

CODES AND STANDARD

BSEN 970 - Visual Inspection & NDE Visual - 6.1
UT - 6.3

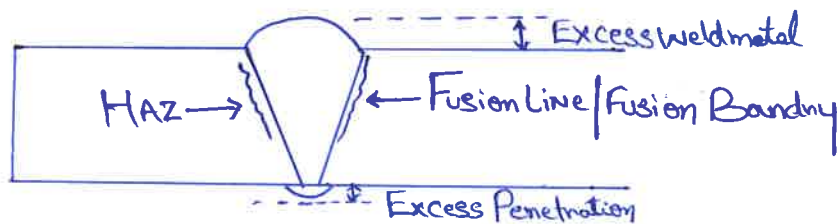
BSEN 287 - Welder Approval (WQT)

BSEN 288/15614 - Welding Procedure Approval (WPAR)

BSEN 499 - Welding Consumables (ISO 2560)

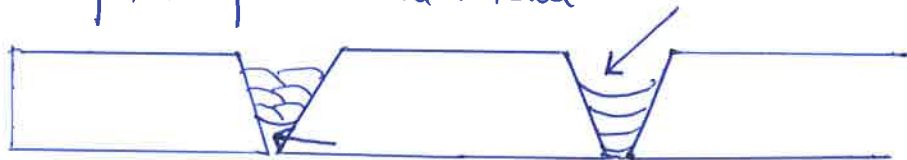
BSEN 25817 - Qualification Acc & Rej Level

MACRO Examination



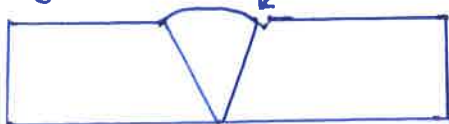
Underfill

Underfill Only In Weld Metal



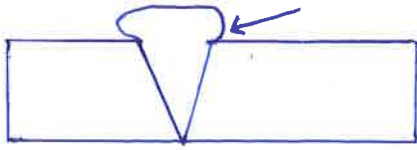
Undercut

Toe Position Removed or Metal Near the toe too High Current (Undercut only in Base Metal)



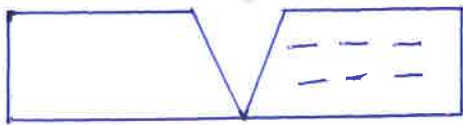
Over Lap

Weld Metal lapping Over Metal and at Same Time No Fusion



Lamination

Lamination Always Straight Line



CRACKS

Linear Crack

Toe Crack

HAZ Crack



Lack of Fusion

Lack of Side wall Fusion : Between Weld Metal and the Base Metal

Lack of Inter-run Fusion : Between the Weld Metal

Lack of Root Fusion : Between the Root Face and the Weld metal

Solid Inclusion

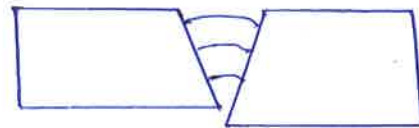
Slag - SMAW

Gas Inclusion

Gas Cavity Mostly Individual In Center
Single Hole Pore
Cluster Porosity

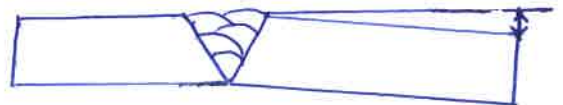
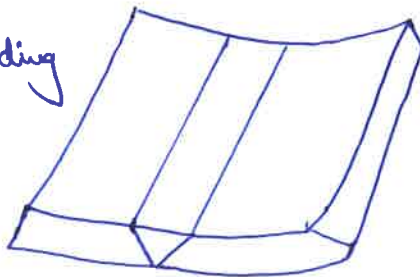
LINEAR MISALIGNMENT

BEFORE welding

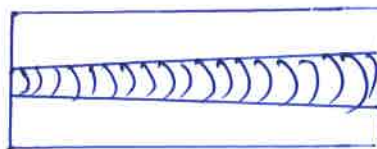


ANGULAR DISTORTION

After Welding



Irregular Width



Incomplete Fillet Groove



GENERAL

WELDING PARAMETERS

WELDING CONSUMABLE

WELDING SYMBOLS

IMPERFECTION AND WELD ABILITY

PRE HEAT, POST HEAT AND PWHT

CODES & STANDARDS

DESTRUCTIVE AND NONDESTRUCTIVE

SPECIFIC

DUTIES OF WELDING INSPECTOR

MODES OF TRANSFER

DESTRUCTIVE TEST AND NON DESTRUCTIVE

HEAT TREATMENT

WELD ABILITY OF STEEL

WPS | PQR | WQT

DUTY CYCLE AND OPERATION FACTOR

WELDING Current

- * Welding Current is Directly Proportional to Penetration
- * If the Current Increase Penetration Increases
- * High Current will lead to Excessive Penetration, Burn through, Spatter, undercut will cause over Heating of Tungsten which will lead to Tungsten Inclusion
- * Low Current will give you Irregular Bead (unacceptable)

Welding Voltage

- * Welding Voltage or Arc Voltage is Directly Related to the Arc Length
- * If Arc Length Varies the Arc Voltage will Increase
- * High Arc Voltage Cause unstable Arc Irregular Bead, Arc Blow and High deposition
- * Open Circuit Voltage is used to Initiate the Spark so the Arc will be generated (start)
- * OCV Value is 50-90V

TRAVEL Speed

Travel Speed is Inversely proportional to Heat
Is Also known as RoL (Runout Length) →

Too Slow Travel speed

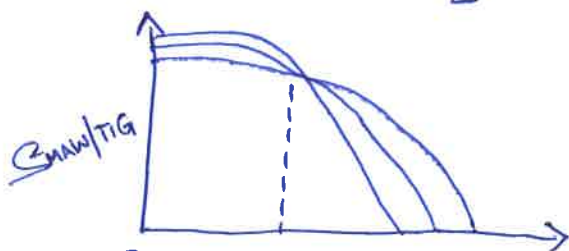
Wide Weld Bead Contour → 
Excess Penetration
Burn through

High Travel speed

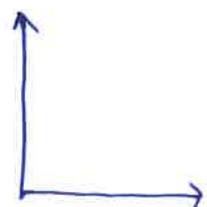
Lack of Root Fusion
Incomplete Root Fusion
Undercut
Poor Bead Profile, difficult Slag Removal

Power SOURCE

MMA
TiG
SAW > 1000 Amps } Constant Current / Drooping Characteristic
(constant voltage)



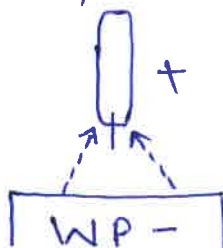
GMAW
(MIG/MAG/FAW)
SAW up to 1000 Amps } Constant Voltage
Flat Characteristic



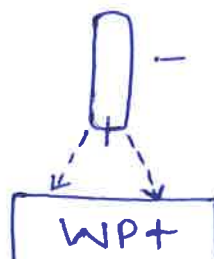
Polarity

MMA	}	DC +VE (Commonly)	DC -VE (Rarely)	AC (To Avoid ARC)
SAW		↓	↓	
GMAW		Deep Penetration	High deposition	

GITAW DC -VE (Commonly)
DC +VE Not Used (To Avoid Tungsten Inclusion)
AC - Aluminium and Magnesium Alloy

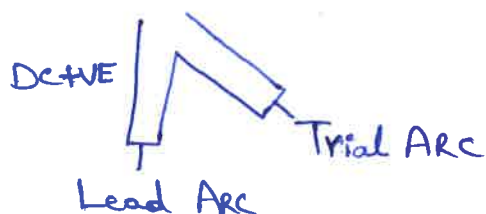
DC +VE, DCEP (Direct Current Electrode Positive)
Reverse Polarity
90% Heat on WP (Weld Piece)


