Guide to weld symbols

For Senior Welding Inspectors CSWIP 3.2

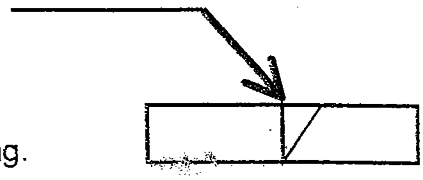
BS 499 BSEn 22553 & AWS A2.4

By A B Whitaker 15-03-02

Inc Eng. Inc M Weld Inst. LCG. EWT.

1) Convention of BS 499 (UK):

The arrow line:

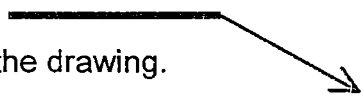


a) **Shall** touch the joint intersection.

b) **Shall** not be parallel to the drawing.

c) **Shall** point towards a single plate preparation.

Reference line:



a) **Shall** join the arrow line.

b) **Shall** be parallel to the bottom of the drawing.

Symbols:

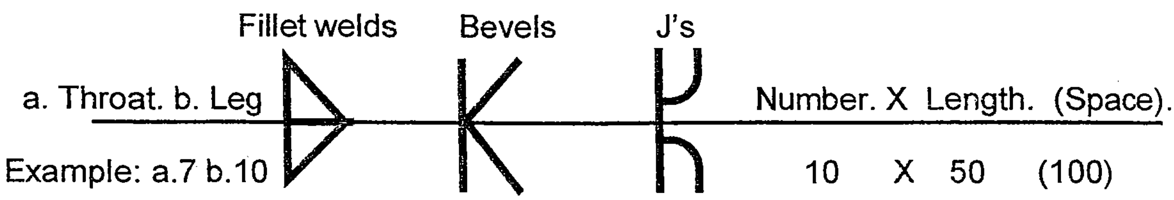
a) Welds this side of joint, go underneath the reference line.

b) Welds the other side of the joint, go on top of the reference line.

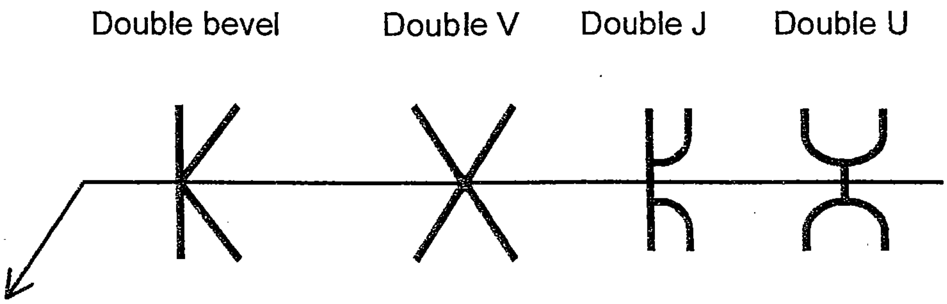
c) Symbols with a vertical line component must be drawn with the vertical line to the left side of the symbol.

d) All cross sectional dimensions are shown to the left of the symbol.

