2.15 Weather Conditions:

Do not assign a welder to a job under any of the following conditions listed below unless the welder and the work area are properly protected:

- When the atmospheric temperature is less than 0°F
- When the surfaces are wet
- When rain or snow is falling, or moisture is condensing on the weld surfaces
- During periods of high wind

At temperatures between 0°F and 32°F, heat the weld area within 3 inches of the joint with a torch to a temperature warm to the hand before beginning to weld.

2.16 Type of Pipes:

Transportation pressure is a factor that determines the type of pipe used. As the transport of oil or gas involves high pressure, the strength of the pipe has to be higher. The typical specification for steel pipes for pipelines is API 5L of the American Petroleum Institute (API), which is widely applied around the world. As shown in Table 4, the pipe grades vary ranging from A25 for mild steel to X80 for high strength steel with a minimum tensile strength of 620 N/mm^2. The number following to "X" of the pipe grade specifies the minimum yield strength of the steel by an American traditional unit of kilo square inch (ksi): X60 with a minimum yield strength of 60 ksi (410 N/mm^2) for instance.

Table-2: Grades of pipes specified by API 5L

A.P.I. specification	Quality	Mechanical propr. N/mm²		Chemical composition %		Carbonium (max) equivalent
		Yielding point	Tensile strength	Carbon (max)	Manganese (max)	
5 L	A 25	170	310			0,31
5 L - 5 LS	A	210	330	0,21	0,90	0,37
5 L - 5 LS	B	240	410	0,27	1,15	0,46
5 LX	X 42	290	410	0,28	1,25	0,50
5 LX	X 46	320	430	0,28	1,25	0,53
5 LX	X 52	360	500	0,28	1,25	0,53
5 LX	X 56	390	520	0,26	1,35 e/o (Nb/V/Ti)	0,48
5 LX	X 60	410	540	0,26	1,35 e/o (Nb/V/Ti)	0,48
5 LX	X 65	450	550	0,26	1,40 e/o (Nb/V/Ti)	0,49
5 LX	X 70	480	560	0,23	1,60	0,49

2.17 Starting the Welding:

Before you start to weld, ensure that you have all the required equipment and accessories. Listed below are some additional welding rules that should be followed:

- Clear the welding area of all debris and clutter.
- Do not use gloves or clothing that contains oil or grease.
- Check that all wiring and cables are installed properly.
- Ensure that the machine is grounded and dry.
- Follow all manufacturers' directions on operating the welding machine.
- Have on hand a protective screen to protect others in the welding area from FLASH bums.
- Always keep fire-fighting equipment on hand.
- Clean rust, scale, paint, or dirt from the joints that are to be welded.

2.18 Preheating:

Depending on the type of metal, sometimes it is necessary to preheat the base metal to lessen distortion, to prevent spalling or cracking, and to avoid thermal shock. The preheating temperature depends on the carbon and alloy content of the base metal. In general, as carbon content increases so does the preheating temperature. Improper heating can adversely affect a metal by reducing its resistance to wear, by making it hard and brittle, or by making it more prone to oxidation and scaling.

To preheat properly, you must know the composition of the base metal. A magnet can be used to determine if you are working with carbon steel or austenitic manganese steel. Carbon steel is magnetic, but be careful because work-hardened austenitic manganese steel is also magnetic. Make sure that you check for magnetism in a nonworked part of the austenitic manganese steel. There are other ways to tell the difference between metals, such as cast iron and cast steel. Cast iron chips or cracks, while cast steel shaves. Also, some metals give off telltale sparks when struck by a chisel.

In preheating, you should raise the surface temperature of the workpiece to the desired point and then soak it until the heat reaches its core. After wearfacing, cool the work places slowly.

CHAPTER-3

THEORETICAL DEVELOPEMENT

3.1 Review of Welding Procedure Specification and Welder's Qualification:

It includes all the stipulations of API-1104 as per following:

3.1.1 PROCEDURE QUALIFICATION:

Before production welding is started, a detailed procedure specification shall be established and qualified to demonstrate that welds with suitable mechanical properties such as (strength, ductility and hardness) and soundness can be made by the procedure. The quality of the welds shall be determined by destructive testing.

3.1.2 Record:

The details of each qualified procedure shall be recorded. The record shall show complete results of the procedure qualification test. Forms similar to those as shown in figure

3.2 PROCEDURE SPECIFICATION:

3.2.1 General:

The procedure specification shall include the information specified as following, where applicable.

3.2.2 Specification Information:

3.2.2.1 Process:

The specific process or combination of processes used shall be identified. The use of a manual, semiautomatic, or automatic welding process or any combination of these shall be specified.

3.2.2.2 Pipe and Fitting Materials:

The materials to which the procedure applies shall be identified. API Specification 5L pipe, as well as materials that conform to acceptable ASTM specifications, may be grouped, provided that the qualification test is made on the material with the highest specified minimum yield strength in the group.

3.2.2.3 Diameters and Wall Thicknesses:

The ranges of outside diameters and wall thicknesses over which the procedure is applicable shall be identified.

3.2.2.4 Joint Design:

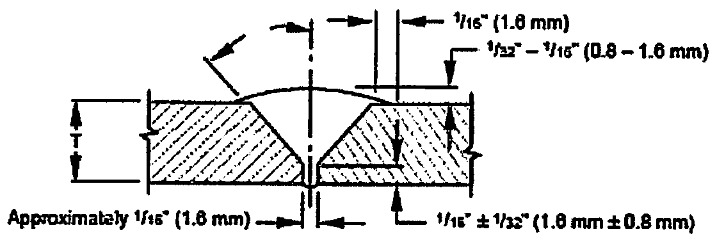
The specification shall include a sketch or sketches of the joint that show the angle of bevel, the size of the root face, and the root opening or the space between abutting members. The shape and size of fillet welds shall be shown. If a backup is used, the type shall be designated.

Reference: API Standard 1104, 5.2

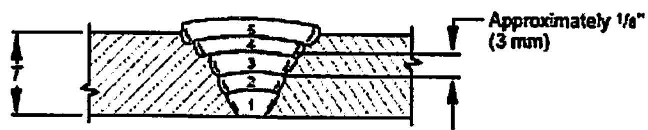
PROCEDURE SPECIFICATION NO. ________

For ____________ Welding of ____________ Pipe and fittings
Process ____________
Material ____________
Pipe outside diameter and wall thickness ____________
Joint design ____________
Filler metal and no. of beads ____________
Electrical or flame characteristics ____________
Position ____________
Direction of welding ____________
No. of welders ____________
Time lapse between passes ____________
Type and removal of lineup clamp ____________
Cleaning and/or grinding ____________
Preheat/stress relief ____________
Shielding gas and flow rate ____________
Shielding flux ____________
Speed of travel ____________
Plasma gas composition ____________ Plasma gas flow rate ____________
Plasma gas orifice size ____________
Sketches and tabulations attached ____________

Tested ____________ Welder ____________
Approved ____________ Welding supervisor ____________
Adopted ____________ Chief engineer ____________



Standard V-Bevel Butt Joint



Sequence of Beads

Note: Dimensions are for example only.

ELECTRODE SIZE AND NUMBER OF BEADS				
Bead Number	Electrode Size and Type	Voltage	Amperage and Polarity	Speed

Fig.-14: Sample Procedure Specification Form

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.

Fig.-15: Sample Coupon Test Report

3.2.2.5 Filler Metal and Number of Beads:

The sizes and classification number of the filler metal and the minimum number and sequence of beads shall be designated.

3.2.2.6 Electrical Characteristics:

The current and polarity shall be designated, and the range of voltage and amperage for each electrode, rod, or wire shall be shown.

3.2.2.7 Flame Characteristics

The specification shall designate whether the flame is neutral, carburizing, or oxidizing. The size of the orifice in the torch tip for each size of rod or wire shall be specified.

3.2.2.8 Position

The specification shall designate roll or position welding.

3.2.2.9 Direction of Welding

The specification shall designate whether the welding is to be performed in an uphill or downhill direction.

3.2.2.10 Time between Passes

The maximum time between the completion of the root bead and the start of the second bead, as well as the maximum time between the completion of the second bead and the start of other beads, shall be designated.

3.2.2.11 Type and Removal of Line up Clamp

The specification shall designate whether the line up clamp is to be internal or external or if no clamp is required. If a clamp is used, the minimum percentage of root-bead welding that must be completed before the clamp is released shall be specified.

3.2.2.12 Cleaning and/or Grinding

The specification shall indicate whether power tools or hand tools are to be used for cleaning, grinding, or both.

3.2.2.13 Pre- and Post-Heat Treatment

The methods, temperature, temperature-control methods, and ambient temperature range for pre- and post-heat treatment shall be specified.

3.2.2.14 Shielding Gas and Flow Rate

The composition of the shielding gas and the range of flow rates shall be designated.

3.2.2.15 Shielding Flux

The type of shielding flux shall be designated.

3.2.2.16 Speed of Travel

The range for speed of travel, in inches (millimetres) per minute, shall be specified for each pass.

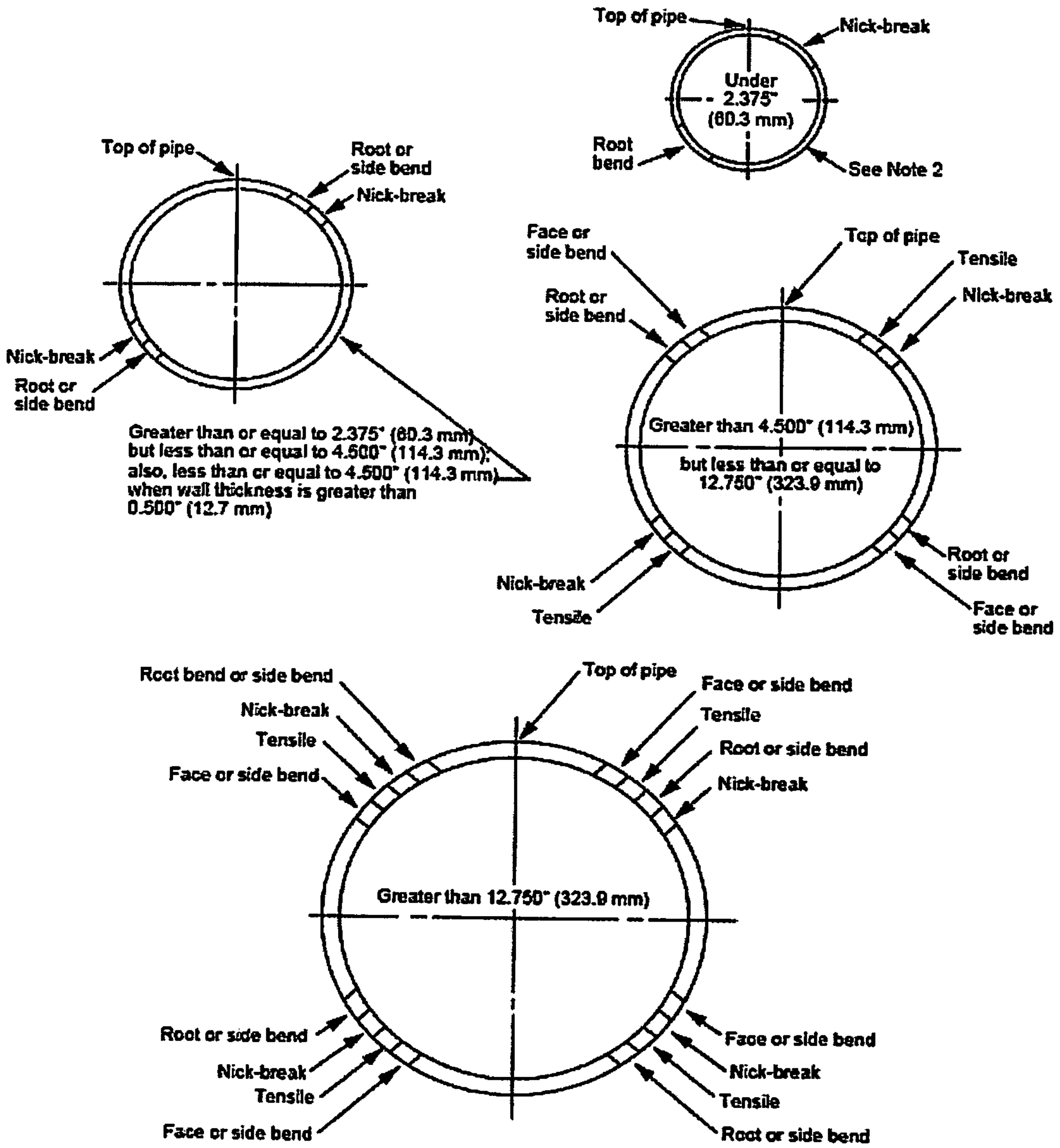


Fig.-16: Location of Test Butt-Weld Specimens for Procedure Qualification Test

Notes:

1. At the company's option, the locations may be rotated, provided they are equally spaced around the pipe; however, specimens shall not include the longitudinal weld.

2. One full-section tensile specimen may be used for pipe with an outside diameter less than or equal to 1.315 in. (33.4 mm).

3.3 ESSENTIAL VARIABLES:

3.3.1 General:

A welding procedure must be re-established as a new procedure specification and must be completely requalified when any of the essential variables listed below are changed. Changes other than those given as following may be made in the procedure without the need for re-qualification, provided the procedure specification is revised to show the changes.

3.3.2 Changes Requiring Requalification:

3.3.2.1 Welding Process or Method of Application:

A change from the welding process or method of application established in the procedure specification constitutes an essential variable.

3.3.2.2 Base Material:

A change in base material constitutes an essential variable. When welding materials of two separate material groups, the procedure for the higher strength group shall be used. For the purposes of this standard, all materials shall be grouped as follows:

a. Specified minimum yield strength less than or equal to 42,000 psi (290 MPa).
b. Specified minimum yield strength greater than 42,000 psi (290 MPa) but less than 65,000 psi (448 MPa).
c. For materials with specified minimum yield strength greater than or equal to 65,000 psi (448 MPa), each grade shall receive a separate qualification test.

3.3.2.3 Joint Design:

A major change in joint design (for example, from V groove to U groove) constitutes an essential variable. Minor changes in the angle of bevel or the land of the welding groove are not essential variables.

3.3.2.4 Position:

A change in position from roll to fixed, or vice versa, constitutes an essential variable.

3.3.2.5 Wall Thickness:

A change from one wall-thickness group to another constitutes an essential variable.

3.3.2.6 **Filler Metal:**

The following changes in filler metal constitute essential variables:

a. A change from one filler-metal group to another.
b. For pipe materials with a specified minimum yield strength greater than or equal to 65,000 psi (448 MPa), a change in the AWS classification of the filler metal.
c. Changes in filler metal within filler metal groups may be made within the material groups specified. The compatibility of the base material and the filler metal should be considered from the standpoint of mechanical properties.

3.3.2.7 Electrical Characteristics:

A change from DC electrode positive to DC electrode negative or vice versa or a change in current from DC to AC or vice versa constitutes an essential variable.

3.3.2.8 Time between Passes:

An increase in the maximum time between completion of the root bead and the start of the second bead constitutes an essential variable.

3.3.2.9 Direction of Welding:

A change in the direction of welding from vertical downhill to vertical uphill, or vice versa, constitutes an essential variable.

3.3.2.10 Shielding Gas and Flow Rate:

A change from one shielding gas to another or from one mixture of gases to another constitutes an essential variable. A major increase or decrease in the range of flow rates for the shielding gas also constitutes an essential variable.

3.3.2.11 Shielding Flux:

Refer to Table-3, Footnote a, for changes in shielding flux that constitute essential variables.

3.3.2.12 Speed of Travel:

A change in the range for speed of travel constitutes an essential variable.

3.3.2.13 Preheat:

A decrease in the specified minimum preheat temperature constitutes an essential variable.

Table-3: Filler Metal Groups

Group	AWS Specification	Electrode	Flux[c]
1	A5.1 A5.5	E6010, E6011 E7010, E7011	
2	A5.5	E8010, E8011 E9010	
3	A5.1 or A5.5 A5.5	E7015, E7016, E7018 E8015, E8016, E8018 E9018	
4[a]	A5.17	EL8 EL8K EL12 EM5K EM12K EM13K EM15K	P6XZ F6X0 F6X2 F7XZ F7X0 F7X2
5[b]	A5.18 A5.18 A5.28 A5.28	ER70S-2 ER70S-6 ER80S-D2 ER90S-G	
6	A5.2	RG60, RG65	
7	A5.20	E61T-GS[d] E71T-GS[d]	
8	A5.29	E71T8-K6	
9	A5.29	E91T8-G	

Note: Other electrodes, filler metals, and fluxes may be used but require separate procedure qualification.

A. Any combination of flux and electrode in Group 4 may be used to qualify a procedure. The combination shall be identified by its complete AWS classification number, such as F7A0-EL12 or F6A2- EM12K. Only substitutions that result in the same AWS classification number are permitted without requalification.

B. A shielding gas shall be used with the electrodes in Group 5.

C. In the flux designation, the X can be either an A or P for As Welded or Post-Weld Heat-Treated.

D. For root-pass welding only.

3.3.2.14 Post-Weld Heat Treatment (PWHT):

The addition of PWHT or a change from the ranges or values specified in the procedure shall each constitute an essential variable.