DC -VE DCEN (DC Electrode Negative) Straight Polarity

90% Heat on


SAW TWIN Wire System

AC is used to Avoid ARC blow



SHIFTING of Polarity And its Characteristics

DC +ve to DC -ve = High deposition

DC -ve to DC +ve = Deep Penetration

AC to DC +ve = Deep Penetration

AC to DC -ve = High deposition

DC +ve to AC = Penetration decrease & Slightly
increase in deposition

DC -ve to AC = decrease in deposition and Slightly
increase in Penetration

HEAT INPUT

The Energy Supplied by the welding Arc to the
work piece

$$\text{HEAT Input} = \text{ARC Energy} \times \text{thermal Efficiency Factor}$$

ARC Energy

Heat Generated in the Weld Arc Per unit Length
of weld

Arc Energy

$$\text{Arc Energy (KJ/mm)} = \frac{\text{Volts} \times \text{Amps}}{\text{Travel Speed (mm)} \times 1000}$$

$$\text{Volt} = 220\text{V}$$

$$\text{Amps} = 24$$

$$\text{Rot} = 180/\text{min}$$

$$\text{Arc Energy} = ?$$

$$\text{Arc Energy} = \frac{\text{Volts} \times \text{Amps}}{\text{Travel Speed} \times 1000}$$

$$= \frac{220 \times 24}{180/60 \times 1000}$$

$$= \frac{220 \times 24 \times 60}{180 \times 1000}$$

$$= \underline{\underline{2.64 \text{ KJ/mm}}}$$

$$\begin{aligned} \text{Typical heat Input Value For MMA/ SMAW} \\ = 1 \text{ to } 3.5 \text{ KJ/mm} \end{aligned}$$

$$\begin{aligned} \text{Typical heat Input Value For GMAW/MIG/MAG} \\ = 0.1 \text{ to } 2.0 \text{ KJ/mm} \end{aligned}$$

Proportionality

Welding Current = Penetration

Welding Voltage = Arc Length = Deposition = Weld Profile

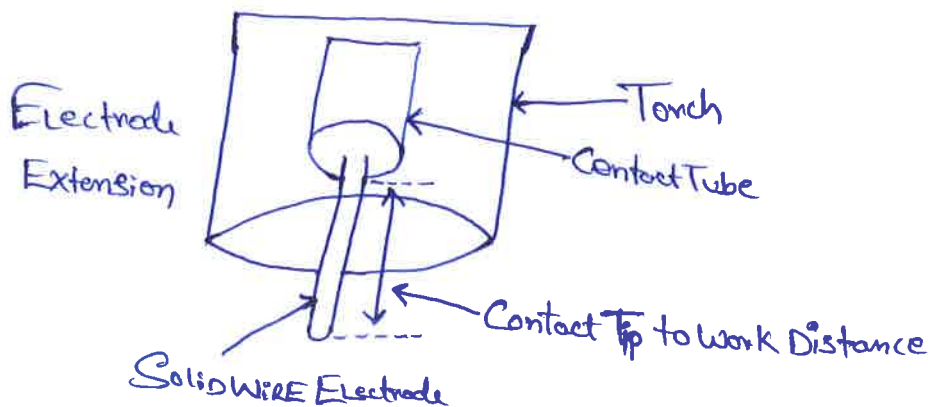
Wire Feed Speed = Weld Current

Wire Feed Speed = Burn Off Rate

Heat Input Inversely Proportional to Travel Speed

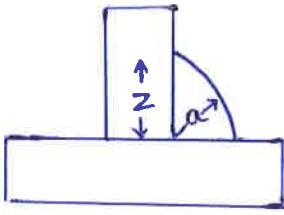
Weaving of Electrode is inversely Proportional to Travel Speed

Contact Tip To Work Distance (CTWD)



- * CTWD is inversely Proportional to welding Current
- * Weld Feed Speed is Reduced with Increase in CTWD
- * Wire Feed Speed is directly Proportional to Electrode Extension and also to welding Current

Fillet Weld



Z = Leg length

a = throat thickness

$$Z = 1.414 \times a(\text{mm}) \times$$

$$a = 0.707 \times Z(\text{mm})$$

$$\text{Excess weld metal} = [a - (0.7 \times Z)]$$

Actual throat - Design throat = Excess

High Heat Input = Low Toughness

Low Heat Input = High Hardness

Fillet Weld Strength = throat thickness

Fillet Weld Size = Leg length

① $I = 220 \text{ Amps}$

$V = 21 \text{ Volts}$

$R_oI = 270 \text{ mm/min}$

thickness = 50 mm

ARC Energy = ?

$$\text{ARC Energy} = \frac{\text{Volts} \times \text{Amps}}{T.S \times 1000}$$

$$\frac{21 \times 220}{270/60 \times 1000}$$

$$= \frac{21 \times 220 \times 60}{270 \times 1000} = \frac{277200}{270000}$$

$$= \underline{\underline{1.02 \text{ KJ/mm}}}$$

② throat thickness = 8mm

Minimum Leg Length Required - ?

$$a = 8\text{mm}$$

$$Z = 1.414 \times a$$

$$= 1.414 \times 8$$

$$= \underline{\underline{11.312\text{mm}}}$$

③ Current 250Amps

Volts 24V thickness 5mm Polarity Dc+Vc

Rol 180mm/min ARC Energy?

$$\text{ARC Energy} = \frac{\text{Volts} \times \text{Amps}}{T_s \times 1000}$$

$$= \frac{24 \times 250}{180/60 \times 1000} = \frac{24 \times 250 \times 60}{180 \times 1000}$$

$$\frac{360000}{180000} = \underline{\underline{2\text{ kJ/mm}}}$$

④ Amp 190

Volts 24

Rol 120mm/min

$$\text{ARC Energy} = \frac{24 \times 190}{120/60 \times 1000}$$

$$\frac{24 \times 190 \times 60}{120 \times 1000} = \frac{273600}{120000}$$

$$= \underline{\underline{2.28\text{ kJ/mm}}}$$

WELDING CONSUMABLES

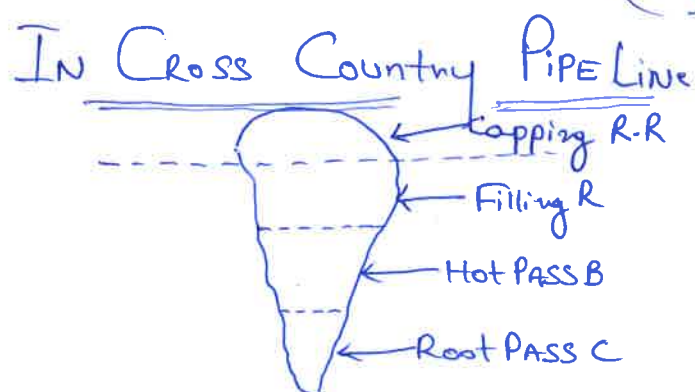
SMAW/MMA

BASIC - E7018 - Calcium Carbonate

Rutile - E6013 - Titanium Oxide

Cellulosic - E6010 - Organic Matter (Wool, Wood)

Rutile Recovery - E7024 Rutile + Fe Powder
(Iron Powder)



BASIC E7018

- * Hot PASS technique
 - * Having Very good Mechanical Properties
 - * Required Baking due to the High Moisture Pickup
 - * H_2 Level $< 5 \text{ ml} / 100 \text{ gm}$ of Weld Metal
 - * No Risk of H_2 Cracking
 - * It is used for All position
 - * Efficient for overhead Position
 - * Baking temp $300-350^\circ\text{C}$ for 2 hours
 - * Holding Oven Temp 150° for 1 hour
 - * Portable oven $70-90^\circ\text{C}$
- Note - up to 4 hour No Moisture Solidification time is less good for PE Position