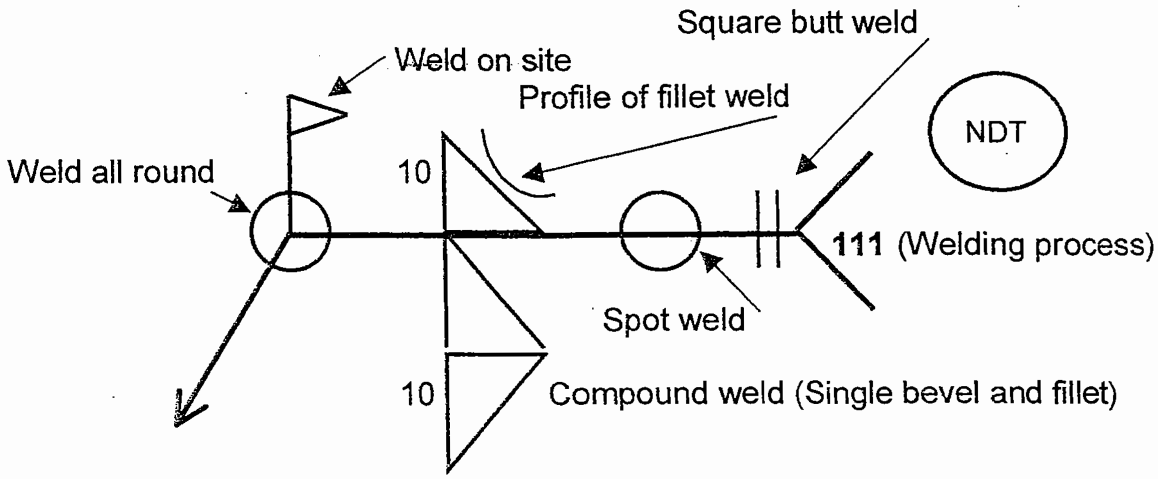
e) All linear dimensions are shown on the right of the symbol i.e. Number of welds, length of welds, length of any spaces.



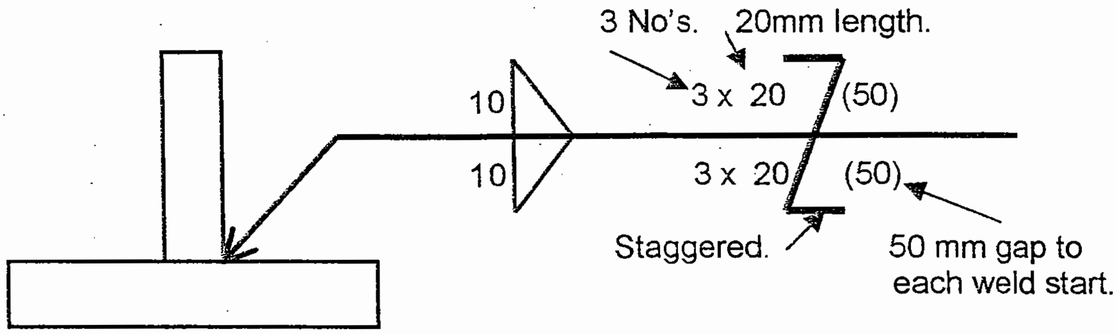
Examples of BS 499 double sided butt weld symbols



2) Supplementary & further weld symbols to BS 499:



Intermittent plug and fillet welds are shown pitched to the **start** of each weld as shown below:

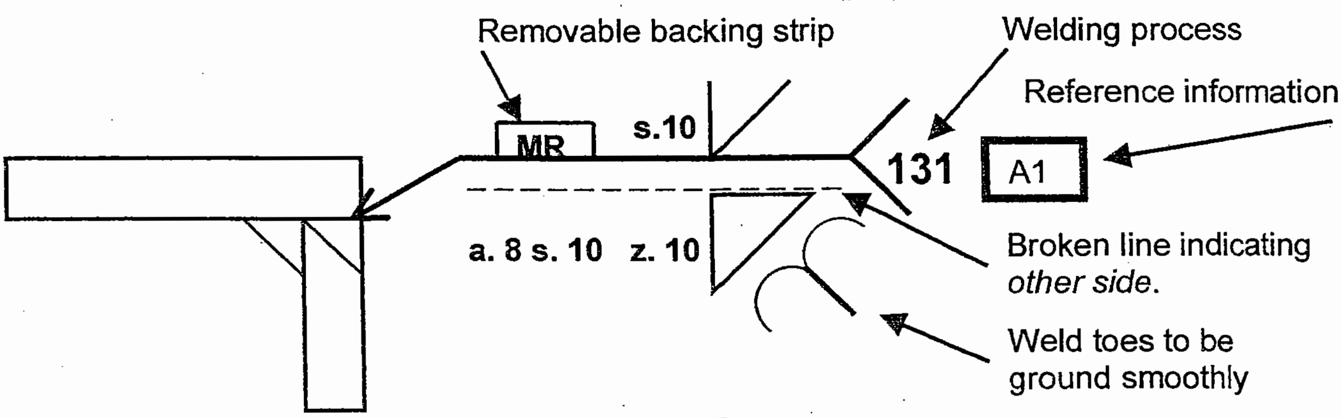


3) Convention of ISO2553/ BS En 22553:

(Has replaced BS 499 in UK & Europe)

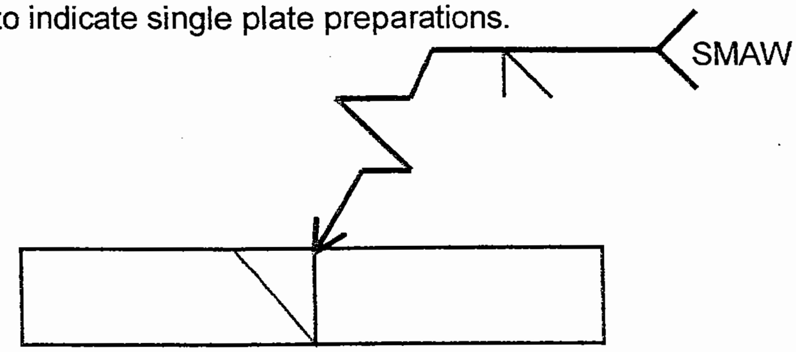
This standard uses a different method to represent arrow side and other side of the weld joint.
A broken line **shall** be shown above or below the reference line, **except** in the case of welds that are totally **symmetrical** about the central axis of the plate

Weld symbols are basically as per BS 499 however, fillet weld leg length **must** always be preceded by the letter **z** and *nominal throat thickness* by the letter **a**. In deep penetration fillet welds and partial penetration butt welds, the *effective throat thickness* must always be indicated by the letter **s**.

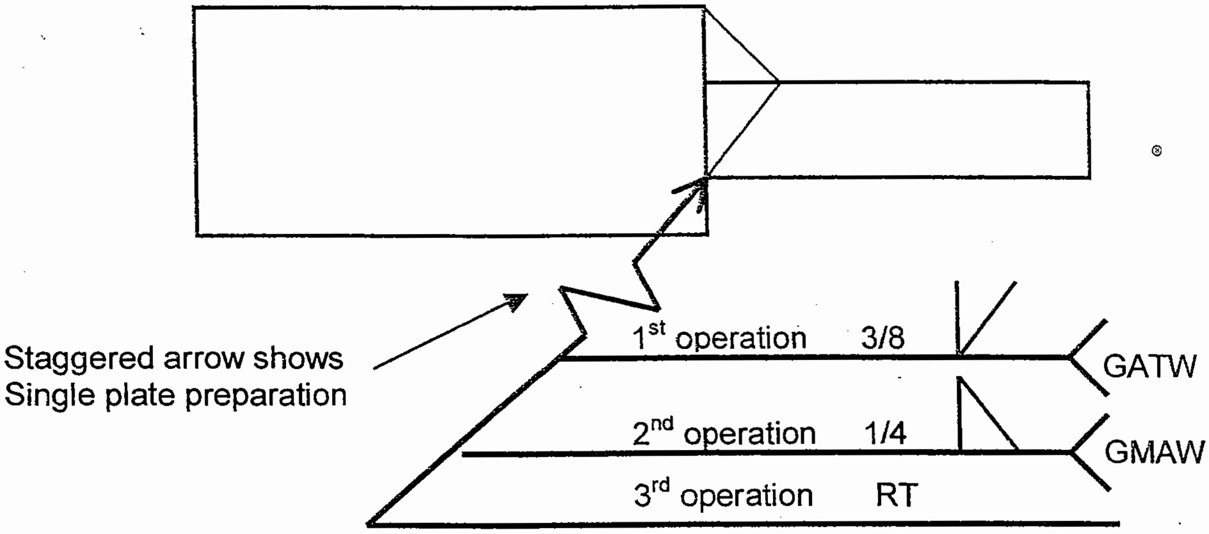


4) Convention of AWS A2.4 (USA):

This standard uses the same convention as BS499 to show this side and other side of the reference line. Some special symbols are used in this standard.
A difference between the conventions is that in AWS A2.4 a change of direction in the arrow line is used to indicate single plate preparations.