3.4 QUALIFICATION OF WELDERS:

3.4.1 General:

The purpose of the welder qualification test is to determine the ability of welders to make sound butt or fillet weld using previously qualified procedures. It is the intent of this standard that a welder, who satisfactorily completes the procedures test, is a qualified welder.

Before starting the qualification tests, the welder shall be allowed reasonable time to adjust the welding equipment to be used. The welder shall use the same welding technique and proceed with the same speed he will use if he passes the test and is permitted to do production welding.

The qualification of welders shall be conducted in the presence of a company representative.

The essential variables for welder qualification are specified in the following section.

3.4.2 Single Qualification:

3.4.2.1 General:

For single qualification, a welder shall make a test weld, using a qualified procedure to join pipe nipples or segments of pipe nipples. The welder shall make a butt weld in either the rolled or the fixed position.

When the welder is qualifying in the fixed position, the axis of the pipe shall be in the horizontal plane, in the vertical plane, or inclined from the horizontal plane at an angle of not more than 45 degree.

3.4.2.2 Scope:

A welder who has successfully completed the qualification test described earlier shall be qualified within the limits of the essential variables described below. If any of the following essential variables are changed, the welder using the new procedure shall be requalified:

(a) A change from one welding process to another welding process or combination of processes.

(b) A change in the direction of welding from vertical uphill to vertical downhill.

(c) A change of filler –metal classification from Group 1 or 2 to group 3, or from group 3 to group 1or 2.

(d) A change from one outside-diameter group to another.

These groups are defined as follows:

- Outside diameter less than 60.3mm.
- Outside diameter from 60.3mm through 323.8mm.
- Outside diameter greater than 323.8mm

(e) A change from one wall thickness group to another group are defined as follows:

- Nominal pipe wall thickness less than 3/16 inch (4.78mm).
- Nominal pipe wall thickness from 3/16 inch (4.78) through 3/4 inch (19.05mm).
- Nominal pipe wall thickness greater than 3/4 inch (19.05mm).

(f) A change in the joint design (for example, the use of a backing strip or a change from V bevel to U bevel).

3.4.3 Multiple Qualifications:

3.4.3.1 General:

For multiple qualifications, a welder shall successfully complete the two tests described below, using qualified procedures. For the first test, the welder shall make a butt weld in the fixed position with the axis of the pipe either in the horizontal plane or inclined from the horizontal plane at an angle of not more than 45degrees. This butt weld shall be made on pipe with an outside diameter of at least 6.625 in. (168.3 mm) and with a wall thickness of at least 0.250 in. (6.4 mm) without a backing strip.

For the second test, the welder shall lay out, cut, fit, and weld a full-sized branch-on-pipe connection. This test shall be performed with a pipe diameter of at least 6.625 in. (168.3 mm) and with a nominal wall thickness of at least 0.250 in. (6.4 mm). A full-size hole shall be cut in the run. The weld shall be made with the run-pipe axis in the horizontal position and the branch-pipe axis extending vertically downward from the run. The finished weld shall exhibit a neat, uniform workman- like appearance.

3.4.3.2 Scope:

A welder who has successfully completed the butt-weld qualification test described earlier on pipe with an outside diameter greater than or equal to 12.750 in. (323.9 mm) and a full-size branch-connection weld on pipe with an outside diameter greater than or equal to 12.750 in. (323.9 mm) shall be qualified to weld in all positions; on all wall thicknesses, joint designs, and fittings; and on all pipe diameters. A welder who has successfully completed the butt-weld and branch connection requirements on pipe with an outside diameter less than 12.750 in. (323.9 mm) shall be qualified to weld in all positions; on all wall thicknesses, joint designs, and fittings; and on all pipe outside diameters less than or equal to the diameter used by the welder in the qualification tests. If any of the following essential variables are changed in a procedure specification, the welder using the new procedure shall be requalified:

a. A change from one welding process to another welding process or combination of processes, as follows:
    I. A change from one welding process to a different welding process; or
    II. A change in the combination of welding processes, unless the welder has qualified on separate qualification tests, each using the same welding process that is used for the combination of welding processes.
b. A change in the direction of welding from vertical uphill to vertical downhill, or vice versa.
c. A change of filler-metal classification from Group 1 or 2 to Group 3 or from Group 3 to Group 1 or 2 (see Table 3).

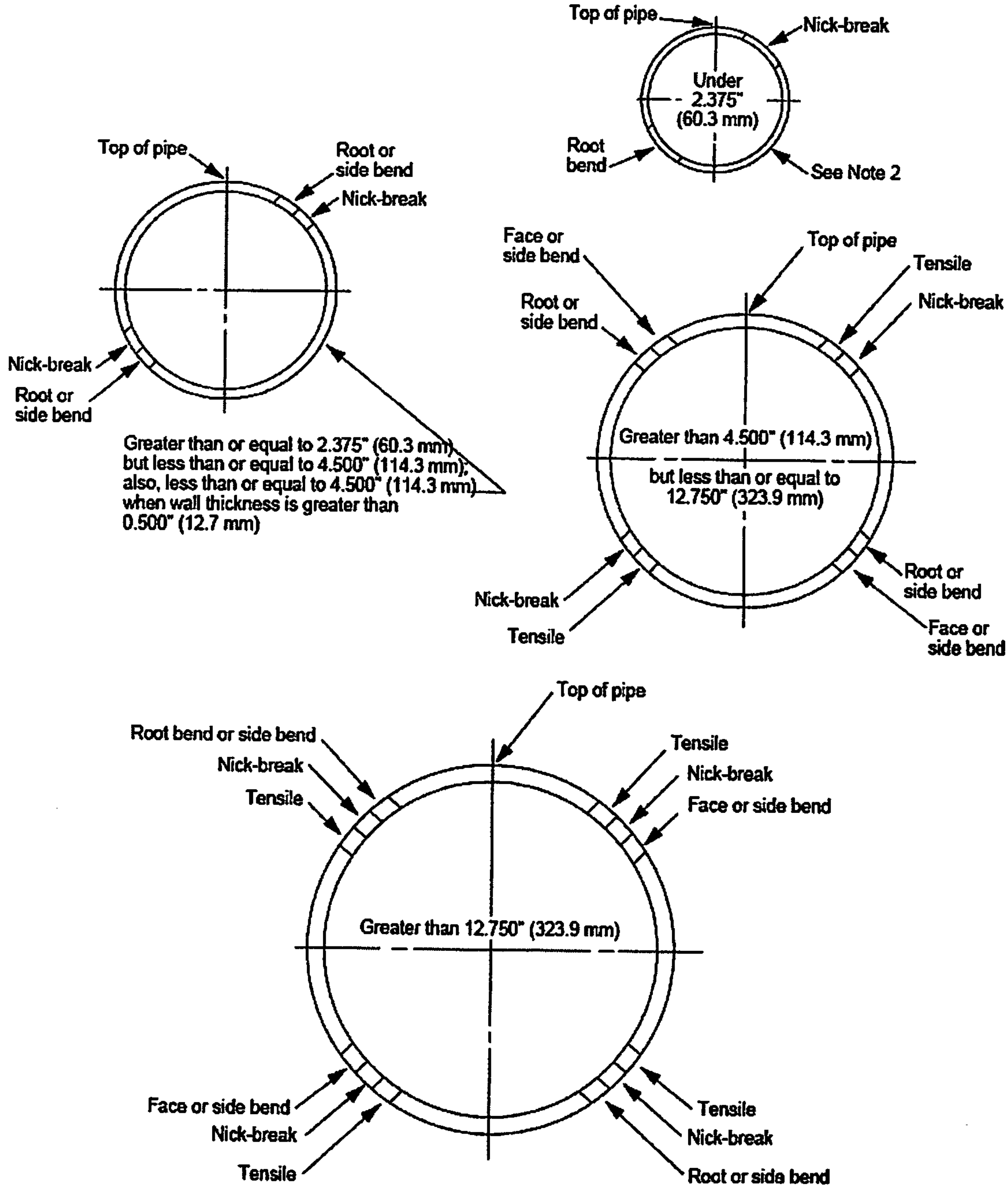


Fig.-17: Location of Test Butt-Weld Specimens for Welder Qualification Test

Note:

1. At the company's option, the locations may be rotated, provided they are equally spaced around the pipe; however, specimens shall not include the longitudinal weld.
2. One full-section tensile specimen may be used for pipe with an outside diameter less than or equal to 1.315 in. (33.4 mm).

3.5 DESIGN AND PREPARATION OF A JOINT FOR PRODUCTION WELDING:

3.5.1 General:

Qualified welders using qualified procedures shall weld piping. The surfaces to be welded shall be smooth, uniform and free from laminations, tears, scale, slag, grease, and paint and other deleterious material that might adversely affect the welding. The joint design and spacing b/w abutting ends shall be in accordance with the procedure specification used.

3.5.2 Alignment:

The alignment of the abutting end shall minimize the offset b/w surfaces for pipe ends of the same nominal wall thickness, the offset shall not exceed 1/16 inch (1.5mm). If a larger offset is caused by dimensional variations, it shall be equally distributed around the circumference of the pipe. Hammering of the pipe to obtain proper lineup should be kept at minimum.

3.5.3 Use of Lineup clamp for Butt welds:

Lineup clamps shall be used for butt welds in accordance with the procedure specification. When an internal lineup clamp is used and conditions make it difficult to prevent movement of the pipe or if the weld will be unduly stressed, the root bead shall be completed before clamp tension is released.

Root bead segments used in connection with external clamps shall be uniformly spaced around the circumferences of the pipe and shall have an aggregate length of at least 50 % of the pipe circumferences before the clamp is removed.

3.5.4 Bevel:

3.5.4.1 Mill Bevel: All mill bevels on pipe ends shall conform to the joint design used in the procedure specification.

3.5.4.2 Field Bevel: The beveled ends shall be reasonably smooth and uniform and dimension shall be in accordance with the procedure specification.

3.5.5 Weather Conditions:

Welding shall not be done when the quality of the completed weld would be impaired by the prevailing weather condition are suitable for welding.

3.5.6 Clearance:

When the pipe is welded above ground, the working clearance around the pipe at the welds should not be less than 16 inch (406mm). When the pipe is welded in a trench; the bell hole shall be large enough to provide the welder or welders with ready to access to the joint.

3.5.7 Cleaning between Beads:

Scale and slag shall be removed from each bead and groove. Power tools shall be used when called for in the procedure specification; otherwise, cleaning may be with either hand or power tools.

3.5.8 Position Welding:

3.5.8.1 Procedure:

All position welds shall be made with the parts to be joined secured against movement and with adequate clearance around the joint to allow the welder or welder's space in which to work.

3.5.8.2 Filler and Finish Beads:

At no point shall the crown surface of the pipe, nor should be raised above the parent metal by more than 1/16 inch (1.59mm).

Two beads shall not be started at the same location .The face of the completed weld should be approximately 1/8 inch wider than the width of the original groove. The completed weld shall be thoroughly brushed and cleaned.

3.5.9 Roll Welding:

3.5.9.1 Alignment:

At the company's option, roll welding shall be permitted, provided alignment is maintained by the use of skids or a structural frame work with an adequate number of roller dollies to prevent sag in the support length of pipe.

3.5.9.2 Filler and Finish Beads

For roll welding, the number of filler and finish beads shall be such that the completed weld has a substantially uniform cross section around the entire circumference of the pipe. At no point shall the crown surface fall below the outside surface of the pipe, nor should it be raised above the parent metal by more than 1/16 in. (1.6 mm).

The face of the completed weld should be approximately 1/8 inch wider than the width of the original groove. As the welding progresses, the pipe shall be rolled to maintain welding at or near the top of the pipe. The completed weld shall be thoroughly brushed and cleaned.

Table-4: Type and Number of Butt-Weld Test Specimens per Welder for Welder Qualification Test and Destructive Testing of Production Welds

Outside Diameter of Pipe		Number of Specimens					
Inches	Millimetres	Tensile Strength	Nick-Break	Root Bend	Face Bend	Side Bend	Total
		Wall Thickness ≤ 0.500 in. (12.7 mm)					
< 2.375	< 60.3	0	2	2	0	0	4[a]
2.375–4.500	60.3–323.9	0	2	2	0	0	4
> 4.500–12.750	114.3–323.9	2	2	2	0	0	6
> 12.750	> 323.9	4	4	2	2	0	12
		Wall Thickness > 0.500 in. (12.7 mm)					
≤ 4.500	≤ 114.3	0	2	0	0	2	4
> 4.500–12.750	> 114.3–323.9	2	2	0	0	2	6
> 12.750	> 323.9	4	4	0	0	4	12

[a] For pipe less than or equal to 1.315 in. (33.4 mm) in outside diameter, specimens from two welds or one full-section tensile-strength specimen shall be taken.

3.6 DESTRUCTIVE TESTING:

In destructive testing, sample portions of the welded structures are required. These samples are subjected to loads until they actually fail. The failed pieces are then studied and compared to known standards to determine the quality of the weld. The most common types of destructive testing are known as free bend, guided bend, nick-break, and impact; fillet welded joint, etching, and tensile testing. The primary disadvantage of destructive testing is that an actual section of a weldment must be destroyed to evaluate the weld. **This type of testing is usually used in the certification process of the welder.**

Some of the testing requires elaborate equipment that is not available for use in the field. Three tests that may be performed in the field without elaborate equipment are the free-bend test, the guided-bend test, and the nick-break test.

3.6.1 Face-Bend Test:

The FACE-BEND TEST is designed to measure the ductility of the weld deposit and the heat-affected area adjacent to the weld. Also it is used to determine the percentage of elongation of the weld metal. Ductility, you should recall, is that property of a metal that allows it to be drawn out or hammered thin.

The first step in preparing a welded specimen for the free-bend test is to machine the welded reinforcement crown flush with the surface of the test plate. When the weld area of a test plate is machined, as is the case of the guided-bend as well as in the free-bend test, perform the machining operation in the opposite direction that the weld was deposited.

The next step in the free-bend test is to scribe two lines on the face of the filler deposit. Locate these lines 1/16 inch from each edge of the weld metal, as shown in fig.-18, view B. Measure the distance, in inches, between the lines to the nearest 0.01 inch and let the resulting measurement equal (x). Then bend the ends of the test specimen until each leg forms an angle of 30 degrees to the original centerline.

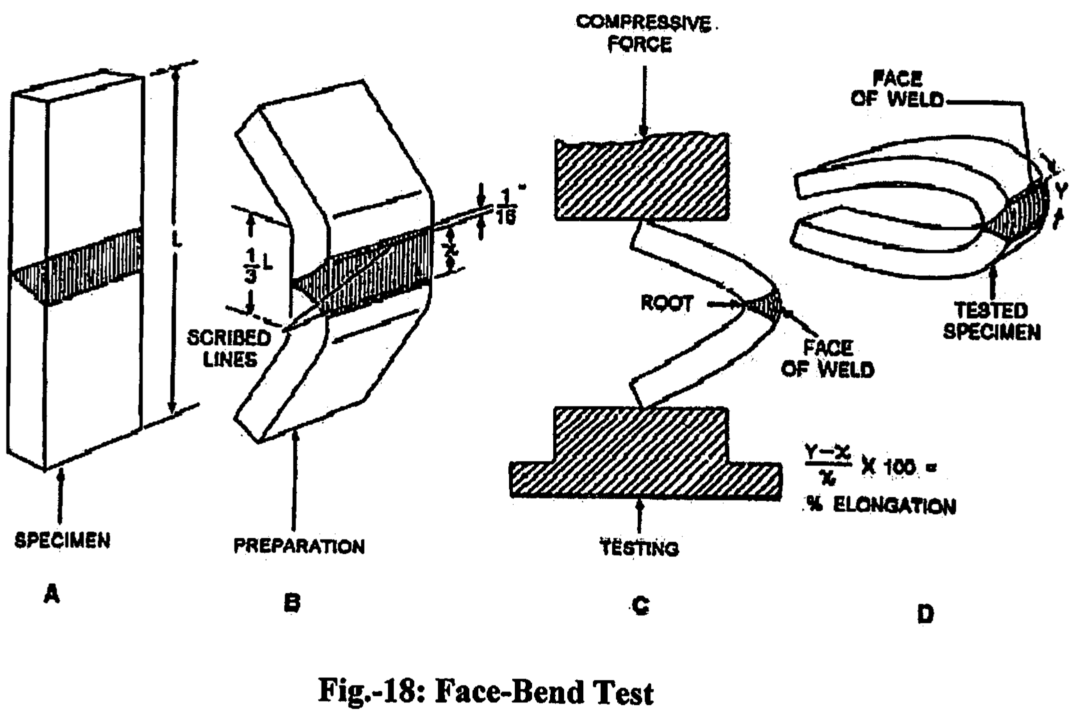


Fig.-18: Face-Bend Test

With the scribed lines on the outside and the piece placed so all the bending occurs in the weld, bend the test piece by using a hydraulic press or similar machine. When the proper precautions are taken, a blacksmith's forging press or hammer can be used to complete the bending operation. If a crack more than 1/16 inch develops during the test, stop the bending because the weld has failed; otherwise, bend the specimen flat. After completing the test, measure the distance between the scribed lines and call that measurement (y). The percent- age of elongation is then determined by the formula:

$$\frac{Y-X}{X} \times 100 = \%\ elongation$$

Requirements for a satisfactory test are: area minimum elongation of 15 percent and no cracks greater than 1/16 inch on the face of the weld.