CELLULOSIC E6010

- * IN CROSS Country PIPELINE, It is Used In Root Run
- * High Risk of H₂ Cracking or HAZ Cracking
- * H₂ level 80-90ml/100gm of Weld Metal
- * Give Very Deep Penetration
- * Used For Stove PIPE Welding
- * Good For Vertical down Position Because It give's deep Penetration Even in High Travel Speed

Rutile E6013

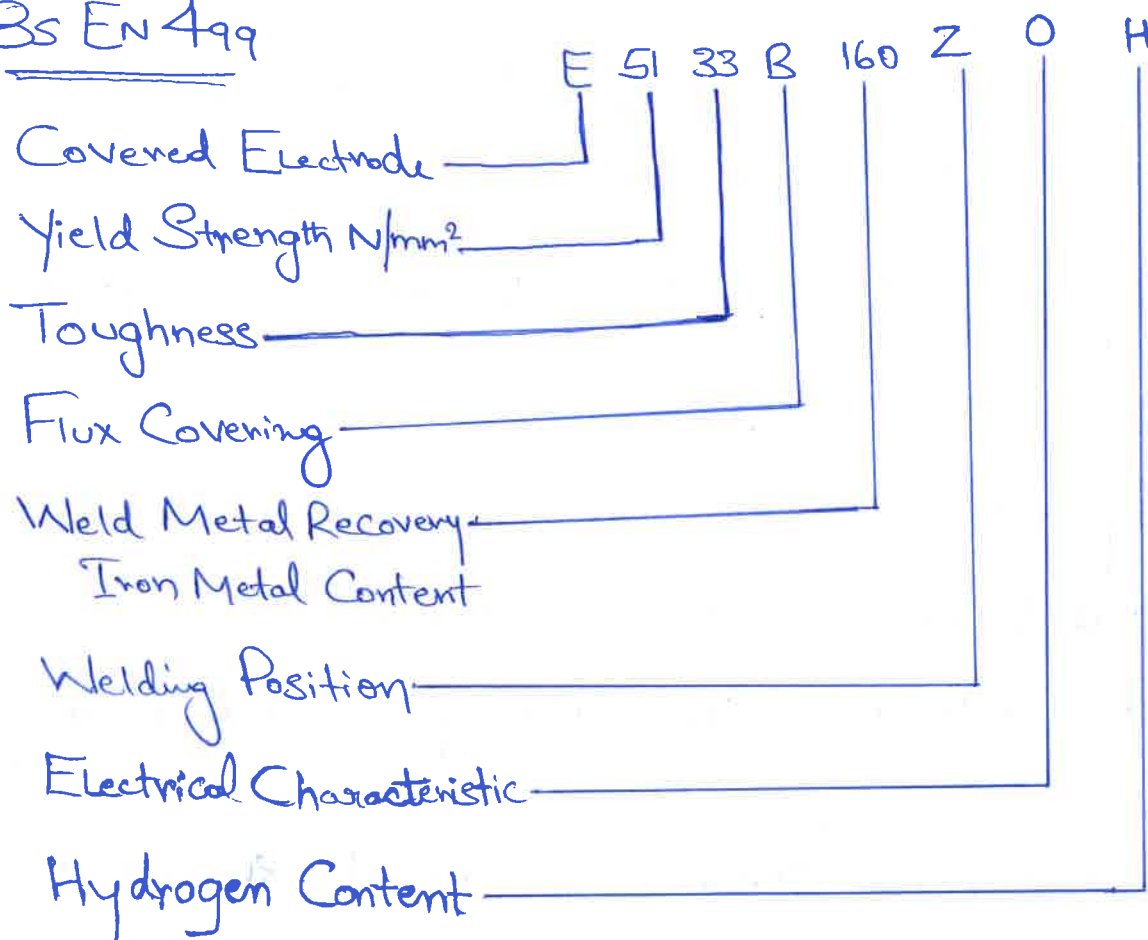
- * In Cross Country PIPELINE Used For Capping
- * Moderate H₂ Level about 25-30ml
- * Good Finishing
- * Efficient For PB Position
- * Don't Required backing But It Should Be dried Before Use
- * Re drying at about 80°C is all that is needed

Rutile Recovery E7024 / Heavy Rutile / High Iron Powder

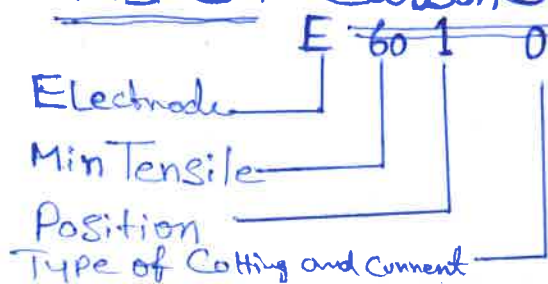
- * Good for Both PA (IG) & PB (2F) Positions
- * Good Mechanical Properties
- * It's Nothing But the titanium Oxide (Rutile)
Mixed With Ferric Powder to Improve or Enhance the Deposition Rate

Electrode Classification

BS EN 499



AWS 5.1 Carbon Steel Electrode For SMAW



ELECTRODE EFFICIENCY

Electrode Efficiency Could be Increased by Allowing the Electrode With Iron Powder

In Iron Powered Electrode Has 180% Usual Electrode has 70-90%

$$\text{Electrode Efficiency} = \frac{\text{MASS of Weld Metal deposited}}{\text{MASS of Cone Wire Melted}}$$

GTTAW

- * Tungsten Electrodes are Produced by Powder Forging Technology
- * They are available From 1.6 - 10mm Dia
- * there are Four types of Tungsten Electrodes Suits different application
- * Pure tungsten Is used for Welding Aluminium while Polarity is Ac
- * Thoriated Electrodes Contain Small Percentage of thorium Oxide (thoria) which mainly used for Welding Steels
- * Polarity used when Welding with thoriated Should be Dc-Ve
- * Zirconiated Electrode are alloyed with Zirconium oxide Also used for Aluminium with Ac mode But Unlike Pure Tungsten it could Retain Ball End during Welding

(388824)

* Ceriated and Lanthanated Electrodes are used Sometimes as a Replacement for thoriated

(288814)

* Thoriated is More Radio Active than Ceriated and Lanthanated

SHEILDING GAS

* Argon

* Helium

* Argon + Helium

* Sometimes for Austenitic Stainless Steel & Cupro-Nickel alloys Argon with 5% of Hydrogen to Improve Penetration and Reduce Porosity

Copper & Nickel - highly Resistant
↑ [Corrosion Seawater]

Note - CO_2 Not Used

CONSUMABLE INSERTS

- * It is also known as Fusable Inserts or Backup
- * It is inserted in the Root Gap during Welding the Insert Melts and provide a Backup for Root Penetration
- * It Controls the Penetration level and melts along with Filler material
- * It has a preplaced Filler material to backup Penetration

Note - Only AVAILABLE in STANDARD SIZE

SHAPES OF INSERTS

Inverted T

J

K

RECTANGULAR

SAW

SAW

Flux

- * Fluxes are used to give good Weldability and gr Finish
- * It Also Has a greater Tolerance Over the so Contaminants.
- * There are two types of Flux used Namely Fused and agglomerated.