AWS A2.4 may also use a number of reference lines from the arrow line to indicate the sequence or procedure of welding.



A further difference between BS 499 and AWS standards is that the AWS A2.4 standard, dimensions the pitch of intermittent fillet welds and plug welds to the **centre** of each weld. (BS dimensions these to the start of each weld)

Staggered intermittent fillet welds are indicated to AWS as below:

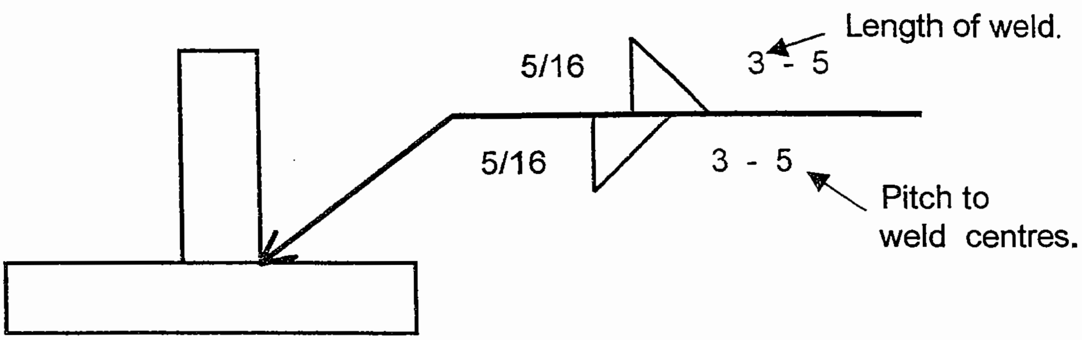


Table 10.* Numerical indication of process

No	Process
1	**Arc welding**
11	Metal-arc welding without gas protection
111	Metal-arc welding with covered electrode
112	Gravity arc welding with covered electrode
113	Bare wire metal arc welding
114	Flux cored metal-arc welding
115	Coated wire metal-arc welding
118	Firecracker welding
12	Submerged arc welding
121	Submerged arc welding with wire electrode
122	Submerged arc welding with strip electrode
13	Gas shielded metal-arc welding
131	MIG welding
135	MAG welding: metal-arc welding with non-inert gas shield
136	Flux cored metal-arc welding with non-inert gas shield
14	Gas-shielded welding with non-consumable electrode
141	TIG welding
149	Atomic-hydrogen welding
15	Plasma arc welding
18	Other arc welding processes
181	Carbon arc welding
185	Rotating arc welding
2	**Resistance welding**
21	Spot welding
22	Seam welding
221	Lap seam welding
225	Seam welding with strip
23	Projection welding
24	Flash welding
25	Resistance butt welding
29	Other resistance welding processes
291	HF resistance welding
3	**Gas welding**
31	Oxy-fuel gas welding
311	Oxy-acetylene welding
312	Oxy-propane welding
313	Oxy-hydrogen welding
32	Air fuel gas welding
321	Air-acetylene welding
322	Air-propane welding
4	**Solid phase welding; Pressure welding**
41	Ultrasonic welding
42	Friction welding
43	Forge welding
44	Welding by high mechanical energy
441	Explosive welding
45	Diffusion welding
47	Gas pressure welding
48	Cold welding
7	**Other welding processes**
71	Thermit welding
72	Electroslag welding
73	Electrogas welding
74	Induction welding
75	Light radiation welding
751	Laser welding
752	Arc image welding
753	Infrared welding
76	Electron beam welding
77	Percussion welding
78	Stud welding
781	Arc stud welding
782	Resistance stud welding
9	**Brazing, soldering and braze welding**
91	Brazing
911	Infrared brazing
912	Flame brazing
913	Furnace brazing
914	Dip brazing
915	Salt bath brazing
916	Induction brazing
917	Ultrasonic brazing
918	Resistance brazing
919	Diffusion brazing
923	Friction brazing
924	Vacuum brazing
93	Other brazing processes
94	Soldering
941	Infrared soldering
942	Flame soldering
943	Furnace soldering
944	Dip soldering
945	Salt bath soldering
946	Induction soldering
947	Ultrasonic soldering
948	Resistance soldering
949	Diffusion soldering
951	Flow soldering
952	Soldering with soldering iron
953	Friction soldering
954	Vacuum soldering
96	Other soldering processes
97	Braze welding
971	Gas braze welding
972	Arc braze welding