3.6.2 Guided-Bend Test:

Use the GUIDED-BEND TEST to determine the quality of weld metal at the face and root of a welded joint. This test is made in a specially designed jig. An example of one type of jig is shown in fig. The test specimen is placed across the supports of the die. A plunger, operated from above by hydraulic pressure, forces the specimen into the die. To fulfill the requirements of this test, you must bend the specimen 180 degrees—the capacity of the jig. No cracks should appear on the surface greater than 1/8 inch. The face- bend tests are made in this jig with the face of the weld in tension (outside), as shown in fig.-19. The root- bend tests are made with the root of the weld in tension (outside), as shown in fig.

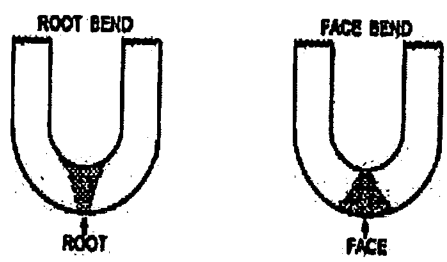


Fig.-19: Guided-Bend Test Specimens

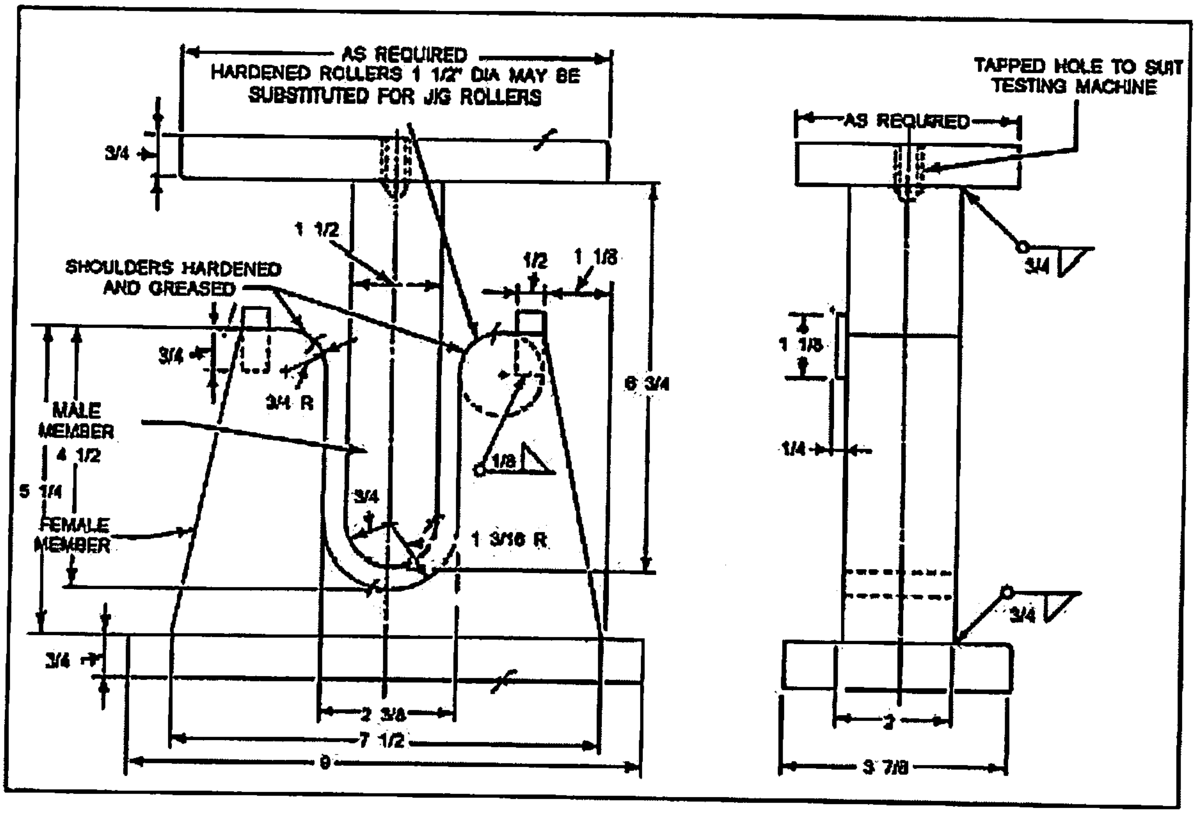


Fig.-20: Guided-Bend Test Jig

3.6.3 Nick-Break Test:

The NICK-BREAK TEST is useful for determining the internal quality of the weld metal. This test reveals various internal defects (if present), such as slag inclusions, gas pockets, lack of fusion, and oxidized or burned metal. To accomplish the nick-break test for checking a butt weld, you must first flame-cut the test specimens from a sample weld (fig.- 21). Make a saw cut at each edge through the center of the weld. The depth of cut should be about 1/4 inch.

Next, place the saw-nicked specimen on two steel supports, as shown in fig. Using a heave hammer, break the specimen by striking it in the zone where you made the saw cuts. The weld metal exposed in the break should be completely fused, free from slag inclusions, and contain no gas pockets greater than 1/16 inch across their greatest dimension. There should not be more than six pores or gas pockets per square inch of exposed broken surface of the weld.

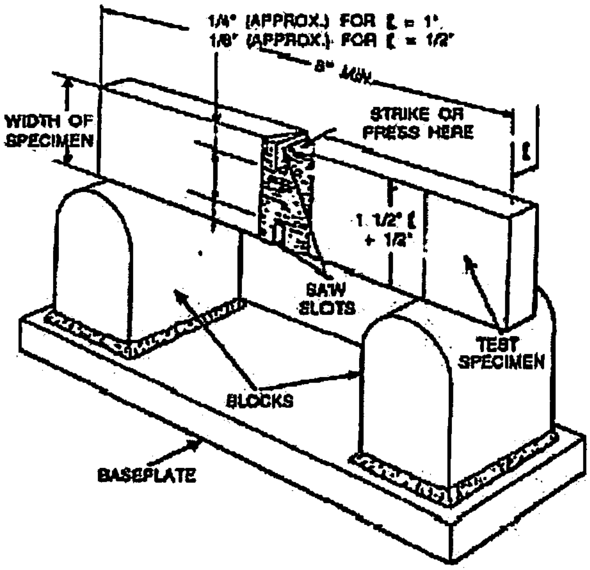


Fig.-21: Nick-Break Test of a Butt Weld

3.6.4 Impact Test:

Use the IMPACT TEST to check the ability of a weld to absorb energy under impact without fracturing. This is a dynamic test in which a test specimen is broken by a single blow, and the energy used in breaking the piece is measured in foot-pounds. This test compares the toughness of the weld metal with the base metal. It is useful in finding if the welding process destroyed any of the mechanical properties of the base metal. The two kinds of specimens used for impact testing are known as Charpy and Izod (fig.-22). Both test pieces are broken in an impact-testing machine. The only difference is in the manner that they are anchored. The Charpy piece is supported horizontally between two anvils and the pendulum strikes opposite the notch, as shown in (fig.-22, view A). The Izod piece is supported as a vertical cantilever beam and is struck on the free end projecting over the holding vise (fig.-22, view B).

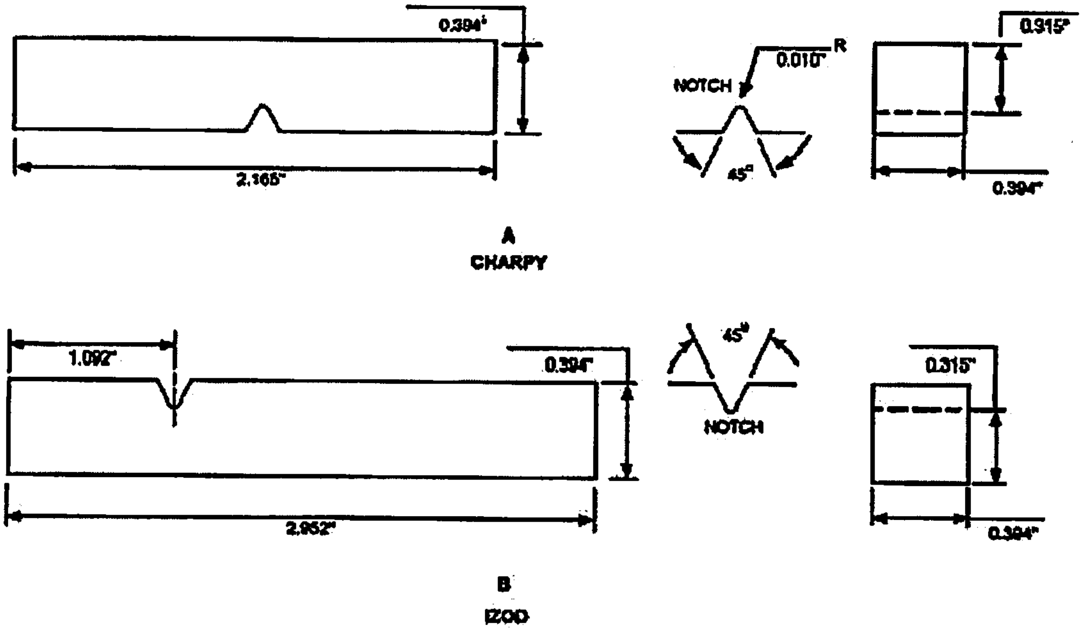
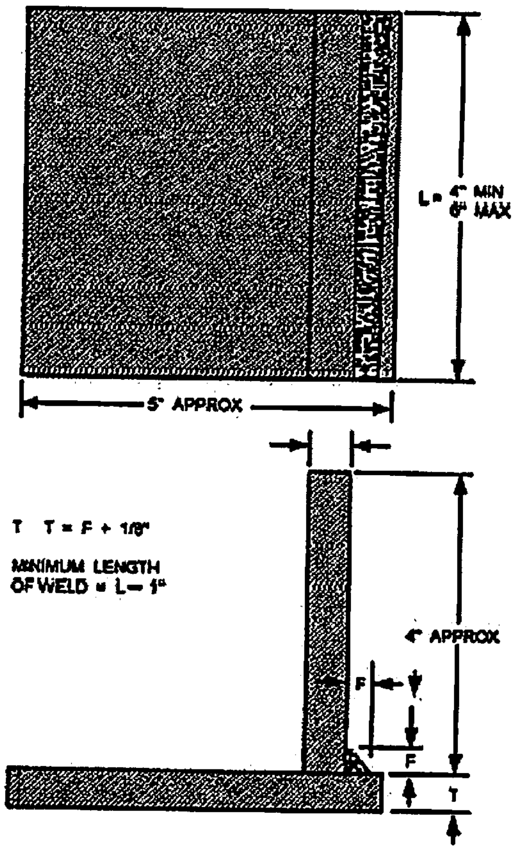


Fig.-22: Test Pieces for Impact Testing

3.6.5 Fillet-Welded Joint Test:

Use the FILLET-WELDED JOINT TEST to check the soundness of a fillet weld. Soundness refers to the degree of freedom a weld has from defects found by visual inspection of any exposed welding surface. These defects include penetrations, gas pockets, and inclusions. Prepare the test specimen, as shown in fig.-23. Now apply force at Point A (fig.-24) until a break occurs in the joint. This force may be applied by hydraulics or hammer blows. In addition to checking the fractured weld for soundness, now is a good time to etch the weld to check for cracks.



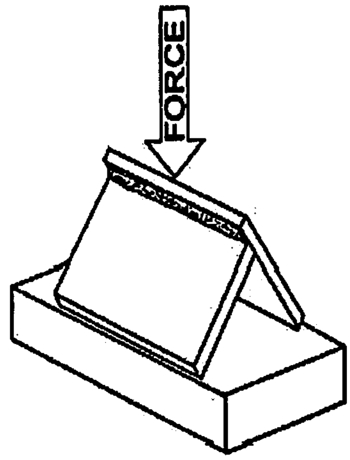


Fig.-24:Rupturing Fillet Weld Test Plate

Fig.-23: Test Plate for Fillet Weld Test

3.6.6 Etching Test:

The ETCHING TEST is used to determine the soundness of a weld and also make visible the boundary between the base metal and the weld metal.

To accomplish the test, you must cut a test piece from the welded joint so it shows a complete transverse section of the weld. You can make the cut by either sawing or flame cutting. File the face of the cut and then polish it with grade 00 abrasive cloth. Now place the test piece in the etching solution.

The etching solutions generally used are hydrochloric acid, ammonium persulfate, iodine and potassium iodide, or nitric acid. Each solution highlights different defects and areas of the weld. The hydrochloric acid dissolves slag inclusions and enlarges gas pockets, while nitric acid is used to show the refined zone as well as the metal zone.

3.6.7 Tensile Strength Test:

The term TENSILE STRENGTH may be defined as the resistance to longitudinal stress or pull and is measured in pounds per square inch (Psi) of cross section. Testing for tensile strength involves placing a weld sample in a tensile testing machine and pulling on the test sample until it breaks.

The essential features of a tensile testing machine are the parts that pull the test specimen and the devices that measure the resistance of the test specimen. Another instrument, known as an extensometer or strain gauge, is also used to measure the strain in the test piece. Some equipment comes with a device that records and plots the stress-strain curve for a permanent record.

The tensile test is classified as a destructive test because the test specimen must be loaded or stressed until it fails. Because of the design of the test machine, weld samples must be machined to specific dimensions. This explains why the test is made on a standard specimen, rather than on the part itself. It is important that the test specimen represents the part. Not only must the specimen be given the same heat treatment as the part but it also must be heat-treated at the same time.

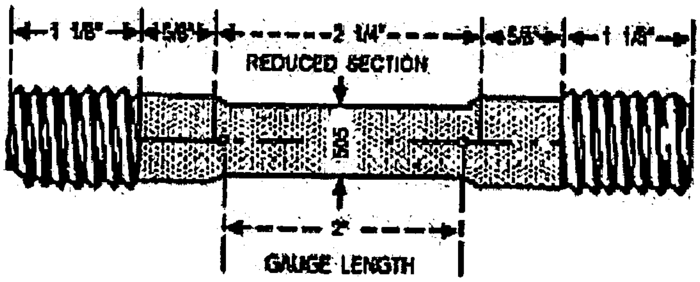


Fig.-25: Standard Tensile Test Specimen

There are many standard types of tensile test specimens, and fig.40 shows one standard type of specimen commonly used. The standard test piece is an accurately machined specimen. Overall length is not a critical item, but the diameter and gauge lengths are. The 0.505-inch-diameter (0.2 square inch area) cross section of the reduced portion provides an easy factor to manipulate arithmetically. The 2-inch gauge length is the distance between strain-measuring points. This is the portion of the specimen where you attach the extensometer. In addition, you can use the gauge length to determine percent elongation.

The tensile test amount to applying a smooth, steadily increasing load (or pull) on a test specimen and measuring the resistance of the specimen until it breaks. Even if recording equipment is not available, the test is not difficult to perform. During the test, you observe the behavior of the specimen and record the extensometer and gauge readings at regular intervals. After the specimen breaks and the fracturing load are recorded, you measure the specimen with calipers to determine the percent of elongation and the percent reduction in area. In addition, you should plot a stress-strain curve. From the data obtained, you can determine tensile strength; yield point, elastic limit, modulus of elasticity, and other properties of the material.

3.7 NONDESTRUCTIVE TESTING:

Non-destructive testing is a method of testing that does not destroy or impair the usefulness of a welded item. These tests disclose all of the common internal and surface defects that can occur when improper welding procedures are used. A large choice of testing devices is available and most of them are easier to use than the destructive methods, especially when working on large and expensive items.

3.7.1 Visual Inspection:

The welder usually does visual inspection automatically as he completes his welds. This is strictly a subjective type of inspection and usually there are no definite or rigid limits of acceptability. The welder may use templates for weld bead contour checks. Visual inspections are basically a comparison of finished welds with an accepted standard. This test is effective only when the visual qualities of a weld are the most important.

3.7.2 Magnetic Particle Inspection:

Magnetic particle inspection is most effective for the detection of surface or near surface flaws in welds. It is used in metals or alloys in which you can induce magnetism. While the test piece is magnetized, a liquid containing finely ground iron powder is applied. As long as the magnetic field is not disturbed, the iron particles will form a regular pattern on the surface of the test piece. When the magnetic field is interrupted by a crack or some other defect in the metal, the pattern of the suspended ground metal also is interrupted. The particles of metal cluster around the defect make it easy to locate.

You can magnetize the test piece by either having an electric current pass through it, or by having an electric current pass through a coil of wire that surrounds the test piece. When an electric current flows in a straight line from one contact point to the other, magnetic lines of force are in a circular direction. When the current flow is through a coil around the test piece, the magnetic lines of force are longitudinal through the test piece.

When a defect is to show up as a disturbance in the pattern of the iron particles, the direction of the magnetic field must be at right angles to the major axis of the defect. A magnetic field having the necessary direction is established when the current flow is parallel to the major axis of the defect. Since the orientation of the defect is unknown, different current directions must be used during the test.

When you use magnetic particle inspection, hairline cracks that are otherwise invisible are readily indicated by an unmistakable outline of the defect. Large voids beneath the surface are easier to detect than small voids, but any defect below the surface is more difficult to detect than one that extends through to the surface. Since false indications frequently occur, you must be able to interpret the particle indications accurately.