AGGLOMERATED

- * Its a basic flux
- * It has a Capacity of the Moisture pickup when It has to be kept at Lower temperature For Keep it
- * It is available in powdered or in a ^{dry} Round granules
- * It Produce a good quality Weld with High Strength and Toughness.
- * The Slag Removal is tough and Cannot be Recycled

FUSED

- * It is Acidic
- * Available in a Small Crystals glass like Crystals
- * Huge Lump of Fused Flux is First Heated above 1000°C to Pulverize it into a Small Crystals
- * It is Flaky and Sharp
- * It Produces Low quality Weld But Gives High Productivity
- * Slag Removal is Easy
- * It Could Be Recycled For Further Use.

GMAW

Inert - Ar, He, N

Active - O_2 , CO_2

Combination of Inert & Active

Pure Inert - MIG

Pure Active - MAG

Inert + Active - MAG

Pure Argon - MIG (Spray or pulse Welding Aluminium Alloy's)

Pure CO_2 - MAG (Dip transfer Welding For Steel)

Argon + 5 - 20% CO_2 - MAG (Dip or pulse Welding of Steel)

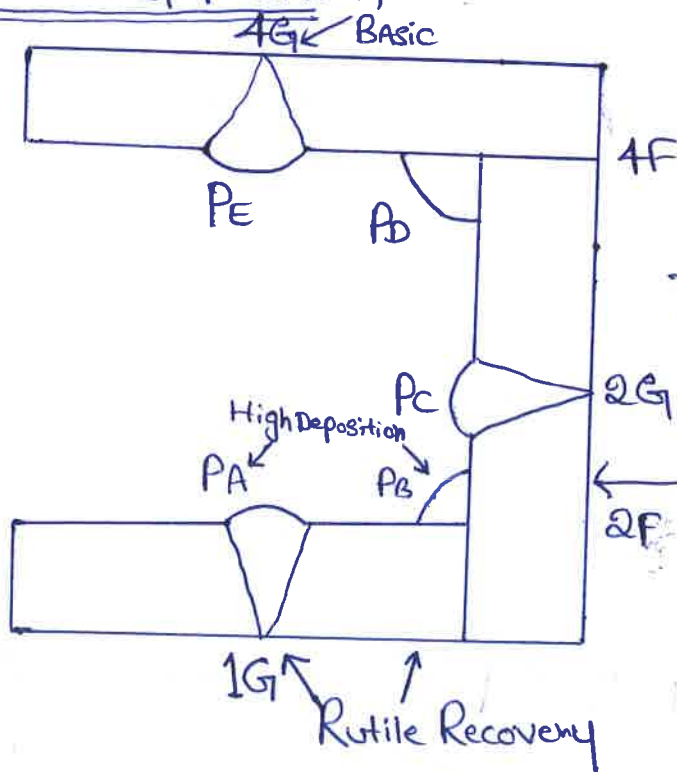
Argon + 1 - 2% O_2 or CO_2 - MAG (Spray or Pulse Welding of Austenitic or Ferric Stainless Steel only)

FCAW

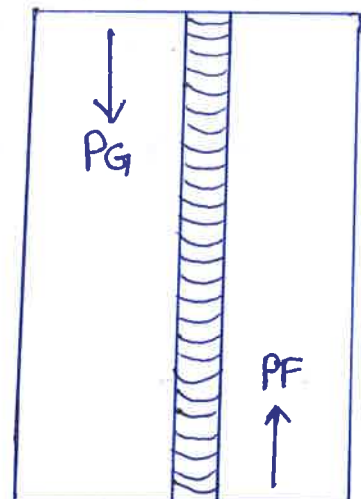
WIRE TYPE

- * Rutile Cored Wire gives good Positional Capabilities and Good Finish.
- * BASIC Cored is Very good on dirty Materials and Gives Excellent quality.
- * Iron Powdered Wire Gives High Productivity than Rutile and have Excellent Root Run Capabilities
- * Baking of Cored Wire is in Effective and Will not Restore the Condition of Contaminate Flux

WELDING Position



PF - VERTICALLY UP
Low Travel Speed High
Input
PF - Highest Heat Input
Amount All position
Rutile
3G



PG - CELLULOSIC
VERTICAL DOWN High Travel
Speed Low Heat Input

GMAW MODES OF METAL TRANSFER

Dip Transfer/Short Circuit Transfer

Spray Transfer

Pulsed Transfer

GLOBULAR Transfer

METAL Deposited

SHORT CIRCUIT TRANSFER	lbs/hr 2-6	Kg/hr 0.9-2.7
SPRAY TRANSFER	6-12	2.7-5.4
GLOBULAR TRANSFER	4-7	1.8-3.2
PULSED SPRAY TRANSFER	2-6	0.9-2.7

Dip TRANSFER

- * USED With Relatively Low Welding Currents It also Uses Electrode Wire Sizes Under 0.045" (1.1mm)
- * All Position Welds are Made Easily
- * Short Circuiting Transfer Has a Low Heat Input Into the Base Metal
- * The Continuously Feed Electrode Again touches the Molten Pool and the process Repeats
- * Main Problem With this Transfer is Weget Lack of Side Wall Fusion and High Level of Spatter

- * To Reduce the High Spatter level We are using Electrical Circuit Called Inductance
- * If a 150A Current is Set on the arc Welding Machine, the Amperage May Rise Rapidly to the Maximum output of the Machine When the Electrode Short-Circuits

SPRAY TRANSFER

- * The Current and Voltage Setting are Increased above those Required For global Transfer
- * Droplets Travel at a High Rate of Speed Directly through the Arc Stream to the Weldpool
- * Spray Transfer Will Only take place When a High Percentage of Argon is used
- * The Droplets are Squeezed off Cleanly and Transferred Across the Arc Gap in a Straight path
- * Spray Transfer Occurs Only When at least 90% Argon is used as the Shielding Gas
- * Common Shielding gas Mixtures For Carbon and Low Alloy Steel are 98% Ar plus 2% O_2 , 95% Ar plus 5% O_2 , 95% Ar plus CO_2 and 90% Ar plus 10% CO_2
- * The Spray transfer Method Produces deep Penetration
- * Spray Transfer is Best Done in the Flat or Horizontal WELDING position