*** This table complies with International Standard ISO 4063**

(7)

A. Ramasishi

TECHNICAL NOTES

RAD,U/T,MPI,PEN

PENETRANT/MPI

TEMP. PEN. 5-50 C [ABOVE 50 USE DRY POWDER]

VIEWING LIGHT PEN/MPI 500 LUX +

FLOURESCENT

USE FLOURESCENT INK [NO BACKGROUND]
LAMP POWER UVA 800 MICROWATT/SQ. CM
VIEWING DARKNESS BELOW 10 LUX

MPI

THROUGH PAINT—UP TO 50 MICRON
SUB SURFACE DEFECTS-YES -ON D.C ONLY—2MMDEEP MAX

YOKE NO CURRENT RECORDED
BUT MUST SHOW LIFT POWER 4.5 KG
NORMALLY A.C [BUT CAN BE EITHER]

PRODS 7.5 AMPS/MM [OF SPACE]
TYP. I.E : 200MM SPACE = 1500 AMPS
THEREFORE MUST RECORD SPACE + AMPS

ALL MUST RECORD
2 DIRECTIONS AT 90 DEG
BURMAH CASTROL STRIP INDICATIONS [3 LINES VISIBLE]

ULTRASONICS

PROBES
0 [COMPRESION PROBE] FOR LAMINATIONS

LESS THAN 10MMt – 70
10 – 15MMt --------60+70
15MMt +-------------45+60
OVER @ 50MMt--------45 ONLY

MHz "NORMAL WELDS"—4—5 MHz [HIGHER /LESS PEN]
RECORD CRYSTAL SIZE[USUALL 10MM]/SINGLE/TWIN ?

SENSITIVITY WHAT CALIBRATION BLOCK?
HOLE DIA. + DEPTH [SIDE DRILLED HOLE]

COUPLANT RECORD TYPE

VARIOUS TECH INFO

U/T

ASME V = NDT CODE eg ARTICLE 4 = U/T

F.S.H = FULL SCREEN HEIGHT
B.W.E = BACK WALL ECHO
SINGLE COMP. PROBES HAVE A "DEAD ZONE"; SO DEFECTS MAY BE MISSED.

RECORD BATCH No`s / SERIAL No`s

RAD

$$\text{SENSITIVITY} = \frac{\text{IQI DIAMETER OF SMALLEST WIRE}}{\text{THICKNESS OF METAL UNDER WIRE}} \times 100\%$$

RADIOGRAPHY

X RAY *K.V AS LOW AS POSS.=BEST DEFINITION*

GEN. 80 K.V LOWEST[PERHAPS OK ON ALUMINIUM]
MINIMUM @ 140 K.V FOR STEEL

FOCAL SPOT THE LARGER IT IS / LONGER FFD [FILM FOCUS DISTANCE]