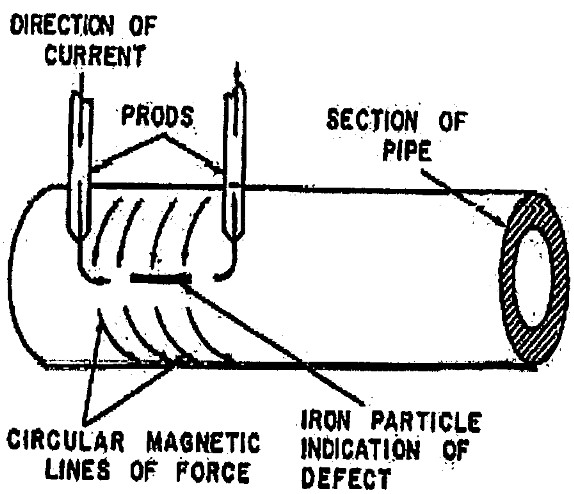


Fig.-26: Circular Magnetization (PROD Method)

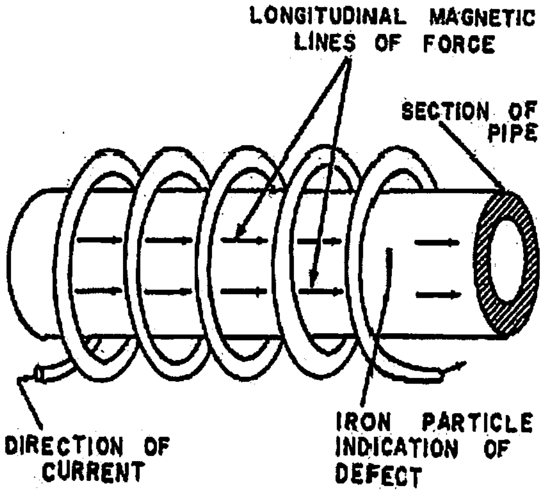


Fig.-27: Longitudinal Magnetization (COIL Method)

The factors that help you interpret the test results include the amount of magnetizing current applied, the shape of the indication, and the sharpness of the outline, the width of the pattern, and the height or build-up of the particles. Although these characteristics do not determine the seriousness of the fault, they do serve to identify the kind of defect. The indication of a crack is a sharp, well-defined pattern of magnetic particles having a definite build up. A relatively low-magnetizing current produces this indication. Seams are revealed by a straight, sharp, fine indication. The build-up of particles is relatively weak, and the magnetizing current must be higher than that required to detect cracks. Small porosity and rounded indentations or similar defects are difficult to detect for inexperienced inspectors. A high-magnetizing current continuously applied is usually required. The particle patterns for these defects are fuzzy in outline and have a medium build-up.

The specifications governing the job determine whether or not an indicated defect is to be chipped or ground out and repaired by welding. Surface cracks are always removed and repaired. The inspector evaluates indications of subsurface defects detected by magnetic particle inspection. When the indication is positive, the standard policy is to grind or chip down to solid metal and make the repair. Unless the inspector can differentiate accurately between true and false indications, the use of magnetic particle inspection should be restricted to the detection of surface defects, for which this application is almost foolproof. After the indicated defects have been repaired, you should reinspect the areas to ensure that the repair is sound. The final step in magnetic particle inspection is to demagnetize the work piece. This is especially important when the work piece is made of high-carbon steel. Demagnetization is essential when you use direct current to induce the magnetic field; however, it is not as necessary when alternating current was used in the test. In fact, the usual demagnetization procedure involves placing the work piece in an ac coil or solenoid and slowly withdrawing it while current passes through the coil.

3.7.3 Liquid Penetrant Inspection:

Liquid penetrant methods are used to inspect metals for surface defects that are similar to those revealed by magnetic particle inspection. Unlike magnetic particle inspection, which can reveal subsurface defects, liquid penetrant inspection reveals only those defects that are open to the surface.

Four groups of liquid penetrants are presently in use. Group I is a dye penetrant that is no water washable. Group II is a water washable dye penetrant. Group III and Group IV are fluorescent penetrants. Carefully follow the instructions given for each type of penetrant since there are some differences in the procedures and safety precautions required for the various penetrants.

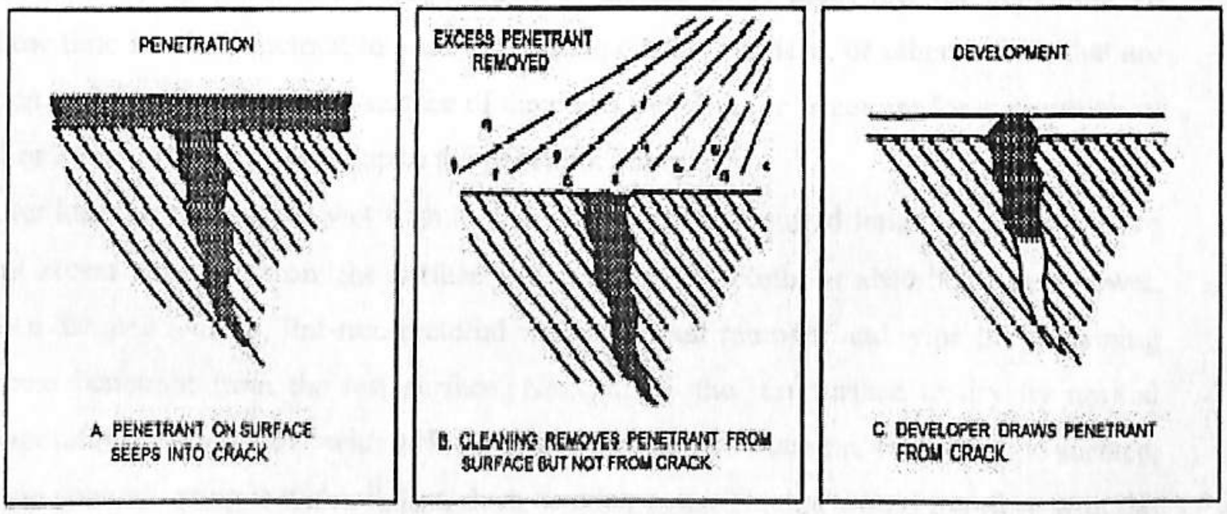


Fig.-28: Liquid Penetrant Inspection

Before using a liquid penetrant to inspect a weld, remove all slag, rust, paint, and moisture from the surface. Except where a specific finish is required, it is not necessary to grind the weld surface as long as the weld surface meets applicable specifications. Ensure the weld contour blends into the base metal without undercutting. When a specific finish is required, perform the liquid penetrant inspection before the finish is made. This enables you to detect defects that extend beyond the final dimensions, but you must make a final liquid penetrant inspection after the specified finish has been given.

Before using a liquid penetrant, clean the surface of the material very carefully, including the areas next to the inspection area. You can clean the surface by swabbing it with a clean, lint-free cloth saturated in a non- volatile solvent or by dipping the entire piece into a solvent. After the surface has been cleaned, remove all traces of the cleaning material. It is extremely important to remove all dirt, grease, scale, lint, salts, or other materials and to make sure that the surface is entirely dry before using the liquid penetrant.

Maintain the temperature of the inspection piece and the liquid penetrant in the range of 50°F to 100°F. Do not attempt to use the liquid penetrant when this temperature range cannot be maintained. Do not use an open flame to increase the temperature because some of the liquid penetrant materials are flammable.

After thoroughly cleaning and drying the surface, coat the surface with the liquid penetrant. Spray or brush on the penetrant or dip the entire piece into the penetrant. To allow time for the penetrant to soak into all the cracks, crevices, or other defects that are open to the surface, keep the surface of the piece wet with the penetrant for a minimum of 15 or 30 minutes, depending upon the penetrant being used.

After keeping the surface wet with the penetrant for the required length of time, remove any excess penetrant from the surface with a clean, dry cloth, or absorbent paper towel. Then dampen a clean, lint-free material with penetrant remover and wipe the remaining excess penetrant from the test surface. Next, allow the test surface to dry by normal evaporation or wipe it dry with a clean, lint-free absorbent material. In drying the surface, avoid contaminating it with oil, lint, dust, or other materials that would interfere with the inspection.

After the surface has dried, apply another substance, called a developer. Allow the developer (powder or liquid) to stay on the surface for a minimum of 7 minutes before starting the inspection. Leave it on no longer than 30 minutes, thus allowing a total of 23 minutes to evaluate the results.

The following actions take place when using dye penetrants. First, the penetrant that is applied to the surface of the material will seep into any passageway open to the surface, as shown in fig, view A. The penetrant is normally red in color, and like penetrating oil, it seeps into any crack or crevice that is open to the surface. Next, the excess penetrant is removed from the surface of the metal with the penetrant remover and a lint-free absorbent material. Only the penetrant on top of the metal surface is removed (fig., view B), leaving the penetrant that has seeped into the defect.

Finally, the white developer is applied to the surface of the metal, as shown in fig, view C. The developer is an absorbing material that actually draws the penetrant from the defect. Therefore, the red penetrant indications in the white developer represent the defective areas. The amount of red penetrant drawn from the defective areas indicates the size and sometimes the type of defect. When you use dye penetrants, the lighting in the test area must be bright enough to enable you to see any indications of defects on the test surface.

The indications you see during a liquid penetrant inspection must be carefully interpreted and evaluated. In almost every inspection, some insignificant indications are present. Most of these are the result of the failure to remove all the excess penetrant from the surface. At least 10 percent of all indications must be removed from the surface to determine whether defects are actually present or whether the indications are the result of excess penetrant. When a second inspection does not reveal indications in the same locations, it is usually safe to assume that the first indications were false.

Remove all penetrant inspection materials as soon as possible after the final inspection has been made. Use water or solvents, as appropriate. Since some of the liquid penetrant materials are flammable, do not use them near open flames, and do not apply them to any surface that is at a temperature higher than 100°F. In addition to being flammable, many solvents are poisonous in the vapor form and highly imitating to the skin in the liquid form.

3.7.4 Radiographic Inspection:

Radiographic inspection is a method of inspecting weldment by the use of rays that penetrate through the welds. X rays or gamma rays are the two types of waves used for this process. The rays pass through the weld and onto a sensitized film that is in direct contact with the back of the weld. When the film is developed, gas pockets, slag inclusions, cracks, or poor penetration will be visible on the film. Because of the danger of these rays, only qualified personnel are authorized to perform these tests.

In addition to producing high quality radiographs, the radiographer must also be skilled in radiographic interpretation. Interpretation of radiographs takes place in three basic steps:

(1) Detection,

(2) Interpretation, and

(3) Evaluation.

All of these steps make use of the radiographer's visual acuity. Visual acuity is the ability to resolve a spatial pattern in an image. The ability of an individual to detect discontinuities in radiography is also affected by the lighting condition in the place of viewing, and the experience level for recognizing various features in the image.

3.7.4.1 Welding Discontinuities:

The following discontinuities are typical of all types of welding.

3.7.4.1.1 Cold lap is a condition where the weld filler metal does not properly fuse with the base metal or the previous weld pass material (interpass cold lap). The arc does not melt the base metal sufficiently and causes the slightly molten puddle to flow into the base material without bonding.

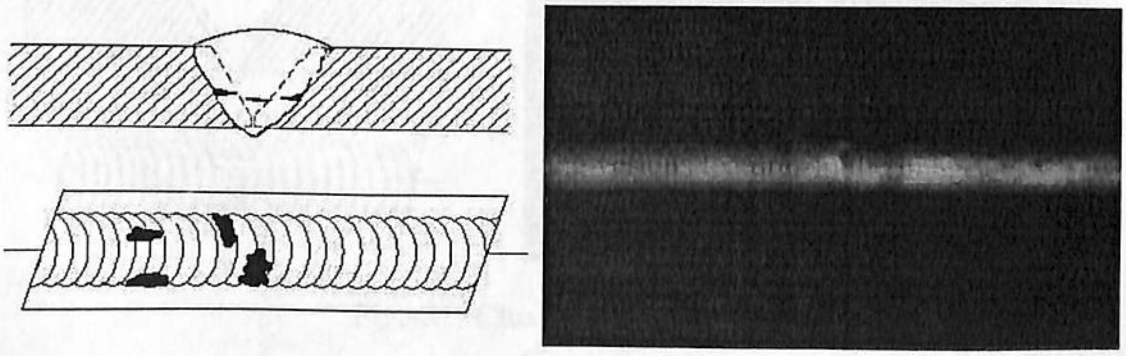
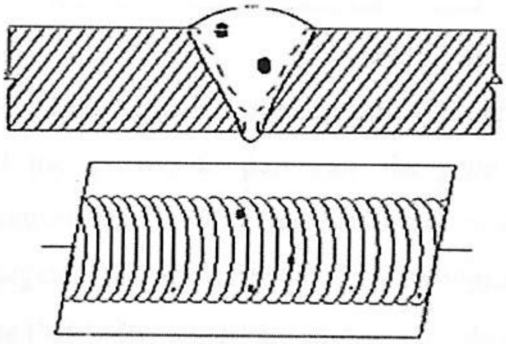


Fig.-29: Cold Lap

3.7.4.1.2 Porosity is the result of gas entrapment in the solidifying metal. Porosity can take many shapes on a radiograph but often appears as dark round or irregular spots or specks appearing singularly, in clusters, or in rows. Sometimes, porosity is elongated and may appear to have a tail. This is the result of gas attempting to escape while the metal is still in a liquid state and is called wormhole porosity. All porosity is a void in the material and it will have a higher radiographic density than the surrounding area.



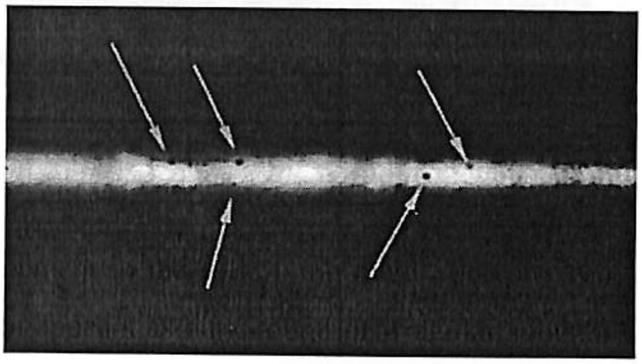
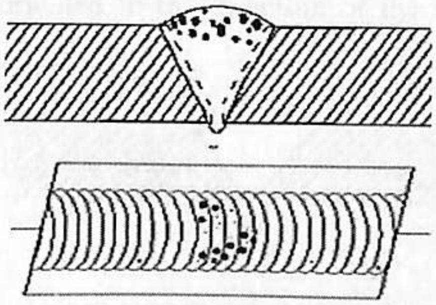


Fig.-30: Porosity

3.7.4.1.3 Cluster porosity is caused when flux coated electrodes are contaminated with moisture. The moisture turns into a gas when heated and becomes trapped in the weld during the welding process. Cluster porosity appears just like regular porosity in the radiograph but the indications will be grouped close together.

3.7.4.1.4 Slag inclusions are nonmetallic solid material entrapped in weld metal or between weld and base metal. In a radiograph, dark, jagged asymmetrical shapes within the weld or along the weld joint areas are indicative of slag inclusions.



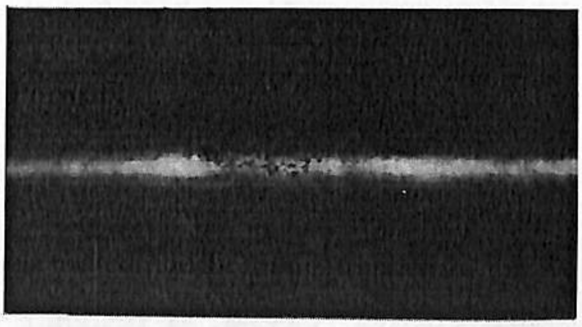


Fig.–31: Cluster Porosity

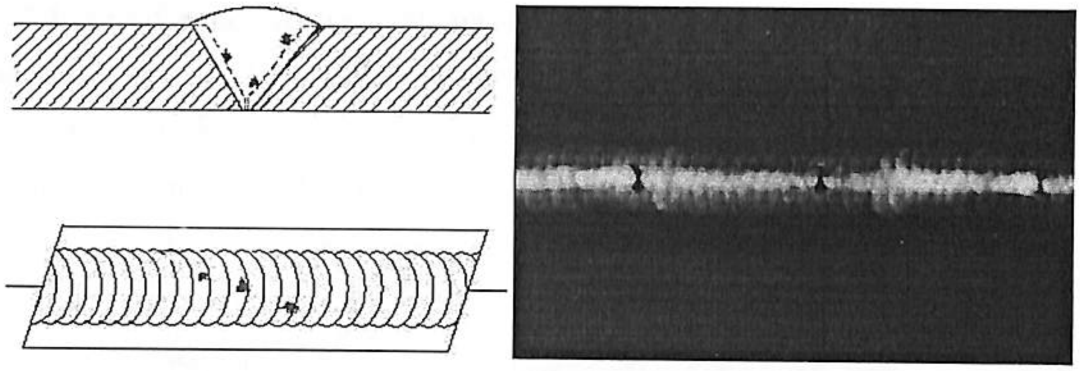


Fig.–32: Slag Inclusions

3.7.4.1.5 Incomplete penetration (IP) or lack of penetration (LOP) occurs when the weld metal fails to penetrate the joint. It is one of the most objectionable weld discontinuities. Lack of penetration allows a natural stress riser from which a crack may propagate. The appearance on a radiograph is a dark area with well-defined, straight edges that follows the land or root face down the center of the weldment.