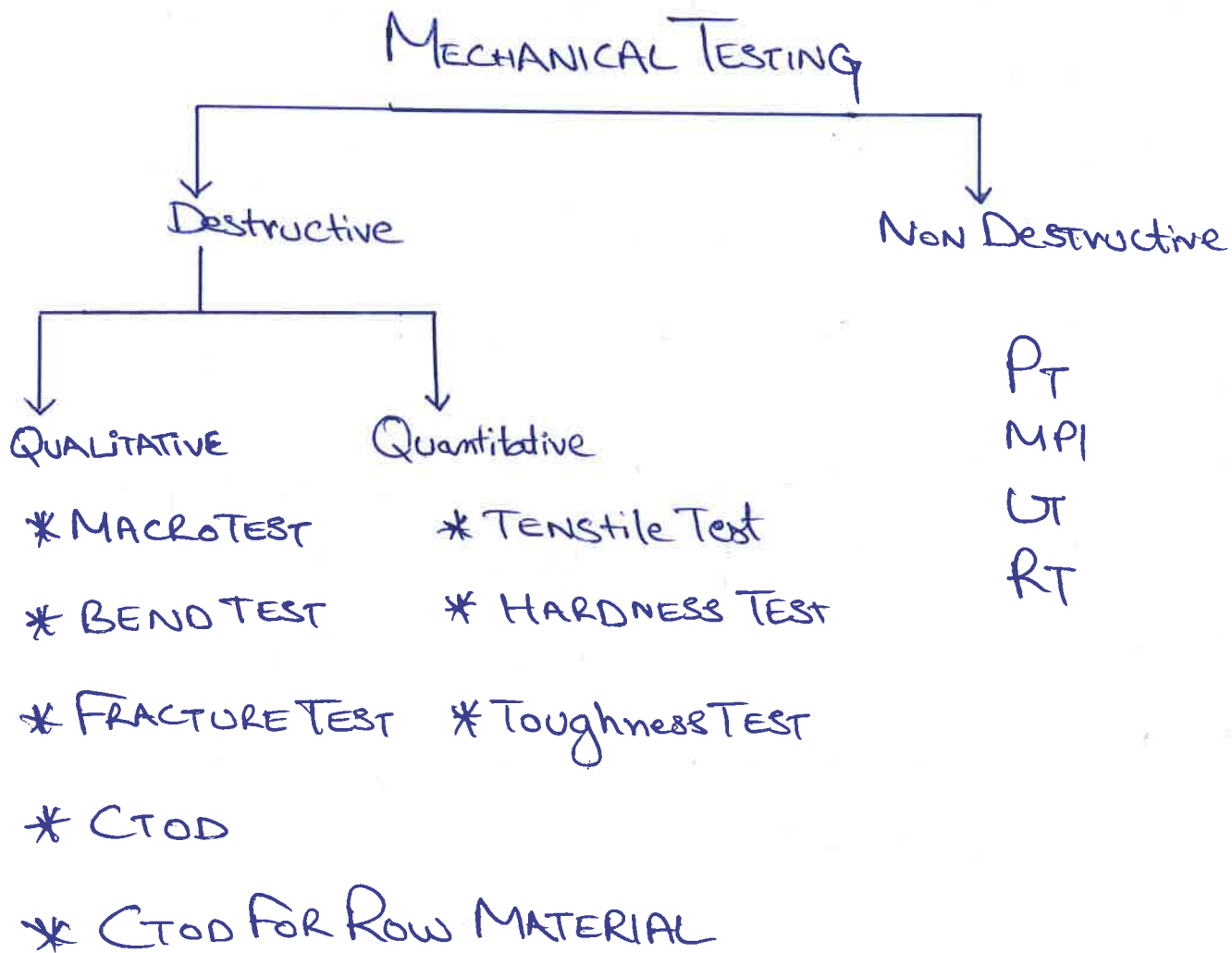
PULSED TRANSFER

- * Special Circuits Within Power Source (WELDING MACHINE) Cause to Pulse
- * A Low Level Current In the globular Transfer Range to used to Maintain the ARC
- * The Current is Increased at a Regular Frequency to the Peak Current
- * the Rate of Metal Transfer Increase and the droplet Size decreases as the pulse Frequency Increases
- * This Method Creates Very Little Metal Spatter
- * The Pulsed Spray Transfer Method Can use Large Diameter Electrode Wire

GLOBULAR TRANSFER

- * Occurs When the Welding Current is set Slightly above the Range used for Short Circuiting Metal
- * In the globular Metal Transfer process the Metal Transfer Across the ARC as large, Irregular Shaped Drops
- * Drops May Fall Erratically and Cause Spatter
- * one way to Minimize Spatter when using CO_2 is to Increase the current Slightly

* When Using globular transfer welding Can be Done Only in flat welding position



QUALITATIVE TEST :- these tests are performed to check the quality. these don't have any units (Eg:- Fracture test, BEND test, Macro test)

QUANTITATIVE TEST :- These tests are performed to measure the mechanical properties. these tests have units (Tensile, Hardness, Toughness)

TEST PERFORMED TO QUALITY WELDING PROCEDURE

TENStile , Hardness , BENDtest , Toughness

TEST DONE TO QUALIFY A WELDER (WQT)

Fracture Test , BENDTEST , MACROTEST

MECHANICAL PROPERTIES

HARDNESS

- * It is the property of the Material to Resist Surface Indentation
- * Measurement of a Materials Surface Resistance Indentation From another Material by Static Load
- * A steel Weldment With a hardness above a Certain Maximum may be Susceptible to Cracking during Fabrication or in Service

TOUGHNESS

- * It is a Property of the Energy Required by Material to With Stand Impact Load
- * Ability of a Material to Withstand Bending or the application of Shear Stress by Impact Loading without fracture

- * Toughness Value of a Carbon Manganese & Low alloy Steel goes Down on Low temperature it is applied & Also by Variation in the Heat Input Induced
- * the unit of the toughness is joules

TENSILE STRENGTH

- * Measurement of the Maximum Force Required to fracture bar of unit Cross Sectional Area Tension
- * Its an Internal Strength or property of a Material to Withstand the pulling Load or tensile Load with Plastic Deformation.
- * The unit of the tensile Strength is N/mm^2

Ductility

- * Ability of a Material under go Plastic Deformation under Static tensile Loading without Rupture
- * Measurable through Elongation and Reduction in Cross Section Area

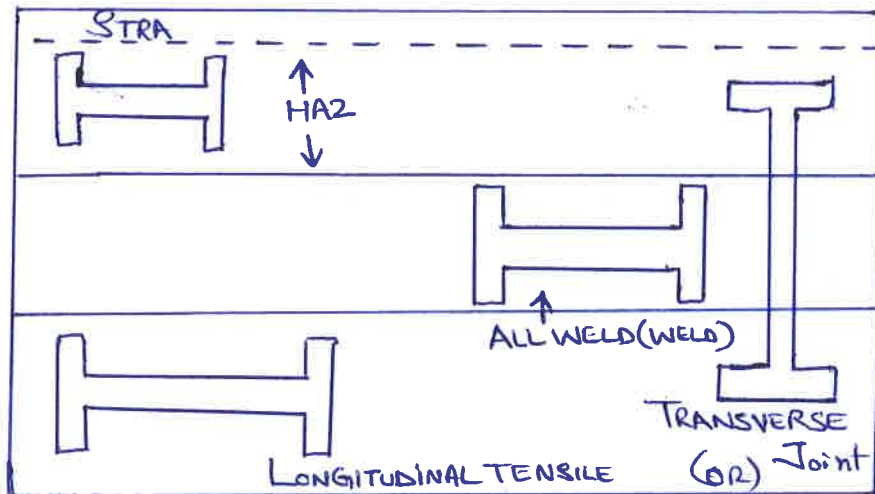
BRITTLENESS

- * MATERIAL having high hardness take Less time to failure in Response to the impact Load given then those Materials are Considered as brittle Material

* A Material is Brittle if when Subjected to Stress It breaks Without Significant Deformation

TENSILE TEST

Types of TENSILE TEST STRA - Short transverse Reduction in Area



ULTIMATE TENSILE STRENGTH

$$UTS = \frac{\text{Load given}}{\text{Cross Sectional Area}} = \frac{\text{Newton}}{\text{mm}^2}$$

% OF ELONGATION

$$\text{Change in Length} = \frac{\text{Increased gauge Length}}{\text{Initial gauge Length}}$$

$$\% \text{ of Elongation} = \frac{\text{Change in Length}}{\text{Initial gauge Length}} \times 100$$

ACCEPTANCE CRITERIA

IN Transverse TENSILE test

* If the Break was in base Material it is Acceptable If the Actual Strength Value is Greater than 95% of which is Specified in WPS

Fillet FRACTURE

- * To Break open the Joint through the weld to permit Examination of the fracture Surface
- * Specimens Are cut to the Required Length
- * A Saw cut approximately 2mm is applied • Also the fillet weld Length
- * Fracture Is usually Made by Striking the Specimen with a Single Hammer blow
- * Visual Inspection For Defect Such as Lack of fusion Porosity and Solid Inclusion