GAMMA SFD TYPICAL @ 500MM [BUT VARIES GREATLY]
SOURSE SIZE TYP. 1.5X1.5 MM

IRIUM 192 NORMAL. COBALT 60 OVER @ 25MM
UTERBIUM ONLY USED ON THIN SECTION [BELOW 10 MM] TIME / COST

SCREENS 0.1 MM FRONT AND BACK GAMMA MUST HAVE X RAY OVER 120K.V

DEVELOPMENT TYP.; 4MINS AT 20 C

DENSITY TYP. 2—3 [EXPECT READINGS ON WELD + PLATE]
SENSITIVITY TYP.2 OR LESS [LOWER IS BEST]

QUALITY CHECK LISTS

RAD,MPI,PENETRANT,U/T

QUALITY CHECK LIST: Radiography

BS 3683 Pt 3 : Terms used in NDT Radiological Flaw Detection

BS 2600 : Methods for radiographic examination of fusion welded butt joints in steel

Pt 1 : 2mm up to and including 50mm thick

Pt 2 : Over 50mm up to and including 200mm thick.

BS 2910 : Radiographic examination of fusion welded circumferential butt joints in steel pipes

BS 3971 : Image quality indicators for radiography and recommendations for their use.

BS 2737 : Radiology of internal defects in castings as revealed by radiography.

Radiography in Modern Industry - Kodak

1) Focal spot or source size and strength should be displayed on the apparatus. Evidence of this to be available.
2) Calibration of densitometers using a traceable film density strip
3) Regular checks to be carried out on safelights.
4) Records to be kept of processing solutions including replenisher.
5) Lead and salt screens to be checked regularly
6) Characteristic curves, exposure charts and IQI charts should be available.
7) Metal step wedges should be available.
8) Radiation safety measures should be employed to the latest regulations. Evidence of radiation monitor calibration should be available.
9) Film storage
10) Certificates of competency.
11) Film test strips should be used for both manual and automatic systems.

QUALITY CHECK LIST: Magnetic Particle

BS 6072 : Magnetic particle flaw detection

BS 4069 : Magnetic flaw detection inks and powders

BS 4489 : Measurement of UV.A radiation (black light) used in NDT

BS 3683 Pt 2 : Terms used in NDT : Magnetic particle flaw detection

BS 5044 : Contrast aid paints used in magnetic particle flaw detection

BS 89 Spec for direct acting indicating electrical measuring instruments and their accessories.

1) Vapour degreaser for acidity

2) Ammeter checks - difference between check ammeter and m/c ammeter shall not exceed 10% of scale reading. Note check ammeter shall be calibrated to a traceable standard.

3) Magnetic ink - composition.
Non-fluorescent - not less than 1.25% and not more than 3.5% by volume.

Fluorescent - not less than 0.1% and not more than 0.3% by volume

Other solids if present not more than 10% by mass of ferro-magnetic content.

Particle size - inks - in at least 99% of a representative sample no particle shall exceed 100μm.

Powders - in at least 99% of a representative sample no particle shall exceed 200μm.

4) Test for solid content and general condition of inks - agitate ink, place sample of 100ml into a settlement flask, allow to settle for 60 minutes. Read off result to nearest 0.1ml. Record as solid contents by volume.

Special test for fluorescent inks - check ink for evidence of yellow - green fluorescence in the supernatant liquid. If observed, discard ink.

5) Functioning test magnetic inks and powders - use ring type test piece, Fig 2 BS 4069. Using 750A (RMS) at least 2 holes should give an indication.

Residual magnetism technique for powders - use test piece Fig 3 BS 4069. Mount test piece on insulated rod, apply 500A DC through threading bar and apply dry powder to each hole in turn commencing with the hole nearest to the surface. Powder should be applied at a distance of 200-300mm.

At least five holes should give an indication.

Magnetic flow technique for inks and powders - use test piece Fig 4 BS 4069. Magnetise test piece parallel to coil axis or use electro-magnets.

The hole should give an indication.

Aerosol containers should be date stamped.

6) Corrosion test - use low carbon steel bar 150mm long, 12.5mm dia, surface texture 3.2um Ra

Partially immerse bar in ink sample for minimum 12 hrs at 25°C

There should be no evidence of corrosion.