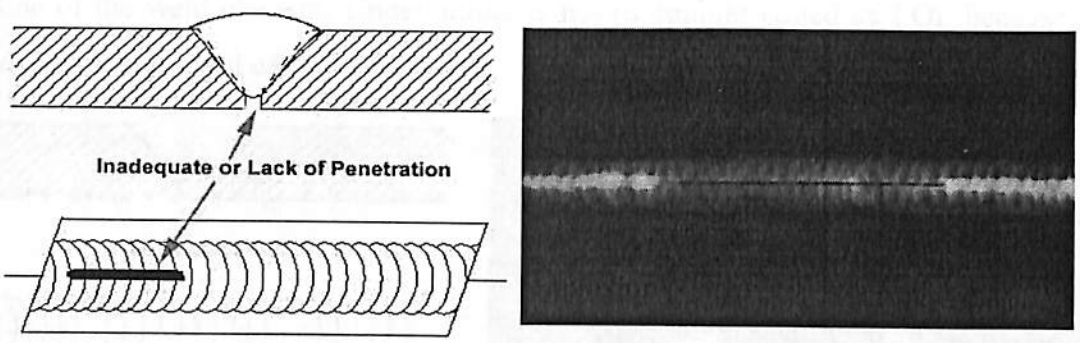


Fig.–33: Incomplete Penetration

3.7.4.1.6 Incomplete fusion is a condition where the weld filler metal does not properly fuse with the base metal. Appearance on radiograph: usually appears as a dark line or lines oriented in the direction of the weld seam along the weld preparation or joining area.

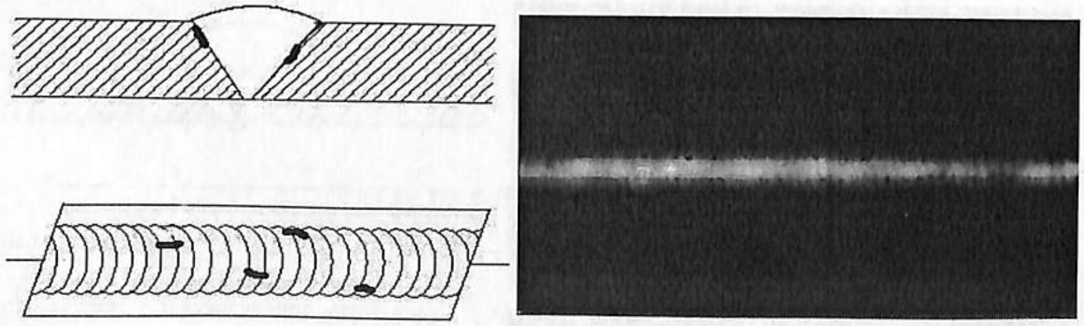


Fig.–34: Incomplete Fusion

3.7.4.1.7 Internal concavity or suck back is a condition where the weld metal has contracted as it cools and has been drawn up into the root of the weld. On a radiograph it looks similar to a lack of penetration but the line has irregular edges and it is often quite wide in the center of the weld image.

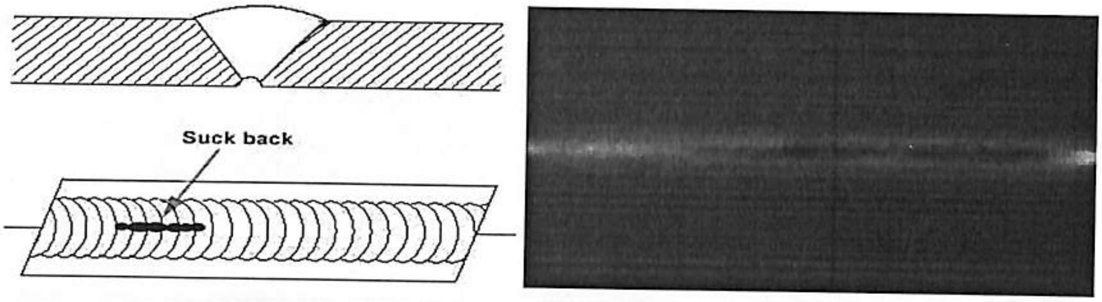


Fig.–35: Internal Concavity or Suck Back

3.7.4.1.8 Internal or root undercut is an erosion of the base metal next to the root of the weld. In the radiographic image it appears as a dark irregular line offset from the centerline of the weld element. Undercutting is not as straight edged as LOP because it does not follow a ground edge.

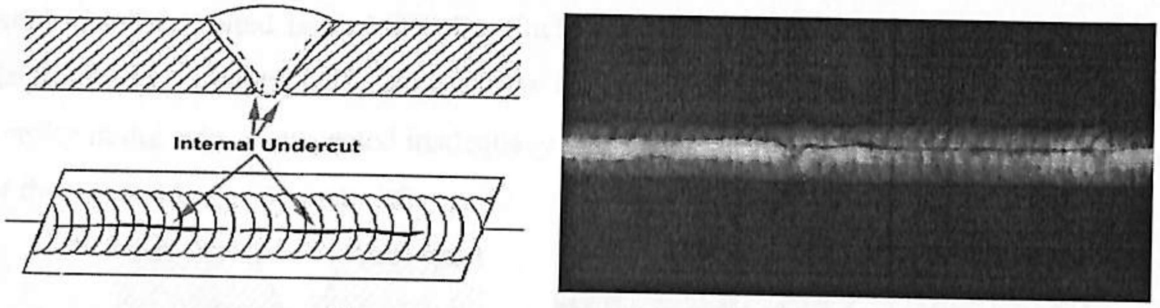


Fig.–36: Internal or Root Undercut

3.7.4.1.9 External or crown undercut is an erosion of the base metal next to the crown of the weld. In the radiograph, it appears as a dark irregular line along the outside edge of the weld area.

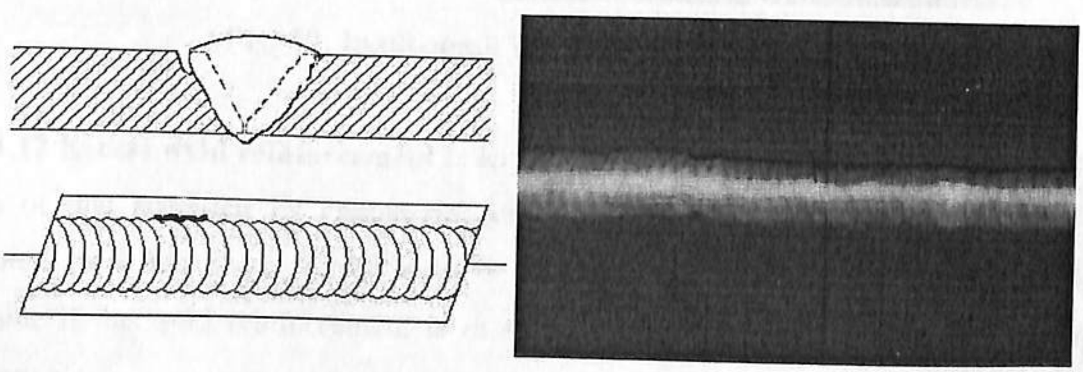


Fig.–37: External or Crown Undercut

3.7.4.1.10 Offset or mismatches are terms associated with a condition where two pieces being welded together are not properly aligned. The radiographic image shows a noticeable difference in density between the two pieces. The difference in density is caused by the difference in material thickness. The dark, straight line is caused by the failure of the weld metal to fuse with the land area.

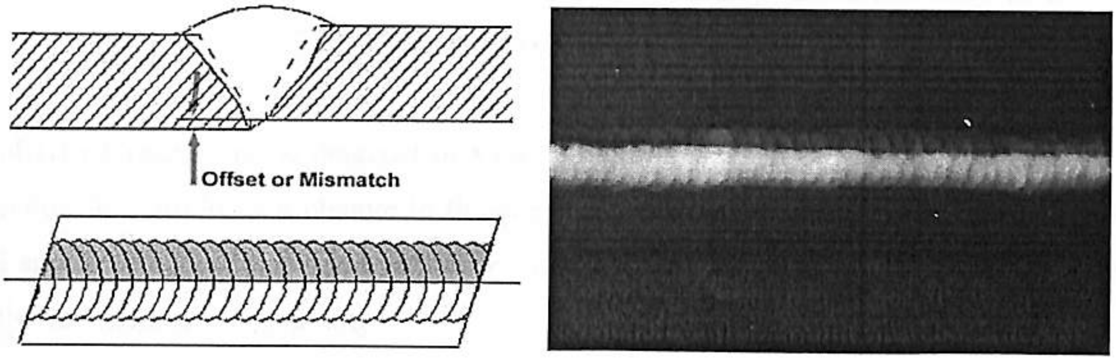


Fig.-38: Offset or Mismatch

3.7.4.1.11 Inadequate weld reinforcement is an area of a weld where the thickness of weld metal deposited is less than the thickness of the base material. It is very easy to determine by radiograph if the weld has inadequate reinforcement, because the image density in the area of suspected inadequacy will be higher (darker) than the image density of the surrounding base material.

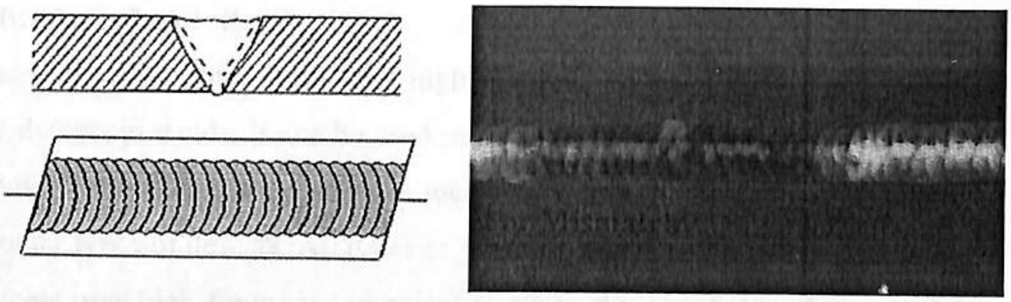


Fig.-39: Inadequate Weld Reinforcement

3.7.4.1.12 Excess weld reinforcement is an area of a weld that has weld metal added in excess of that specified by engineering drawings and codes. The appearance on a radiograph is a localized, lighter area in the weld. A visual inspection will easily determine if the weld reinforcement is in excess of that specified by the engineering requirements.

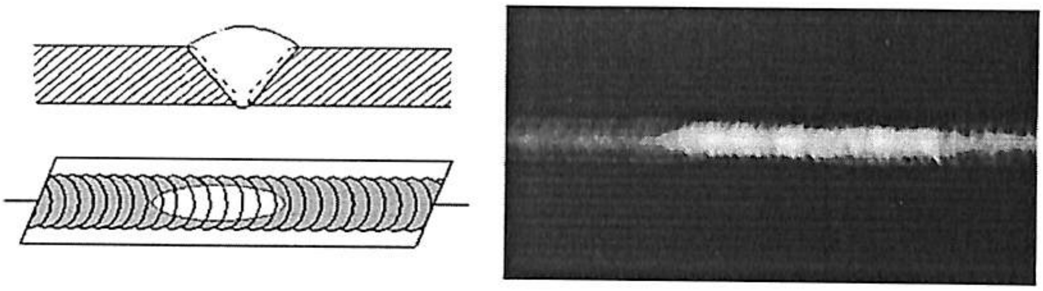


Fig.-40: Excess Weld Reinforcement

3.7.4.1.13 Cracks can be detected in a radiograph only when they are propagating in a direction that produces a change in thickness that is parallel to the x-ray beam. Cracks will appear as jagged and often very faint irregular lines. Cracks can sometimes appear as "tails" on inclusions or porosity.

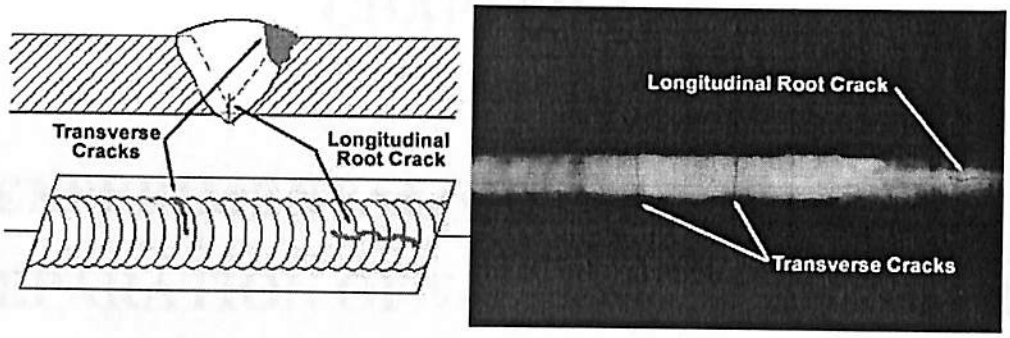


Fig.-41: Cracks

3.7.5 Ultrasonic Inspection:

Ultrasonic inspection of testing uses high-frequency vibrations or waves to locate and measure defects in welds. It can be used in both ferrous and nonferrous materials. This is an extremely sensitive system and can locate very fine surface and subsurface cracks as well as other types of defects. All types of joints can be tested.

This process uses high-frequency impulses to check the soundness of the weld. In a good weld, the signal travels through the weld to the other side and is then reflected back and shown on a calibrated screen. Irregularities, such as gas pockets or slag inclusions, cause the signal to reflect back sooner and will be displayed on the screen as a change in depth. When you use this system, most all types of materials can be checked for defects. Another advantage of this system is that only one side of the weld needs to be exposed for testing.

CHAPTER-4

EXPERIMENTAL/ COMPUTATIONAL

"PREPARATION OF WELDING PROCEDURE SPECIFICATON AND WELDER'S QUALIFICATION"

4.1 Procedure for Welder's Qualification:

- **Scope:**

This Scope Cover the Qualification of Welders for construction of 8" NB (219.1mmOD x 6.4mm Wthk.) pipeline for Khurja City Gas Distribution Project.

- **Applicable Codes & Specification:**
  - Client Specification (Z/02/0036)
  - API 1104
- **Method:**
  - Welders shall be qualified as per Client's Specification. The butt weld test piece of the qualification test shall meet the requirements of visual inspection and radiographic test requirements as per Client's Specification.
  - Approved qualified welders can only put welding Procedure Specification approved by TPIA into practice. Aneri Construction shall take all the necessary measures to implement the welder qualification tests. Every welder shall execute a test weld using a qualified procedure.
  - For welding of 8" NB pipeline, minimum two welders shall be engaged on both of the joint. Every welder shall execute for his qualification test a weld at least on half the circumference of the pipe starting from the top of the pipe until the bottom for 8" NB pipeline.
  - The welded test piece shall be subjected to 100 % radiography for the qualification of the respective welders as per Client's Specification
  - Aneri to submit the welder qualification test reports to TPIA for the approval.
  - A welder who has successfully completed the qualification test shall be qualified. A welder can only participate once to the qualification test. If welder didn't complete successfully the qualification test session, he will be disqualified for the present contract.
  - Aneri shall submit the list of the qualified welders intend to employ before starting of production welding to AEL/TPIA.

4.2 Procedure for Weld Joint Numbering:

- **Scope**

The scope covers numbering of Weld Joint after completion of welding joint for construction of 8" NB API 5L Gr.X42 (219.1 x 6.4mm Wthk.) pipelines for Khurja City Gas Distribution Project. Incase of any conflict between the requirement of this procedure and that of client's specification, the requirement of client's specification shall govern.

- **Applicable Codes & Specification**
  - Tractable Specification (Z/02 /036)
- **Method:**
  - Aneri in co ordination with TPIA shall give different numbers to the joint for each Kilometer Post along the working strip.
  - The code numbers of the installation of owner the welds between KP 0 and KP 1 shall number KM00-01 J01, KM00 -01 J02, KM 00-01 J03 etc. The welds between KP 1 and KP 2 shall number KM01-02 J01, KM01–02 J02, and KM01-02 J03 etc.
  - These numbers shall on the radiographic images preceded by the digit code number of pipeline.
  - For Tie in welding joints Aneri shall use 'T' letter as KM00 TJ30 etc.
  - Kilometer Post before respective joint shall be numbered for the above-mentioned numbers.
  - Aneri shall use an indelible product to indicate the weld number on the pipes next to each weld in a correct and legible manner.

4.3 Procedure for Main Line Welding:

- **Scope**

This Procedure is for welding of 8" NB API 5L Gr.X42 (219.1mm OD x 6.4mm Wthk.) pipeline for Construction of Steel Pipeline Network for KCGD Project. Incase of any conflict between the requirement of this procedure and that of client's specification, the requirement of client's specification shall govern.

- **Applicable Codes & Specification**
  - API 1104
  - ASME: B31.8
  - ASME Sec. II-C.
  - ASME Sec V– NDT
  - Client Specification (Z/02/0036)
- **Method**

1. **Plant & Equipment**

- Pay welders consisting of Lincoln/Advani Make Diesel arc welding machine.
- Mechanical Alignment Clamp-External.
- Grinding machine, Power brush, and depressed wheel.
- Heating Torch with Propane Cylinder

2. **Parameter**

- As per PQR & Qualified WPS

3. **Welding Consumable**

- E 6010 Electrode (2.5 mm) - Root Pass
- E 7010 G Electrode (3.2 mm) – Hot, Filler & Capping Pass.

4. **Welding Process**
   - SMAW (All Passes)
   - Number. of welders –One
5. **Beveling and Cleaning**
   - Bevel Cleaning
   - Weld bevel shall be inspected for damage / improper machining etc. & if any beyond 1.00 mm, they shall be rectified.
   - The defective Bevel or Pipe ends done by using beveling machine shall be examined by 100% DPT, 100% UT for pipe thickness 6.4 mm and Above & visually inspected to ensure free from Laminations
   - If these bevels are beyond repair in the opinion of AEL/TPIA, the damaged ends shall be cut & re–beveled to the satisfaction of AEL/TPIA.