Butt WELD FRACTURE

- * The Other Name of Butt Weld Fracture is Nick Break Test
- * Specimen are cut transverse to the weld
- * A Saw cut approximately 3mm in depth is applied Along the weld's Root and Cap
- * Fracture Is usually made by Striking the Specimen with a Single Hammer blow
- * Visual Inspection For Defect Such as Lack of fusion Solid Inclusion and Porosity

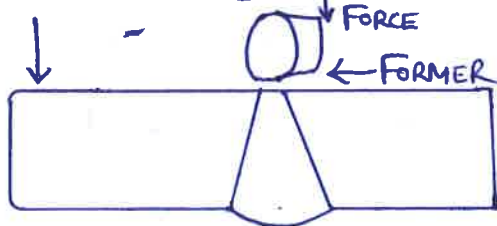
BEND TEST

- * To determine the Soundness of the Weld Zone
- * BEND TESTING Can Also be used to give an Assessment of Weld Zone ductility
- the typical Value of Bending is in the range of $120^\circ - 180^\circ$

TYPES of BEND

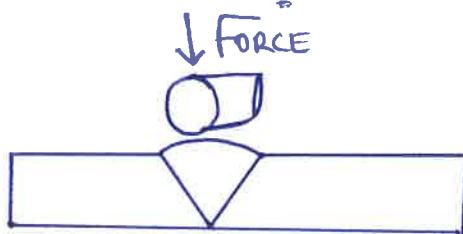
FACE BEND TEST

- * Up to 12mm plate thickness
- * Face will be in tension and root will be in Compression



ROOT BEND TEST

- * Up to 12mm thickness
- * Root will be in tension and Face will be in Compression



SIDE BEND TEST

SIDE BEND TEST Performed When plate thickness is above 12mm It is sometimes used for Welder Qualification Also

DESIGN OF THE FORMER

Diameter of the Former (A) = $4 \times t$ (Plate thickness)

For Low Ductile Material it is lot

5. Throat thickness 20mm Leg Length ?

$$a = 20$$

$$Z = 1.414 \times a$$

$$= 1.414 \times 20$$

$$= 28.28 \text{ mm}$$

6. Leg Length 20 throat thickness ?

$$a = 0.707 \times Z$$

$$= 0.707 \times 20$$

$$= \underline{14.14 \text{ mm}}$$

NOTES ON IMPACT TOUGHNESS TESTING

After CHARPY TEST IF THE SURFACE IS

* Rough & torn (lateral expansion) Then it is Ductile

* Flat & Crystalline than it is Brittle Failure

* Beach mark and Smooth than it is Fatigue failure

WELDABILITY

*Hardness ↑ toughness ↓
Strength ↑*
Weldability Simply means to be welded and many types of weldable Steel have been Developed For a Wide Range of Application

*Hot crack - sulphur
Cold shut - phosphorus*

Steel is usually said to have poor Weldability If it is necessary to take Special precaution to Avoid a particular type of Imperfection.

ALLOYING ELEMENTS AND ITS EFFECTS

IRON(Fe)° - Main Steel Constituent on its own is relatively soft ductile with Low Strength

Carbon(C)° - Major Alloying Elements in Steel
Strengthening Elements with major Influence on HAZ
Hardness Decreases weldability (typically < 0.25)

Silicon(Si)° - Residual Element From Steel
De Oxidation (typically to 0.35%)

Manganese(Mn)° - Secondary only to Carbon for Strength,
Toughness and ductility Secondary de Oxidation and
also reacts with Sulphur to form Manganese
Sulphide up to 1.6% (in C-Mn Steel Improves Strength &
Toughness)

Phosphorus(P)° - Residual Element From Steel
Making Minerals, difficult to Reduce below < 0
Brittleness

Sulphur(S)° - Residual Element from Steel
making Minerals

Aluminium(Al)° - De Oxidant and Grain Size
Control (typically 0.02 to 0.05%)

Chromium : (Cr) Corrosion Resistance

Vanadium : (V) For Strength

Nickel (Ni) : - For low Temperature applicable Mainly alloyed in Stainless Steel for Oxygen services

CLASSIFICATION OF STEELS

Low Carbon Steel 0.01 - 0.3% Carbon

Medium Carbon Steel 0.3 - 0.6% Carbon

High Carbon Steel 0.6 - 1.4% Carbon

Carbon STEEL

Carbon Contents up to about ~ 0.25%

Manganese up to ~ 0.8%

Low Strength and Moderate toughness

Carbon Manganese STEEL

* Manganese up to 1.6%

* Carbon Steel with Improved toughness due to additions of Manganese

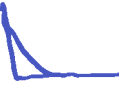
* Low Alloy Steel < 7% alloying elements More Susceptible for Hydrogen Cracking Having Less Strength and Moderate toughness

* High Alloy Steel > 7% alloying elements has High Strength

SHAPE OF FILLET WELD

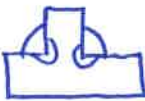
MITRE Fillet WELD  Equal Leg Length

CONVEX Fillet WELD  WELD FACE - EXCESS WELD

CONCAVE Fillet WELD  Design throat

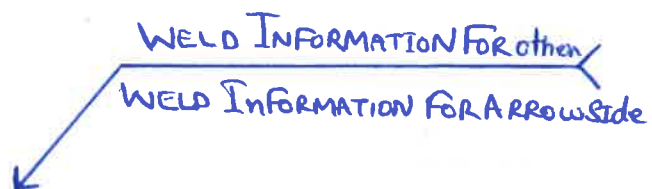
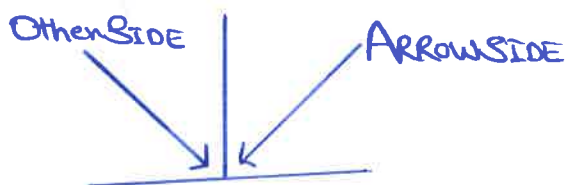
Asymmetrical Fillet weld  Vertical Leg Length Not Equal

Deep Penetration Fillet weld  Deeper than Normal Penetration

Compound Fillet weld  Compound of Butt & Fillet

TYPES OF CRACK

- * Longitudinal Crack, Transverse CRACK
- * Radiating (Crack Radiating From a Common Point)
- * CRATER
- * BRANCHING (Group of Connected CRACK's)



SIZE OF Fillet WELD

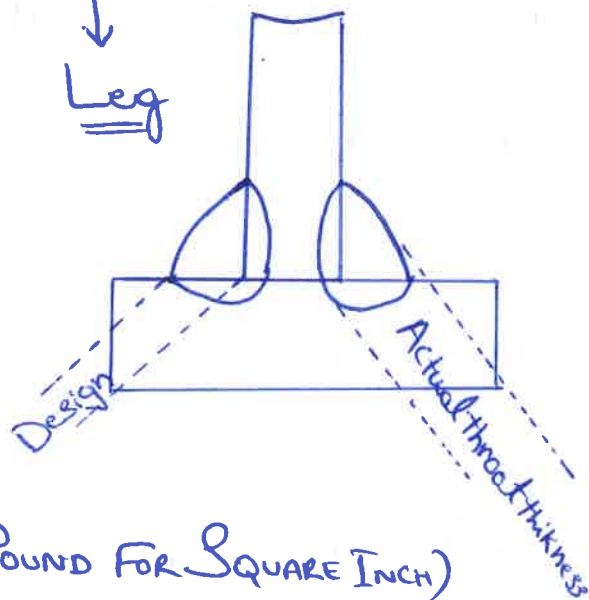
- * Actual throat thickness
- * Design throat thickness (A)
- * Leg Length (Z)