7) Black light - check minimum intensity depending upon type.

50 lux or $0.8mW/cm^2$ or $800uW/cm^2$

8) Check level of white light - minimum 500 lux.

9) Permanent magnetic & DC electro-magnets.

Shall have maximum pole spacing of 150mm.

For pole spacing less than 75mm the lifting capacity shall be not less than 0.24kg per mm of pole spacing. If greater than 75mm the lifting power shall be at least 18kg.

AC electro-magnets - for pole spacing of 300mm or less the lifting capacity shall be 4.5kg.

STANDARD No`s

U/T BS 3923

NOW

PEN. BS 6443 `84 BS EN 571

MPI BS 6072

RAD. BS 2600 [GENERAL/PLT]

RAD BS 2910 [PIPE]

NOW

IQI BS 3971 BS EN 462-1

R. SANKAR

Terms Associated with QA/QC 10.30

A Defect: A welding imperfection that falls outside of a level of acceptance in an applied standard*

Classes of defects:

Minor: Unlikely to cause failure of the product*

Major: Likely to cause failure, but small risk of loss of life*

Critical: Extremely likely to cause failure, with high risk of loss of life*

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Duties of a Senior Inspector 10.55

1) **Plan** — An agreed, pre-determined and structured pathway, that meets a specific aim

2) **Organise** — To make all necessary arrangements required to carry out, or fulfil a plan
Ensuring all things are in the correct place at the correct time

3) **Supervise** — To instruct, and control the work of staff in areas for which you are responsible

4) **Audit** — To carry out a periodic and systematic "check" on a system/process to ensure that it has been carried out as specified*

 32

Planning 11.00

"The really nice thing about not planning is that failure comes as a complete surprise and is not preceded by long periods of worry and depression"*

We make plans every day for the most trivial of things

All delegates must have planned to come here today*

Many tools are used for production planning including: Gant Charts. Forward and Reverse Scheduling. Critical Path Analysis. etc*

 33

Planning Task 11.10

Using the following headings and the days on which they will be covered on the course, make a reverse schedule plan to your exam date, utilising your available free time. Your plan needs to be flexible in case there are any changes to the course structure.

Remember that Radiographic Interpretation (Theory, practical, or sensitometry) is not covered on the course syllabus.

Specific theory → >70 % ← Rad' Int
Fractures → = ← Weld symbols
Oral → Success* ← NDT reports

 34

Organisation 11.15

Once an inspection plan has been made the organisation must then begin*

This may involve the following elements:

1) Any training & certification required
2) Staffing the plan
3) Procurement of equipments
4) Transport to/from site, and at site
5) Accommodation and messing
6) Any special needs (Religious etc)
7) Leave cycles etc*

 35

Supervision 11.20

Once a plan has been organised it is essential that control is exercised so that the plan is successfully implemented

A supervisor is essentially a manager of men which requires certain specific management skills:

Each student should give an attribute/skill that they think is important for "effective supervision of welding inspectors"

Student names to be placed next to their choice on the white board*

Do not open next slide until this task has been carried out**

 36

(8)

R. Sankar

Day 1
09.03

- Welcome to the course, Introductions & Admin
- Discussion + Pre course assessment
- Revision
- Supervision, Planning, Organizing, Auditing
- Lunch
- Man Management
- Course Delegate Exercise
- NDT
- Auditing of NDT Reports Part 1*

 1

Day 2
09.04

- Review of day 1 + Open questions)
- Continue Audit of NDT reports.
- Weldability.
- Health & Safety. *

 2

Day 3
09.05

- Review of day 2 + Open questions
- Mechanical Testing
- Welding Procedures
- Advanced Welding Processes
- Welding Consumables
- Weld Symbols*

 3

Day 4
09.06

- Review of day 3 + Open questions
- Heat Treatments
- Introduction to Modes of in Service Failure
- Fatigue, Ductile & Brittle Fractures
- Fractured Surface Review
- Fractured Surface Reporting Practice
- Revision
- WIS 10 E End of Course Assessment
- End of course review*