- The new bevel end shall be subjected to 100 % visual and DP examination.
- Each weld bevel and adjacent 25mm internal/external area shall be free from any Mill scale/ Grease / Dust etc., which shall be achieved by degreasing where applicable, followed by power brushing.

6. Alignment Spacing & Fit Up

- The first pipe shall be positioned on skids (Size Min 6" each) at minimum height of 500 mm. From the ground and support skids shall be minimum two per pipe, the skid shall have sand/ soft soil/ saw dust bags placed over them to avoid damage to the pipe coating.
- Prior to the line up, pipes shall be checked with **cleaning/gauging pig** to ensure freedom internal dent or debris;
- Pipes shall be locked to prevent their rolling from the skid. The second pipe shall be held by a crane, and shall be aligned with the first pipe in the External clamp. The root gap shall be checked accurately and shall be in accordance with qualified WPS.
- Longitudinal seams (when applicable) of the pipes shall be staggered in the top segment of the pipe by **90° or 100 mm** whichever is less.
- For pipe of the same nominal wall thickness the circumferential offset shall not exceed **1.6 mm.**
- No hot dressing shall be permitted. When different wall thickness are involved, the thickness of thicker pipe shall be tapered to a minimum **1:4** by grinding or any other means approved at site. Alignment and fit-up shall be checked before welding.
- Before commencement of welding works Aneri shall submit Electrode Batch Certificates to the AEL/TPIA for all electrodes prior to deployment on the project.

7. Preheating

- In case of moisture present on the pipe surface, the weld area shall be flame heated to remove the said moisture, by using hand held propane torch.
- Preheating shall extend to at least three times the thickness of the pipe but not less than 50 mm on both sides of the weld area.

- Upon re-starting of any suspended welding operating (after depositing weld metal of at least 50% of pipe thickness) and depending on the material, wall thickness and welding process, a pre-heating of at least. 100^0C shall be carried out.

8. Welding Return Circuit

- Return clamp (Ground clamps) shall be used for connecting pipe to welding machine as a return terminal.

9. Welding

- The welding process to be employed is given in the welding specification; any deviation shall be through the written consent of AEL/TPIA agency.
- The root gap shall be accurately checked and shall be as per qualified WPS. The use of External Clamp is mandatory and shall not be released before 60% completion of the root passes.
- Aneri shall inform AEL/TPIA, if any section of pipeline containing incomplete welds falls from the skid.
- The root pass of butt joints shall be executed properly so as to achieve full penetration with complete fusion of the root edges.
- Welding shall not be interrupted during a pass and shall be completed as early as possible.
- Any kind of movement of components, shocks, vibrations, bumping and stresses are prohibited while welding is in progress.
- Once the deposit of first pass has been started, it must be completed as rapidly as possible in accordance with the WPS, all interruptions to the welding cycle shall be kept to a minimum.
- The welding speed shall be within the parameters as that established in the qualified welding procedure.

10. Cleaning

- Removing the flux, craters, welding irregularities, slag etc. shall be by means of a power brush/ power grinding.

11. Removal of Alignment Clamp

- Alignment Clamps shall not be removed before 60 % completion of the root pass.

12. Hot Pass

- Time lapse between completion of root and the commencement of hot pass shall be as stated in the welding procedure specification (WPS). Normally not exceeding 5 minutes. Two welders shall execute hot pass.

13. Filler and Capping

- After completion of hot pass, all craters, welding irregularities, slag etc, shall be removed by grinding / brushing. Time lapse between hot pass and filler shall be as per that stated in the procedure specification normally not exceeding 10 minutes.

14. Cleaning and Restarting

- Every pass shall be cleaned by power brush, and or grinding machines and chisels.
- Weld bead starting and finishing points shall be staggered for every pass.
- Completed weld shall be carefully brushed and cleaned and shall be free from spatter, slag, surface defects etc.

15. Subsequent Pipe Alignment

- Further, joints shall be welded in the same manner as explained above.
- No welder shall be permitted to work without his possession of a valid identity card covering the welding parameter of the given weld.

16. Weather Protection

- Windshield made of metallic frame covered by G.I sheets / canvas as required shall be provided to enclose the weld and joint, to protect against adverse weather conditions such as rain/drizzle, wind, etc. where ever applicable, in the opinion of the AEL/TPIA

17. Visual Inspection

- All finished welds shall be visually inspected for parallel and axial alignment of the work, reinforcement, concavity, shrinkage, cracks, undercuts, dimensions of weld porosity and other surface imperfections noted shall be rectified, to the satisfaction of the contract specification.

18. NDT

- 100 % radiography of the total line welding and tie-ins and shall be reviewed by TPIA, and the results to be recorded in the approved format.

19. Destructive Testing of WPS / PQR test piece

- The weld joint of WPS / PQR shall be subjected to destructive testing at no extra cost to client.
- The testing of weld coupons shall be conducted at laboratories approved by AEL/TPIA.

20. Identity Cards

- The welder shall have in their procession the identification card as approved by the AEL/TPIA.

21. Others

- Arc strike outside the bevel surface shall not be permitted. If any such arc strikes are made, all such areas shall be repaired to the satisfaction of AEL/TPIA.
- Aneri shall submit welder's performance chart to AEL/TPIA at site for review and approval.
- The skids used during welding shall be removed only, after completion of full welding operation.
- RT shall examine the completed weld/joints of the pipes having different wall thickness and records shall be kept.
- In addition any welds that have already been cut out for defects or for any reason, may also require destructive testing.
- Aneri shall perform the mechanical destructive testing at no extra cost to AEL. If the mechanical test results are unsatisfactory, one more weld shall be cut adjacent to that of previously removed production test joint or the joint welded on the same day. If the second test coupon also gives unsatisfactory results then the welding operation shall be suspended and may not be restarted until such failure causes have been identified and contractor guarantee to prevent reoccurrence. If the second test coupon is giving satisfactory results this assures mainline welding as per the approved WPS.
- The weld joints represented by the unsatisfactory produced mechanically tested welds shall stand rejected unless the investigations prove otherwise.

- Welder's performance report shall be submitted to AEL/TPIA on weekly and monthly basis. 5% repairs shall be considered for rejection and 3% repairs shall be considered for alarming for rejection.

4.4 Procedure for Tie-Ins:

➢ **Scope**

This scope covers the Tie–Ins for construction of 8" NB API 5L Gr. X42 (219.1mm OD x 6.4mm Wthk.) pipeline for Construction of Steel Pipeline Network for KCGD Project. Incase of any conflict between the requirement of this procedure and that of client's specification, the requirement of client's specification shall govern.

➢ **Applicable Codes & Specification**

- API 1104
- ASME: B31.8
- ASME Sec V – NDT
- Client Specification (Z/02/0036)

➢ **Method**

- Welds, joining the sections of the pipeline, valve installation or similar welds are classified as Tie-ins, which shall be made in the trench. Aneri shall do all Tie-in joints alignment utilizing external alignment clamp.
- Seam orientation of welded pipe (when applicable) shall be selected to ensure that at the circumferential welds, the longitudinal welds shall be staggered in the top 900 of the pipeline. For pipes of the same wall thickness the circumferential offset shall not exceed 1.6mm.
- The root gap shall be checked and shall confirm to the qualified welding procedure parameters. All spaces between align up clamp bars or at least 60% of root pass shall be welded before the external clamp is released with the pipe remaining adequately supported on each side of the joint.
- Segments thus welded shall be equally spaced around the circumference of the pipe. Slag etc shall be cleaned off and the ends of the root pass shall be prepared for subsequent welding by grinding, so as to ensure continuity of the weld bead. Qualified welders shall carry out welding as per qualified welding procedure and,

whilst welding is in progress, care shall be taken to avoid any kind of movement of the component, shocks, vibration and undue stress, to preclude possible occurrence of weld crack.

- Electrode starting (start) and finishing (stops) shall be staggered from pass to pass. Arc strikes outside the bevel on the pipe surface shall not be permitted. Arc strike or Arc burn on the pipe surface outside the weld shall be repaired as per the instruction of the AEL/TPIA. Inter pass temperature shall be maintained as per the qualified welding procedure.
- All finished welds shall be visually inspected for parallel and axial alignment of the work, excessive reinforcement, and concavity of welds, shrinkage, cracks, under cuts, dimensions of welds, surface porosity and other surface defects, which shall meet contract specification requirements.
- Parts being welded shall be protected by windshields made of metallic frame covered by Canvas, if necessary, to protect the welding operation from any adverse environmental or weather effects. The completed welds shall be protected with asbestos free type material covered by GI sheets, 100% RT and UT shall be conducted only for critical joints, and the reports shall be submitted to inspection agency for review and approval.
- For Tie-in of adjacent section of pipeline already pressure tested, a single pup or off cuts, which have been hydraulically pre-tested shall be used. Contractor shall keep sufficient stock of hydraulically pre-tested pipes.
- All tie-in weld joints upon acceptance of RT shall receive full joint coating followed by holiday test before any backfilling is commenced.

4.5 Procedure for Repair of accidental arc burn on Pipe:

➢ **Scope**

This scope covers the repair of accidental arc burns on pipes for construction of 8" NB API 5L Gr. X42 (219.1mm OD x 6.4mm Wthk.) for Khurja City Gas Distribution Project. Incase of any conflict between the requirement of this procedure and that of client's specification, the requirement of client's specification shall govern.

➤ **Method**

- Aneri shall make every effort to avoid arc strikes to the pipe wall outside the weld bevel. The electrode tip, un-insulated parts of the electrode holder or bare welding cable coming into contact with the pipe surface, can cause arc strikes per pipe.
- Aneri to take care for the use of inappropriate or poorly fitted earth clamps to avoid the accidental arc burns on pipe.
- Aneri shall remove the arc strike by grinding and excavation blended so as to avoid notches and stress concentration. Welding on pipe is not permitted.
- Following the grinding, Aneri shall test the area by MPT/DP to confirm the absence of cracking, as per Client's Specification.
- Aneri to test the area using 'D' Meter as per Client's Specification. If the wall thickness measured is below the following limits, then the complete area shall be cut out and re-welded.

Pipe Diameter	Wall Thickness Tolerance
8" NB	12.5 %

4.6 Procedure for Liquid Penetrant Test:

➤ **Scope**

This Scope Cover the procedure for checking lamination (whenever a pipe is cut and a new bevel is made) in the construction of 8" NB API 5L Gr.X42 (219.1mm OD x 6.4mm Wthk) pipelines for Construction of Steel Pipeline Network for KCGD Project. Incase of any conflict between the requirement of this procedure and that of client's specification, the requirement of client's specification shall govern.

➤ **Purpose**

The purpose of this procedure is to describe the method of conducting dye penetrant test using solvent removable penetrants for detection of discontinuities open to the surface.

➤ **Applicable Codes & Specification**

- ASME Section V (NDT)
- API 1104 (Welding)
- ASTM – 16.5 (NDT)

- Client Specification (Z/02/0037)

➢ **Method**

- **Surface preparation**

The surface to be examined and all adjacent areas with in at least one inch shall be dry and prepared free of all dirt's, grease, paint, oil, lint, scale and welding spatter by degreasing and power brushing / grinding.

- **Surface condition**

The temperature of the penetrant material and the surface of the part to be examined shall not be less than 60 ° F (16 ° C) nor above 125 ° F (52 ° C) throughout the examination period.

- **Pre-cleaning**

Surface to be inspected shall be cleaned with dry lint free cloth subsequently after spraying the cleaner/remover over the examination surface. Drying process shall be accomplished by normal ambient temperature evaporation.

- **Penetrant application**

The penetrant shall be applied direct to the surface by means of aerosol dispenser can, in such a manner that the entire area is completely covered with penetrant.

- **Dwell time**

Dwell time shall be as recommended by the manufacturer but not less than 10 minutes and not more than 30 minutes.

- **Removal of excess penetrant**

Excess penetrant shall be removed by wiping with a clean lint free cloth, repeating the operation until most traces of penetrant have been removed. Then using lightly moistened cloth with solvent swab the area until all remaining traces of excess penetrant is removed. On removal of excess penetrant drying shall be accomplished by normal ambient temperature evaporation, which approximately one minute.

- **Developer application**

Non-aqueous wet developer will be sprayed directly on to the examination surface of the part from an aerosol (which evaporates rapidly at room temperature) a manner so as to have complete coverage over the test area with a thin and even film of developer.

- **Examination**

Final interpretation shall be made after allowing a development period of not less than 7 minutes or more than 30 minute. To aid in evaluation the observation shall commence immediately with the application of developer if needed.

- **Post cleaning**

Post cleaning is necessary after inspection for subsequent welding; this shall be done by cleaning with lint free cloth / power brushing

➢ **Acceptance standards**

API 1104 & Client Specification

➢ **Consumables**

Cleaner, penetrant and developer shall all be of the correct generic family (solvent removable) and of the same manufacturer.

4.7 Procedure for Radiography Testing:

➢ **Scope:**

This Procedure covers the scope of Radiography for the Khurja City Gas Distribution Project.

➢ **General:**

All the weld joints of pipeline shall be subjected to 100% radiography. The following specifications shall apply in conjunction with the following codes and standards:

- API 1104
- ASME B31.8
- ASNT, recommended practice
- ASME Sec. V

➢ **Work Procedure For Radiography Testing:**

Location	: Khurja
Date of Testing	:
Name of Supervised Contractor	Aneri Construction, ASNT Level-II RT
Specification Reference	ASME Section V, Article-2

Material	API 5L GR. X42
Diameter & Thickness	8" NB & 6.4mm
Type of Weld Joint	Butt Weld
Radiation Source	Iridium-192
Type of Equipment	External, TECH-OPS (660)/SPCT-2T
Strength & Source Size	Up To 25 Curie & 2mm x 2.5mm (Max) in Size
Intensifying Screen Thickness	Lead Screen, 0.1 mm Front & Back
Technique	Double Wall Single Image (DWSI)

Film Type & Make : **Agfa Films (D7 in case of X-ray and D4 In case of Gamma rays)** Type 2 and Type 3 films as per ASTM E-94

Geometric Relation

$$Ug = F\,[2t/SFD]$$

Where Ug = Geometric Unsharpness

t = Thickness of the Job (mm)

F = Source Size (mm)

SFD = Source to Film distance (mm)

SFD would be selected to ensure that Geometric Unsharpness does not exceed 0.5 mm (0.02").

Overlap Per Film : 40 mm

Number of Exposure : 3 Nos.

Exposed Time : As per the Calculation in Minute

$$\frac{F.F \times 2^{(t/T1/2)} \times (SFD)^2 \times 60}{CI \times RHM \times 100^2}$$

Where, FF = Film Factor for AGFA D4 = 4.2

T = Wall Thickness

CI = Curie

RHM = Roentgen Hour Meter

Penetrometer Type (T-233) : For 6.35 mm to 9.52 mm ASTM Set A / Set B

Up To 19.05mm DIN 62 FE 6 ISO 12

Placement of Penetrometer: Source Side for SWSI/DWDI & Film Side for DWSI **(T-277-1)**

Identification in Radiograph: Dia, IQI, Welder No, Joint No, Date,
Symbol (R/RS/RT), B

Where, R = Repair
RS = Reshoot
RT = Retake
B = Back Scattered Radiation on back side of the film

Density : On Weld – 1.8 to 3.5
On Parent Metal – Max 3.8

Sensitivity : As per ASME SEC-V (2%)

Processing Detail : Processing would be done in dark room away from radiation, fume, Moisture or dirt. Fog level would be checked for leakage. Chemical level in the tank would be maintained

Developing	= 5 min at 20°C
Stop bath	= 1 min
Fixing	= Double of Developing Time
Washing	= 30 min in running water
Wetting agent detail	= Liquid Soap
Drying	= In dark room atmosphere
Facility for viewing	= In dark room having a viewer
Developer & mixer brand	= Primer market by M/S Allied Photograph Pvt. Ltd., Bombay
Reporting	= As Format Attached

4.8 Procedure for Weld Repair:

➢ **Scope**

The scope covered in this procedure is limited to removing the weld metal where discontinuities are beyond acceptable limit, and to facilitate reweld as per the approved WPS, which shall be welded by qualified welders for 8" NB API 5L Gr.B (219.1mm OD x 6.4mm Wthk.) pipelines for Construction of Steel Pipeline Network for KCGD Project. In case of any conflict between the requirement of this procedure and that of client's specification, the requirement of client's specification shall govern.

- **Method**
  - ✓ **Equipment**
    - DG Set.
    - Propane hand held torch along with cylinder.
    - Grinding machine.
  - ✓ **Process of Welding**
    - A single welder as per the WPS will do repair with SMAW process.
  - ✓ **Location**
    - With respect of radiography or other NDT method, repair location will be marked on the weld to ref. Points on film.
  - ✓ **Method of evaluation**

    Partial Repair

    - Each layer will be thoroughly checked for this type of discontinuity predicted NDT reports. Smooth grinding will be done to make "V" groove and clean all surfaces. This is limited to 30% of weld length only.