FORMULA

$$A = 0.707 \times Z (\text{Leg}) - Z = 1.41 \times A (\text{throat})$$

↓
WELD throat

↓
Leg



7016

$70 \times 1000 = 70,000 \text{ PSI (POUND FOR SQUARE INCH)}$

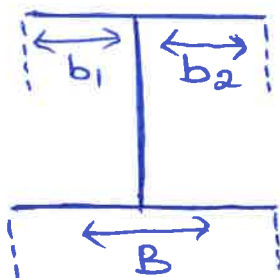
70 - Strength of WELD

1 - Position

6 - Electrode Flux Coating (Penetration Current use type)

X - Indication What Alloys are in these Electrode

Distortion Formula



$$b-1-68$$

$$b-2-64$$

$$C = \frac{68-64}{2} = 2$$

AUSTENITIC STAINLESS STEEL

- * Alloyed with 18% Chromium 8% Nickel (eg - 304 & 316)
- * Main phase is Austenitic - High Strength and toughness
- * Applicable for Very Low temperature Service (Cryogenic) and High temperature Service
- * Corrosion Resistant
- * Non Magnetic
- * Low Thermal Conductivity High Expansion Coefficient
More distortion during Welding
- * Martensite - High Hardness Leads to CRACK the Hardest phase in Steel, which is produced by Rapid Cooling from the Austenite phase. It mainly occurs below 300°C
- * Duplex Stainless Steel high Level of Chromium it could withstand any type of Corrosion
- * It contains 20% - 25% of Chromium called duplex because there are 2 phases 50% ferrite 50% austenite

HYDROGEN CRACKING

Also known as

- * HAZ Cracking (Occurs in HAZ)
- * Cold Crack (Fast Cooling)
- * Delayed Crack (Occurs 48-72 hrs)
- * Underbead Crack (In Fillet weld)

It Occurs in Heat Affected Zone

Source of Moisture pickup in Electrode and high Moisture Level in Shielding gas

FACTORS AFFECTING HYDROGEN CRACKING

- * Hydrogen $> 15 \text{ ml/100g}$ of weld metal deposited
- * Cooling RATE $< 300^\circ\text{C}$ (Fast Cooling)
- * Hydrogen $> 450 \text{ Hv}$ (300-350 Hv)
- * Susceptible Microstructure - Martensite
- * Stress > 0.5 yield of Material

MATERIALS PRONE TO HYDROGEN CRACKING

- * Carbon Steels
- * Carbon Manganese Steel
- * High Strength Low alloy Steel
- * Material High CEV - Carbon Equivalent Value

$$\text{CEV} = \%C + \frac{\text{Mn}}{6} + \frac{\text{Cr} + \text{Mo} + \text{V}}{5} + \frac{\text{Ni} + \text{Cu}}{15}$$

Mo - Molybdenum Cu: Copper

CEV < 0.45

Higher the CEV Higher the tendency of Hydrogen Cracking the HAZ Hardness Increases

WELDING PROCESS AND HYDROGEN Level

TIG $< 3 \text{ ml}$

MIG $< 5 \text{ ml}$

MMA (If use basic electrode) $> 5 \text{ ml}$

SAW $< 10 \text{ ml}$

FCAW $< 15 \text{ ml}$

HYDROGEN CONTENT RELATED TO 100gms of weld metal Deposited

Scale A - High $> 15 \text{ ml}$

Scale B - Medium $10 \text{ ml} - 15 \text{ ml}$

Scale C - Low $5 \text{ ml} - 10 \text{ ml}$

Scale D - Very low $3 \text{ ml} - 5 \text{ ml}$

Scale E - Ultra Low $< 3 \text{ ml}$

PREVENTION

- * USE Low hydrogen Electrode (Especially basic)
- * Maintaining Proper heat Input (high input Low tough)
- * Avoiding Stress raiser
- * Ensure plate is free from rust, oil, Paint and other Coating
- * Maintaining proper preheat
- * Avoid poor weld profile

WELD DECAY

- * Its an Inter granular Corrosion In Stainless Steel
- * Also Called Sensitization of Stainless Steel (Sensitive to Corrosion)
- * Other Name is Knife Line attack
- * It Occurs in weld HAZ
- * Happen in austenitic Stainless Steel

CAUSES

- * The Elements Chromium and the Carbon Present In the Stainless Steel Combine to form Chromium Carbide during the welding



* This Chromium Carbide Compound depletes the grain boundaries by setting in between the grain boundaries

* Due to the formation of compound there is no enough Chromium left to support the material towards Corrosion. This leads to Corrosion

PRECAUTION

* Select material having Low Carbon Level such as 316L, 304L, etc

* Stabilized grade Stainless Steel eg:- 321, 347, 348 Recommended for severe Corrosive conditions and High temperature operating conditions containing Ti or Nb to form Carbides preferentially to Cr

* Sensitized Stainless Steel could be desensitized by Applying PWHT is also called Solution heat treatment where the temperature is above 1000°C ($1050-1100^{\circ}\text{C}$)

SOLIDIFICATION CRACKING

* Sulphur Content in the parent metal

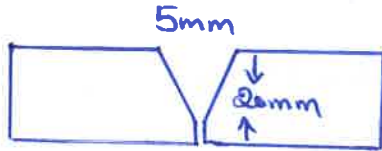
* Sulphur + Iron $\rightarrow$ Iron Sulphide (980°C)

* During Solidification the Sulphur present in the parent metal, due to the high dilution combine with Iron to form Liquid Iron Sulphide film in the weld metal

* Liquid Iron Sulphides film in between the Solidifying grain passes the tensile stress which lead to Crack (weld Center Line)

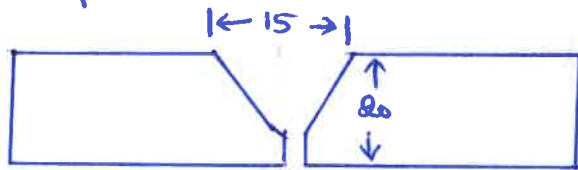
* Also due to the width to depth Ratio

* IF the depth of groove is more compared to width leads to Solidification Crack (deep and



Higher dilution Levels
faster Cooling

$$\frac{\text{Width}}{\text{depth}} = < 0.7 = \frac{5}{20} = 0.25$$



Lower dilution Level
Slower Cooling

$$\frac{\text{width}}{\text{depth}} = > 0.7 = \frac{15}{20} = 0.75$$

PRECAUTION

- * The use of high Manganese and Low Carbon Content fillets
- * Select the Materials having no Impurities Such Sulphen and phosphorus
- * Keep the Joint free from grease, oil, Paint and other Sulphur Content products
- * Select the proper Joint design Maintaining depth to width Ratio

* By finding out the Reduction in area we could get the ductility Value

* IF it is less than Critical Value which is considered as safe than it leads to Crack

PREVENTIVE MEASURES

* Check for Lamination in Rolled plates

* Use Controlled Low Sulphur plate ($<0.05\%$)

* Redesign of the weld

* Redesign of the Joint

* Using a forged T Pieces only in Critical application

* Check through thickness ductility above the Critical point to avoid the problem

* Use of Buttering Layer of high ductility weld Metal beneath the Member to be welding

Enabling the Contractual Stress to be observed

* Use Minimum Restraint

HEAT TREATMENT

- * PRE Heat
- * Post Heat
- * PWHT

PRE HEAT

- * It is done before welding any Material
- * There are so many reasons for doing but mainly Done to Avoid hydrogen Cracking
- * PRE Heating of Steel will drive out the Moisture So Hydrogen get Evolved from the plate
- * Second Reason is to slow down the Cooling RATE of weld and HAZ
- * Slow down the Cooling RATE Reduces the formation Hard Micro Structures.
- * PRE Heat Also Lowers the Stress between the weld and Parent Metal
- * PRE Heat temperature Range depends on material Composition, thickness but tend to be in the Range of $50^{\circ}\text{C} - 250^{\circ}\text{C}$
- * Time allowed for pre Heat is 2min per 25mm

PRE HEAT TEMPERATURE AND INTERPASS TEMPERATURE

- * Preheat temperature is the Minimum temperature at which the welding starts
- * Preheat temperature checked before Commencing First pass and Subsequent passes
- * Interpass temperature is the Maximum temperature Check before Commencing Next pass

If the Material thickness above 5mm then
 $A = 75\text{mm}(\text{min})$

POST WELD

- * Post heat is used to minimize the potential for Hydrogen induced Cracking (HIC)
- * Post heating is DONE after welding
- * Post heating Refers to the Maintenance of Preheat after the weld has been Completed to Allow Increased Rates of hydrogen evolution from the weld to occur
- * After welding has been Completed the Steel Must Not be Allowed to cool to Room temperature Instead it Should be Immediately heated from the Interpass Temperature to the post Heat temperature

- * 230°C is a Common post heating temperature to be maintained for Hour per Inch (25mm) of thickness

Post WELD HEAT TREATMENT

- * PWHT is done after the welding is completed to Relieve the Stress and Soften Any hardened Structure in HAZ
- * It Also improve the Material properties by Retaining Its Phase Structure
- * The typical Stress Relieving temperature is 600°C

PWHT THERMAL CYCLE

PWHT thermal Cycle has three division Namely heating, Soaking and Cooling

Heating RATE

- * It is First Heated gradually to 300°C than to 600°C
- * The heating RATE FOR C-Mn Steel is Above $60 \sim 200^{\circ}\text{C/hr}$

SOAKING

- * Soaking is the process of holding the Material In particular temperature for a time per
- * For C-Mn Steel the Soaking temperature is Same of heating temperature

- * For C-Mn which is used at elevated temp in the range of $700-760^{\circ}\text{C}$
- * It is Monitored Using Thermo Couples
- * Soak time period is hour per 2mm thickness

Cooling

- * Once the Soaking is over we have to Cool the Material to ambient temperature
- * The temperature Should be gradually decreased In the Rate of 300°C Less than this will lead to formation of martensite

SOLUTION HEAT TREATMENT

- * It is done to minimize the formation of Chromium Carbide or Simple weld decay
- * Here the heating temperature is above 1000°C ($1050-1100^{\circ}\text{C}$)

Sagging : Undercut at the Top & overlap at the Base

Overlap : Metal Flowing on the Surface of the Parent Metal without Fusing to it

Welding : Most Economical & Efficient way to Join metals Permanently

Weld DECAY : Crack is developed due to Corrosion (HAZ - During Welding Operation) occurs only in (S.S)

111 - MMA

121 - SAW

131 - MIG

135 - MAG

PIPE PQR :

$$\text{PIPE Dia} = \frac{168}{0.5 \times t} = 84$$

14.3 mm thick - 7 — 28

0.5 THK to 2t

0.5 x 14 to 2 x 14

7 to 28

$\geq 0.5D$ (25mm minimum)

$\geq 0.5 \times 168.3$

≥ 84.15

PQR Test °

PASS Number	1	2	3	4
Electrode Diameter	1.2	1.2	1.2	1.2
Electrode Polarity (D.C)	+	+	+	+
Welding Direction	up	up	up	up
Stick out (mm)	-	-	-	-
Wire Speed (m/min/s)	96	86	81	85
InterPASS temperature (C)	106	117	122	127
Travel Rate (mm)	750	750	750	750
ARC time	6.22	3.58	3.42	3.28
Travel Speed min	ANS	ANS	ANS	ANS
Ampere Minimum	153	206	202	166
Ampere MAXIMUM	157	210	208	171
Volts Minimum	23.8	25.2	25.6	22.8
Volts MAXIMUM	23.8	26	26.8	23.1
Heat Input (J/cm)	Joules/cm			

① Arc Time

Apply min than Press 0⁹⁹⁹

Second - Press 0⁹⁹⁹

② Press 10^{-1}

③ Multiply with travel (Plate Length)

Terminal Efficiency

SAW — 1

Tig — 0.6

Other — 0.8

①
$$\frac{\text{Travel in mm (weld length)}}{\text{Arc time (stopwatch)}} = \text{Travel speed}$$

②
$$\frac{\text{Volts min + MAX}}{2} = \text{Volts}$$

③
$$\frac{V \times A \times \text{Prosses (0.8)}}{\text{Travel speed} \times 1000} = \text{Joules/cm}$$

 (Killgram)

$$= \text{Kg} = \frac{\text{ANS}}{1000} = 0.89 \text{ KJ/mm}$$



← 200mm →

ULTRASONIC

$$\tan 45^\circ - 1$$

$$\tan 60^\circ - 1.73$$

$$\tan 70^\circ - 2.74$$

Thickness - 30

SD - 50

$$\frac{200 \text{ Length} - 90 \text{ Hole} \times 100}{110} = \%$$

$$= \frac{110}{200} \times 100$$

$$= 55 \times 100$$

$$= \underline{\underline{55\%}}$$

$$\underline{\underline{45^\circ}} - \text{Full skip} - \underline{\underline{60}} = \text{SD} = 2t \tan = 2 \times 30 \times 1 = \underline{\underline{60}}$$

$$\underline{\underline{60^\circ}} - \text{Full skip} - \underline{\underline{104}} = \text{SD} - 2t \times \tan = 2 \times 30 \times 1.73 = \underline{\underline{103.8}}$$

$$\underline{\underline{70^\circ}} - \text{Full skip} - \underline{\underline{165}} = \text{SD} - 2t \times \tan = 2 \times 30 \times 2.74 = \underline{\underline{165}}$$

$$\% \text{ of } 45^\circ - \frac{50}{60} \times 100 = \underline{\underline{83\%}}$$

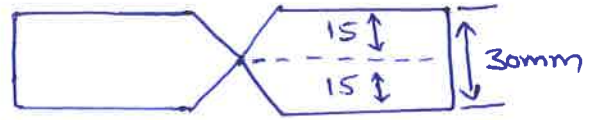
$$60^\circ - \frac{50}{103} \times 100 = \underline{\underline{49\%}}$$

$$70^\circ - \frac{50}{165} \times 100 = \underline{\underline{30\%}}$$

Density (घनत्व)

$$\text{Thickness} \times \text{Width} \times \text{Height} \times 0.785 = \text{Kg}$$

Bevel Preparation



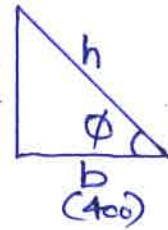
$$\tan \phi (\text{Degree}) \times \text{Thickness (15mm)} = \text{Length}$$

Diagonal Formula (300)

$$\sqrt{300^2} + \sqrt{400^2}$$

$$\sqrt{2,50000}$$

$$= 500 = h^2$$



$$\tan \phi = \frac{\sin \phi}{\cos \phi}$$

$$\sin \phi = \frac{\text{OPP}}{\text{HYP}}$$

$$\sin \phi = \frac{a}{h}$$

$$\cos \phi = \frac{\text{Adj}}{\text{HYP}}$$

$$\cos \phi = \frac{b}{h}$$

$$\tan \phi = \frac{\text{OPP}}{\text{HYP}}$$

$$= \frac{\text{OPP}}{\text{HYP}} \times \frac{\text{HYP}}{\text{Adj}}$$

$$\tan \phi = \frac{\text{OPP}}{\text{Adj}} = \frac{a}{b} = \tan$$