    Through Repair

    - Grinding will be done up to root and root opening will be done by chisel, hacksaw blade. The entire repair portion will be ground smoothly to "V" groove, to attain root of sufficient gap as per WPS. Minimum repair length to be 100 mm as measured over recap length. Limit the root repair to only 20% of weld length.
  - ✓ **Preheating**
    - The welded joint to be repair in the preheated to the extent of 50mm on either side of weld using Propane hand held torch up to 1000 C.
  - ✓ **Welding**
    - After identifying the defects, grinding shall be done to remove the defects. Care shall be taken to ensure that no grinding marks on pipe surface anywhere. DPT examination to be done to ensure the removal of defect. Root sealing or single pass repair deposit shall not be permitted. Internal root defects shall be ground thoroughly and welded with a minimum of two passes as per qualified procedure.

The edge preparation shall be smooth free form burrs, cuts and other surface irregularities. The root gap shall be made carefully.

- The welded area shall be thoroughly cleaned. Repairs opening the root shall be carried out in the presence of the AEL/TPIA. All repairs shall be carried out during the day after initial radiography of as early possible.
- The reports of the all repairs shall be maintained by the Contractor and shall be submitted to the AEL/TPIA.

✓ **Cleaning**

- Each pass will be thoroughly cleaned using Power brush / Grinder.

✓ **Number of Welders**

- One

✓ **NDT**

- After completion of weld repair the repaired portion shall be 100% radiography.

✓ **Acceptance Criteria**

- As per API 1104

✓ **Number of Attempt for Weld Repair**

- Only one attempt at repair of any region is permitted and no re-repairs will be acceptable.

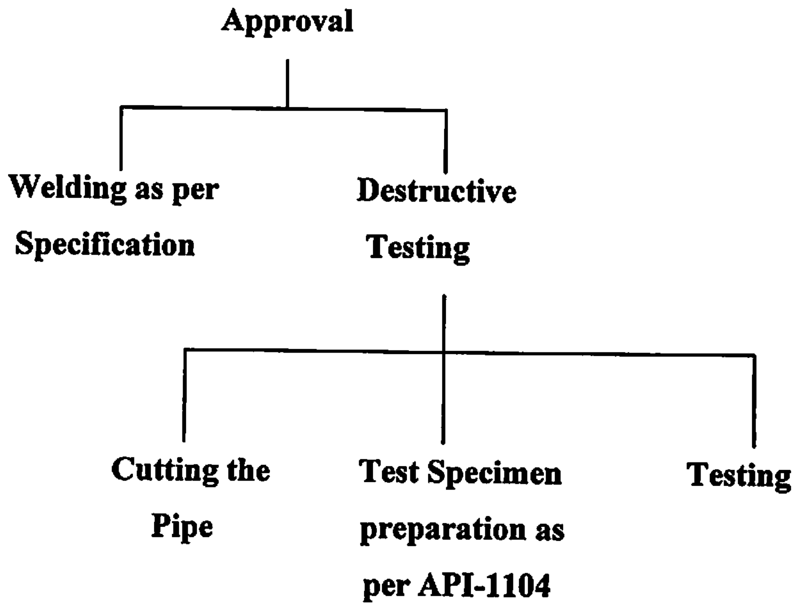
CHAPTER- 5

RESULTS

"APPROVAL OF WELDING PROCEDURE QUALIFICATION AND WELDER'S QUALIFICATION"

5. Welding Procedure Approval:

Approval of the welding procedure specification and welder's qualification is being carried out on the basis of the following flow chart:



5.1 Welding Procedure Qualification Test:

This shows the mainline welding procedure proposed/ approved for use of ANERI CONSTRUCTIONS LIMITED in the KHURJA CITY GAS DISTRIBUTION PROJECT of ADANI ENERGY LIMITED.

PROJECT	KHURJA CITY GAS DISTRIBUTION PROJECT
COMPANY	ADANI ENERGY LIMITED
CONSULTANT	M/S. GERMANISHER LLYOD Gmbh.
CONTRATOR	ANERI CONSTRUCTIONS LIMITED
REFERENCE	API-1104 and TRACTEBEL ENGINEERING
PROCESS	SHIELD METAL ARC WELDING
TYPE	MANUAL
MATERIAL	API 5L Grade X-42
DIAMETER	8" NB
WALL THICKNESS	6.4 mm

JOINT DESIGN	SINGLE 'V' GROOVE
TEST COUPON	8"NB * 6.4 mm
FILLER METAL	E-6010, FLEET WELD, FOR ROOT PASS E-7010G, FOR OTHER PASSES
AWS SPECIFICATION	SFA 5.1 and SFA 5.5
AWS NUMBER (CLASS)	E-6010 & E-7010G
SIZE OF FILLER METAL	E-6010- 2.5 mm, E-7010G- 3.2 mm, Length- 350 mm

ELECTRICAL CHARACTERISTICS:

CURRENT	DC
POLARITY	"+Ve"
POSITION OF GROOVE	5G

Table-5: Electrical Characteristics

S.NO.	Weld Pass	Filler Class	Metal Diameter (mm)	Current Type Polar	Ampere Range	Volt Ranges Volts	Travel Speed Range (mm/sec)
1.	Root Pass	E 6010	2.5	+Ve	65-130	20-32	3.75-4.01
2.	Hot Pass	E7010G	3.2	-do-	90-185	22-34	4.41-4.60
3.	Filler Pass- 1	E7010G	3.2	-do-	90-185	22-34	4.51-4.65
4.	Filler Pass- 2	E7010G	3.2	-do-	90-185	22-34	4.60-4.85
5.	Filler Pass	E7010G	3.2	-do-	90-185	22-34	3.80-4.20

DIRECTION OF WELDING	ROOT DOWN-HILL AND OTHER PASSES DOWN-HILL.
NUMBER OF WELDERS	FOR ROOT AND HOT PASS-02 OTHER PASSES-02

TIME LAPSE B/W PASSES (a) ROOT-HOT PASS: 4min (max)

(b) HOT & OTHER PASSES: 5min (max)

5.1.1 Cutting of Test Piece for Procedure Qualification:

Take a piece from the butt- weld joint of pipe as per the following fig.-42:

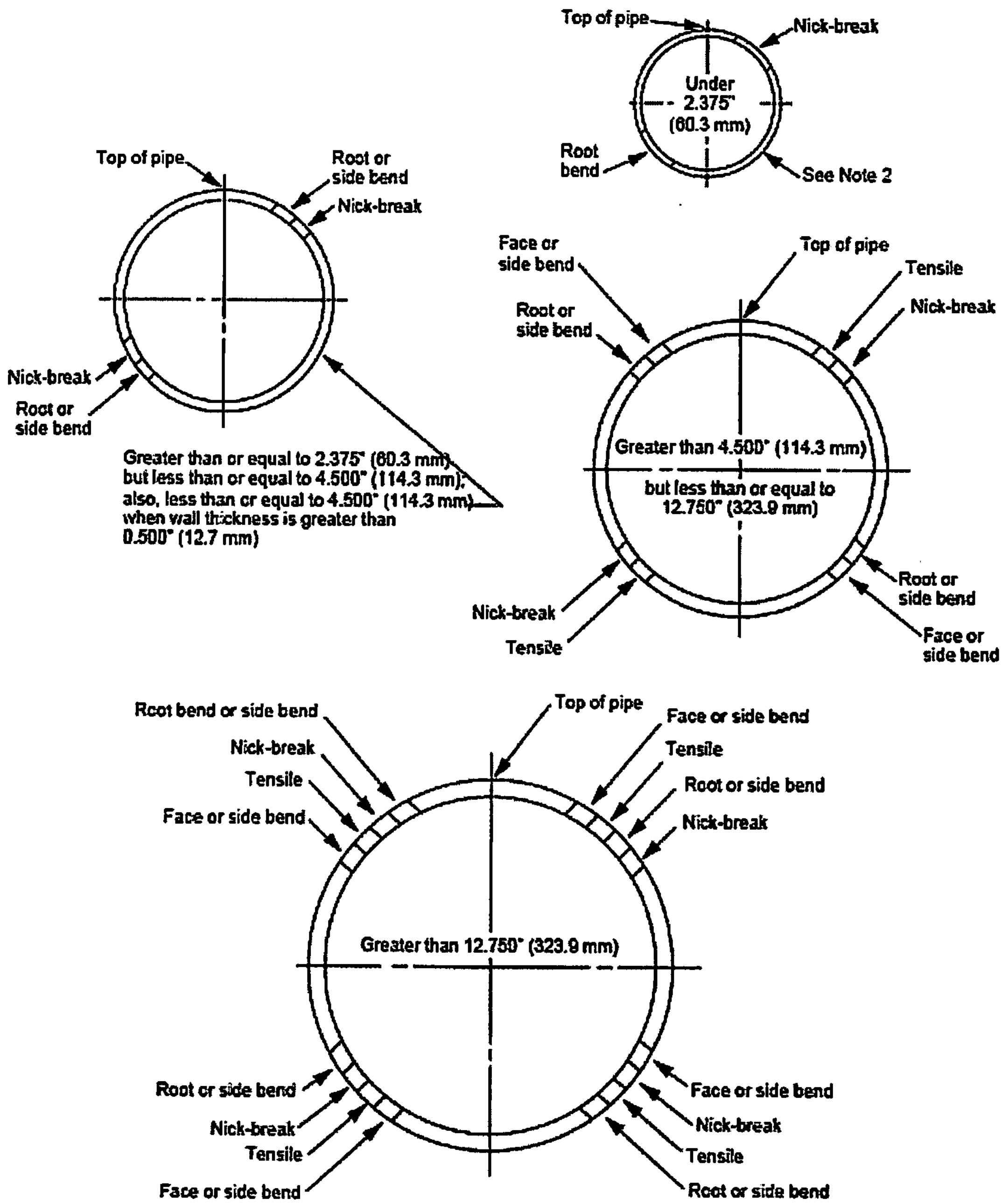


Fig.-42: Location of Test Butt-Weld Specimens for Procedure Qualification Test

5.1.2 Preparation of Test Specimen:

5.1.2.1 Face or Root Bend Test:

Prepare the test specimen as per the following fig.-43:

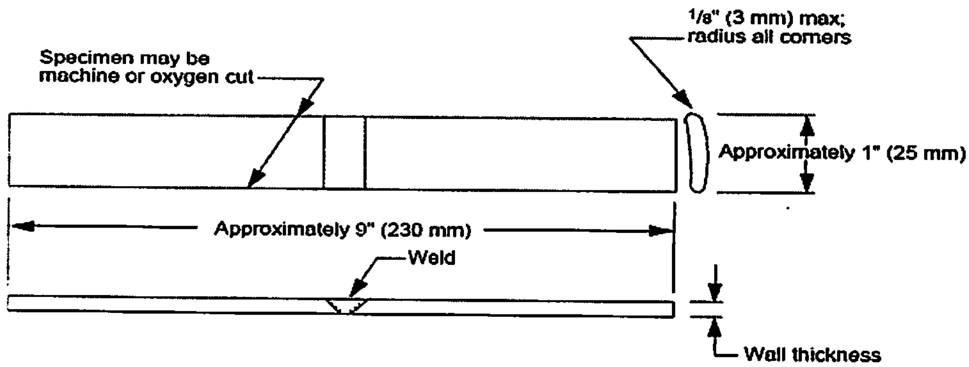


Fig.–43: Root and Face Bend Test Specimen: Wall Thicknesses Less Than or Equal to 0.500 in. (12.7 mm)

Note:

The weld reinforcement shall be removed from both faces with the surface of the specimen.

The specimen shall not be flattened prior to testing.

5.1.2.2 Side Bend Test:

Prepare the test specimen as per the following fig.-44:

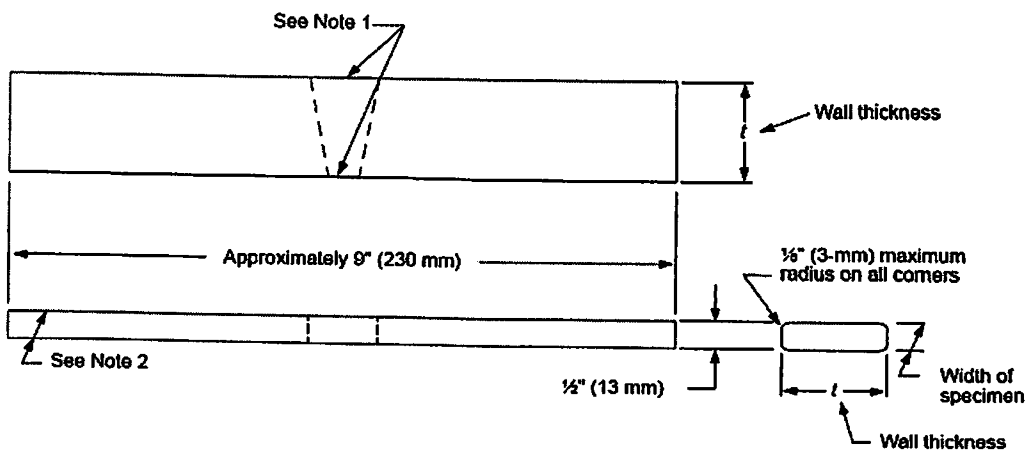


Fig.–44: Side-Bend Test Specimen: Wall Thicknesses Greater than 0.500 in. (13 mm)

5.1.2.3 Tensile Strength Test:

Prepare the test specimen as per the following fig.-45:

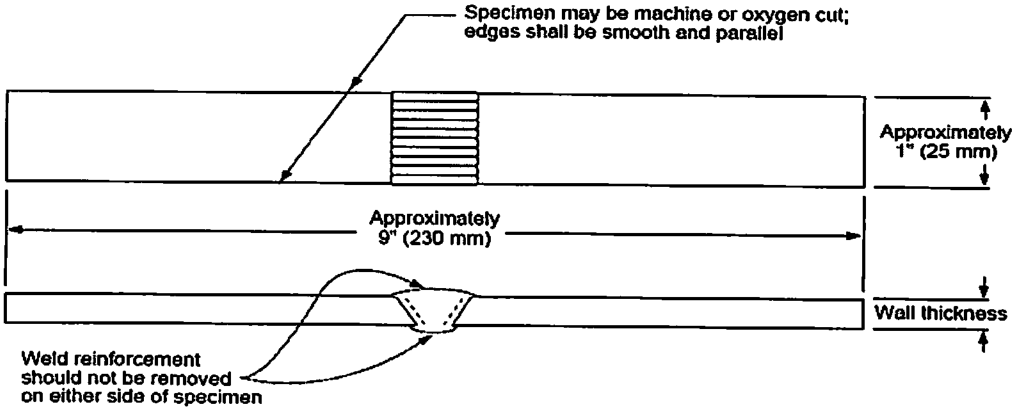


Fig.-45: Tensile-Strength Test Specimen

5.1.2.4 Nick- Break Test:

Prepare the test specimen as per the following fig.-46:

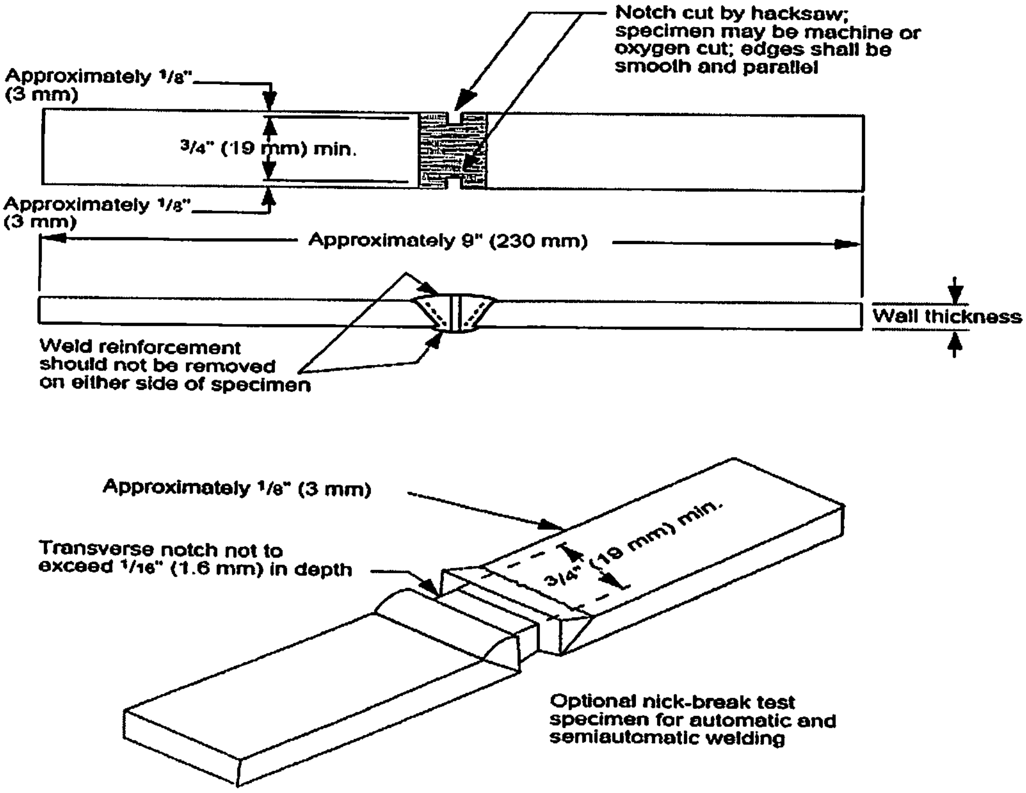


Fig.-46: Nick-Break Test Specimen

5.1.3 Procedure Qualification Test Results:

S. No.	Name of the Test	Max. Crack Propagation	Tested Crack Length	Remarks
1.	**Root and Face Bend Test**	3 mm	0.8 mm	Accepted
2.	**Side Bend Test**	3 mm	0.6 mm	Accepted

S. No.	Name of the Test	Minimum Stress Required	Tested Tensile Stress	% Elongation	Remarks
1.	**Tensile Test**	410 N/mm^2	471.38 N/mm^2	22.4 %	Accepted
2.			472.23 N/mm^2	23.2 %	Accepted

S. No.	Name of the Test	Area of the Specimen	Load Applied	Remarks
1.	**Nick Break Test**	200X6.5 mm^2	63000 KN	Ruptured weld zone reviewed under 10X magnification, observed no evidence of crack, slag inclusion, porosity, and gas pockets. **Accepted** as per API 1104.
2.		200X6.55 mm^2	64800 KN	

The above procedure has been approved as found according to the API-1104 specifications.

5.2 Welder Qualification Test Record:

PROJECT	KHURJA CITY GAS DISTRIBUTION PROJECT
COMPANY	ADANI ENERGY LIMITED
CONSULTANT	M/S. GERMANISHER LLYOD Gmbh.
CONTRATOR	ANERI CONSTRUCTIONS LIMITED
REFERENCE	API-1104 and TRACTEBEL ENGINEERING
PROCESS	SHIELD METAL ARC WELDING
NAME OF WELDERS	Mr. RAJESH KUMAR, Mr. GOPAL SHARMA
TYPE	MANUAL
MATERIAL	API 5L Grade X-42
DIAMETER	8" NB
WALL THICKNESS	6.4 mm
JOINT DESIGN	SINGLE 'V' GROOVE
TEST COUPON	8"NB X 6.4 mm
FILLER METAL	E-6010, FLEET WELD, FOR ROOT PASS E-7010G, FOR OTHER PASSES
AWS SPECIFICATION	SFA 5.1 and SFA 5.5
AWS NUMBER (CLASS)	E-6010 & E-7010G
SIZE OF FILLER METAL	E-6010- 2.5 mm, E-7010G- 3.2 mm, Length- 350 mm

ELECTRICAL CHARACTERISTICS:

CURRENT	DC
POLARITY	"+Ve"
POSITION OF GROOVE	5G

5.2.1 Cutting of Test Piece for Welder Qualification:

Take a piece from the butt- weld joint of pipe as per the following fig. 47:

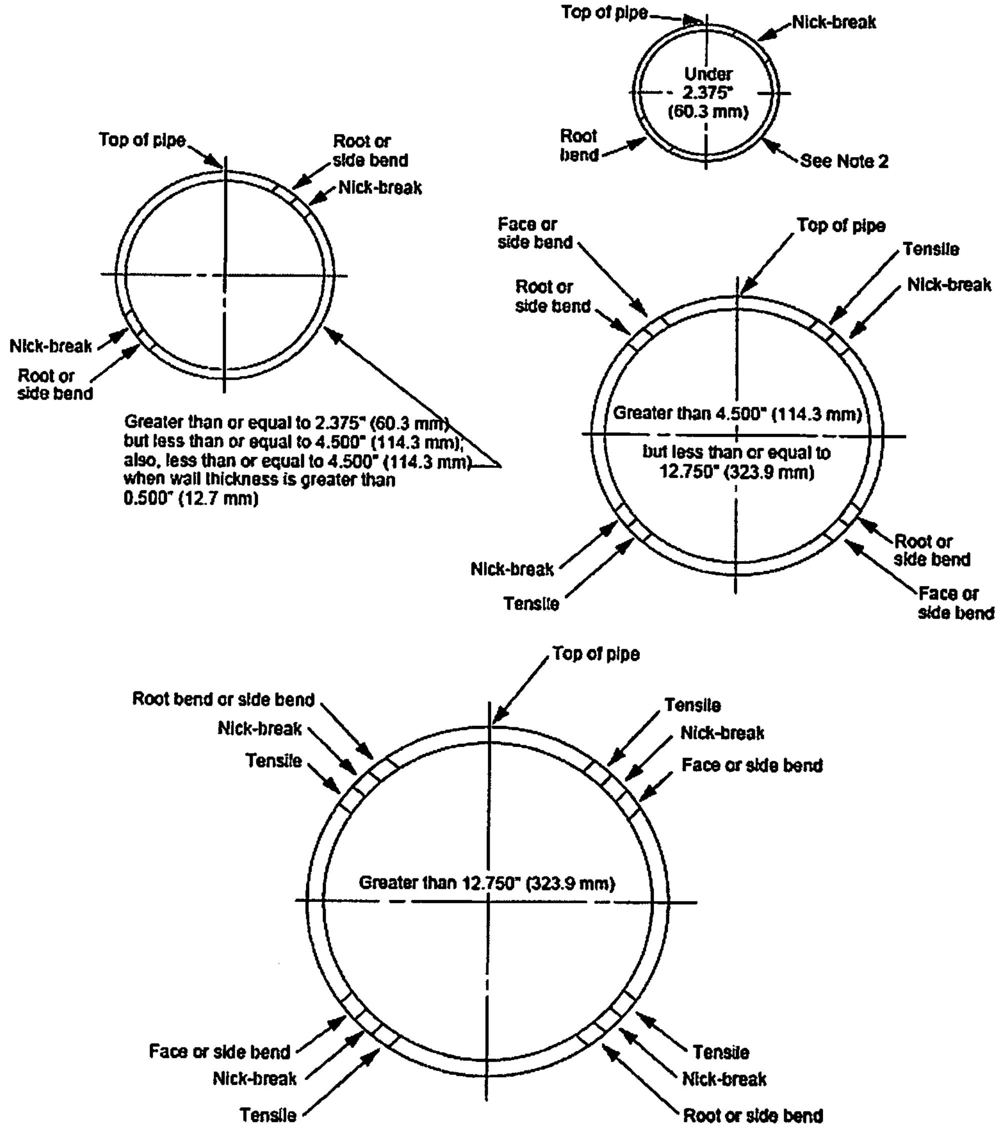


Fig.-47: Location of Test Butt-Weld Specimens for Welder Qualification Test

5.2.2 Welder Qualification Test Specimen and Results:

Testing specimen should be prepared as per above given figures (43, 44, 45, and 46) for the Procedure Qualification Test. Test results are as following:

S. No.	Name of the Test	Max. Crack Propagation	Tested Crack Length	Remarks
1.	Root and Face Bend Test	3 mm	1.1 mm	Accepted
2.	Side Bend Test	3 mm	0.7 mm	Accepted

S. No.	Name of the Test	Minimum Stress Required	Tested Tensile Stress	% Elongation	Remarks
1.	Tensile Test	410 N/mm^2	475.23 N/mm^2	23.4 %	Accepted
2.			470.54 N/mm^2	21.2 %	Accepted

S. No.	Name of the Test	Area of the Specimen	Load Applied	Remarks
1.	Nick Break Test	200X6.55 mm^2	63700 KN	Ruptured weld zone reviewed under 10X magnification, observed no evidence of crack, slag inclusion, porosity, and gas pockets. **Accepted** as per API 1104.
2.		200X6.6 mm^2	64500 KN	

The above procedure has been approved as found according to the API- 1104 specifications.

5.2.3 For E 6010:

Project	Khurja City Gas Distribution Project
Location at	Aneri Constructions Limited
Manufacturer's Name	LINCOLN ELECTRIC COMPANY LIMITED, Australia
Brand Name	Shield ARC HYP
Batch Number	S 17936557
Size Tested	2.5 mm
Qualification and Code	E6010, AWS SFA-5.1
Intended for welding	
In position	1G
In combination with	Nil
Code of reference	ASME Section-II C

All Welders Tensile Test

Base Material Used	IS 2062- 16 mm thick
Pre Heat Temp.	90-110 degree Celsius
Post weld heat	As per SFA 5.1
Treatment Details	Nil
Visual Examination	OK
Radiography Examination	OK

Table-6: Tensile Test Result (E 6010)

Tensile Test Result	Accepted (UTS)	Yield strength	% Elongation
Minimum Required	485 N/mm^2	485 N/mm^2	22.00%
Actual	536 N/mm^2	435 N/mm^2	25.98%

Impact Test Result:

Test temperature	-20 degree Celsius
Type of Specimen	As per SFA 5.1
Notch	"V" notch at weld
Size of specimen	10x10x55 mm^3

Table-7: Impact Test Result (E 6010)

Specimen No.	Impact Value	Average	Required Value	Remarks
Weld 1	52 J			
Weld 2	56 J			
Weld 3	37 J	55.3 J	35 J	Accepted
Weld 4	58J			
Weld 5	62 J			

5.2.4 For E-7010G:

Project	Khurja City Gas Distribution Project
Location at	Aneri Constructions Limited
Manufacturer's Name	LINCOLN ELECTRIC COMPANY LIMITED, Australia
Brand Name	Shield ARC HYP
Batch Number	S 17779303
Size Tested	3.2 mm
Qualification and Code	E7010-G, AWS SFA-5.5
Intended for welding	
In position	1G
In combination with	Nil
Code of reference	ASME Section-II C
All Welders Tensile Test	
Base Material Used	IS 2062- 16 mm thick
Pre Heat Temp.	90-110 degree Celsius
Post weld heat	As per SFA 5.5
Treatment Details	Nil
Visual Examination	OK
Radiography Examination	OK

Table-8: Tensile Test Result (E 7010G)

Tensile Test Result	Accepted (UTS)	Yield strength	% Elongation
Minimum Required	485 N/mm^2	432 N/mm^2	22.00%
Actual	542.40 N/mm^2	437.29 N/mm^2	22.40%

Impact Test Result:

Test temperature -20 degree Celsius

Type of Specimen As per SFA 5.5

Notch "V" notch at weld

Size of specimen 10x10x55 mm^3

Table-9: Impact Test Result (E 7010G)

Specimen No.	Impact Value	Average	Required Value	Remarks
Weld 1	76 J			
Weld 2	80 J			
Weld 3	28 J	64.8 J	35 J	Accepted
Weld 4	86J			
Weld 5	54 J			

CHAPTER- 6

CONCLUSION AND RECOMMENDATIONS

6.1 CONCLUSION:

Summing up my work is necessary there, as to present clearly the task covered by me. To ensure high quality welds only competent and skilled welders should be permitted to work on the job. They shall be qualified as per procedure requirements. They should work only as per the qualified procedure specifications.

Following are the results associated with the work completed by me:

NAME OF QUALIFIED WELDERS	Mr. RAJESH KUMAR, Mr. GOPAL SHARMA
PROJECT	KHURJA CITY GAS DISTRIBUTION PROJECT
COMPANY	ADANI ENERGY LIMITED
CONSULTANT	M/S. GERMANISHER LLYOD Gmbh.
CONTRATOR	ANERI CONSTRUCTIONS LIMITED
REFERENCE	API-1104 and TRACTEBEL ENGINEERING
PROCESS	SHIELD METAL ARC WELDING
TYPE	MANUAL
MATERIAL	API 5L Grade X-42
DIAMETER	8" NB
WALL THICKNESS	6.4 mm
JOINT DESIGN	SINGLE 'V' GROOVE
TEST COUPON	8"NB X 6.4 mm
FILLER METAL	E-6010, FOR ROOT PASS E-7010G, FOR OTHER PASSES
AWS SPECIFICATION	SFA 5.1 and SFA 5.5
AWS NUMBER (CLASS)	E-6010 & E-7010G
SIZE OF FILLER METAL	E-6010- 2.5 mm, E-7010G- 3.2 mm, Length- 350 mm

ELECTRICAL CHARACTERISTICS:

CURRENT	DC
POLARITY	"+Ve"
POSITION OF GROOVE	5G

S.NO.	Weld Pass	Filler Class	Metal Diameter (mm)	Current Type Polar	Ampere Range	Volt Ranges Volts	Travel Speed Range (mm/sec)
1.	Root Pass	E 6010	2.5	+Ve	65-130	20-32	3.75-4.01
2.	Hot Pass	E7010G	3.2	-do-	90-185	22-34	4.41-4.60
3.	Filler Pass- 1	E7010G	3.2	-do-	90-185	22-34	4.51-4.65
4.	Filler Pass- 2	E7010G	3.2	-do-	90-185	22-34	4.60-4.85
5.	Filler Pass	E7010G	3.2	-do-	90-185	22-34	3.80-4.20

DIRECTION OF WELDING — ROOT DOWN-HILL AND OTHER PASSES DOWN-HILL.

NUMBER OF WELDERS — FOR ROOT AND HOT PASS-02
OTHER PASSES-02

TIME LAPSE B/W PASSES — (a) ROOT-HOT PASS: 4min (max)
(b) HOT & OTHER PASSES: 5min (max)

6.2 RECOMMENDATIONS:

A welding procedure must be reestablished as a new procedure specification and must be **completely requalified** when any of the essential variables listed below are changed:

(1) Welding process or method of application.
(2) Base material.
(3) Joint design.
(4) Position.
(5) Wall thickness.
(6) Filler metal.
(7) Electrical characteristic.
(8) Time between passes.
(9) Direction of welding.
(10) Shielding gas and flow rate.
(11) Shielding flux.
(12) Speed of travel.

REFERENCES

1. American Petroleum Institute Standard- API 1104 Welding of Pipelines and Related Facilities, Nineteenth Edition, September 1999
2. American Petroleum Institute Standard- API 5L Specification for Line Pipe, Forty-Second Edition, January 2000
3. Pipeline Welding Handbook, Forth Edition, May 1999
4. Bauerlein, B., A Basic Guide of Arc Welding Electrodes
5. Nondestructive Inspection Methods, NAVAIR, 01-1A-16, Naval Air Systems Command Headquarters, Washington, D.C., 1 March 1990, Change 1, 1 April 1991
6. American Welding Society Standard- AWS B2.1: 2005, Specification for Welding Procedure and Performance Qualification
7. American Society of Mechanical Engineers Code- ASME Boiler and Pressure Vessel Code
8. American Welding Society Standard- AWS B4.0: 2003, Standard Methods for Mechanical Testing of Welds
9. American Society for Testing and Materials Standard- E 165, Standard Test Method for Liquid Penetrant Examination
10. Raad, J. A., Dijkstra, F. H., "Mechanized UT on girth Weld During Pipeline Construction – a mature Alternative to Radiography", The Journal of the British Institute of Non-Destructive Testing, pp. 435-438, Vol. 40, N□6, June, 1998
11. Standard Operating Procedure and specifications provided by Adani Energy Limited
12. ASME B-31.8: Gas Transmission and Distribution Piping Systems, 1999.

APPENDIX-A: Weld Defects and Their Remedies

FAULT OR DEFECT	CAUSE AND/OR CORRECTIVE ACTION
1) POROSITY	A. OIL, HEAVY RUST, SCALE, ETC. ON PLATE B. WIRE – MAY NEED WIRE HIGHER IN Mn AND Si C. SHIELDING PROBLEM; WIND, CLOGGED OR SMALL NOZZLE, DAMAGED GAS HOSE, EXCESSIVE GASFLOW, ETC. D. FAILURE TO REMOVE GLASS BETWEEN WELD PASSES E. WELDING OVER SLAG FROM COVERED ELECTRODE
2) LACK OF PENETRATION	A. WELD JOINT TOO NARROW B. WELDING CURRENT TOO LOW; TOO MUCH C. ELECTRODE STICKOUT WELD PUDDLE ROLLING IN FRONT OF THE ARC
3) LACK OF FUSION	A. WELDING VOLTAGE AND/OR CURRENT TOO LOW B. WRONG POLARITY, SHOULD BE DCRP C. TRAVEL SPEED TOO LOW D. WELDING OVER CONVEX BEAD E. TORCH OSCILLATION TOO WIDE OR TOO NARROW F. EXCESSIVE OXIDE ON PLATE
4) UNDERCUTTING	A. TRAVEL SPEED TOO HIGH B. WELDING VOLTAGE TOO HIGH C. EXCESSIVE WELDING CURRENTS D. INSUFFICIENT DWELL AT EDGE OF WELD BEAD
5) CRACKING	A. INCORRECT WIRE CHEMISTRY B. WELD BEAD TOO SMALL C. POOR QUALITY QF MATER IAL BEING WELDED

6) UNSTABLE ARC	A. CHECK GAS SHIELDING B. CHECK WIRE FEED SYSTEM
7) POOR WELD STARTS OR WIRE STUBBING	A. WELDING VOLTAGE TOO LOW B. INDUCTANCE OR SLOPE TOO HIGH C. WIRE EXTENSION TOO LONG D. CLEAN GLASS OR OXIDE FROM PLATE
8) EXCESSIVE SPATTER	A. USE Ar-CO_2 OR Ar-O_2 INSTEAD OF CO_2 B. DECREASE PERCENTAGE OF He C. ARC VOLTAGE TOO LOW D. RAISE INDUCTANCE ANO/OR SLOPE
9) BURNTHROUGH	A. WELDING CURRENT TOO HIGH B. TRAVEL SPEED TOO LOW C. DECREASE WIDTH OF ROOT OPENING D. USE Ar-CO_2 OR Ar-O_2 INSTEAD OF CO_2
10) CONVEX BEAD	A. WELDING VOLTAGE AND/OR CURRENT TOO LOW B. EXCESSIVE ELECTRODE EXTENSION C. INCREASE INDUCTANCE D. WRONG POLARITY, SHOULD BE DCRP E. WELD JOINT TOO NARROW