 4

Day 5
09.07

For WIS 10 E CSWIP 3.2 Exam 9am – 5pm

For WIS 10

- Review of days 1 - 4 + Open questions
- End of Course Assessment
- Review of Course
- Open Questions
- Course Disperse *

 5

The CSWIP 3.2 Exam
09.09

Specific Theory/Practical:

4 from 6	Time 1 hr 15 minutes
Weld Symbols	Time 1 hr
Fractured Surfaces x2	Time 1 hr
NDT Reports x 3	Time 1 hr
Oral	Time 15 min's

Radiography: Holders of PCN or CSWIP Rad Int level 2 exempt

Radiographic Interpretation x 6	Time 1 hr 30 minutes
Multi Choice Radiography	Time 30 minutes
Sensitometry	Time 1 hr

Total exam time: 7 hours 30 minutes *

 6

Terms & Definitions

09.32

A Weld:* A union between materials caused by heat, and or pressure

A Joint:* A configuration of members

 7

Types of Welds

09.33

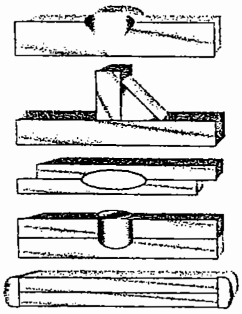
Butt welds:

Fillet welds:

Spot/Seam welds:

Plug/Slot welds:

Edge welds:



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Types of Joints

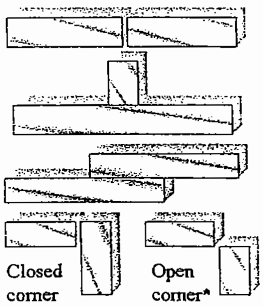
09.35

Butt joints:

T joints:

Lap joints:

Corner joints:

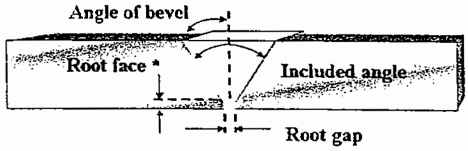


 9

Weld Preparations

09.37

Sometime we need to prepare the joint to successfully carry out the process of welding. i.e. Full fusion through the faces and access for the process. The terms for V and bevel butt welds are given below



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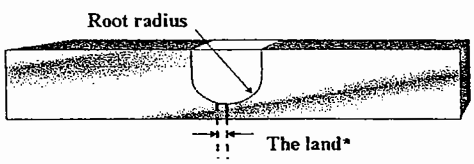
Weld Preparations

09.38

For U & J preparations there are other measurements that need to be known and given when machining the preparation



 11

Types of Single Butt Preparation

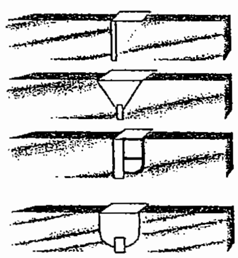
09.40

Single bevel

Single V

Single J

Single U*



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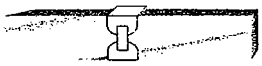
Types of Double Butt Preparation 09.41

Double bevel 

Double V 

Double J 

Double U* 

Weld Preparations 09.43

Remember, the purposes of a weld preparation is to allow access for the welding process, penetration and fusion through the area of the joint and its faces

The basic rule is this:

The more you take out, then the more you must put back in.

This has major effects on economics and distortion control etc

The root face, root gap and angle of bevel values, the choice of single, or double sided preparations, are dictated only by the type of welding process, the position and accessibility of the joint*

Welded Joints 09.45

Butt Joints

A *butt* welded butt joint 

A *fillet* welded butt joint 

A *compound* welded butt joint* 

Welded Joints 09.46

T Joints

A *fillet* welded T joint 

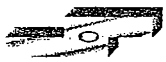
A *butt* welded T joint 

A *compound* welded T joint* 

Welded Joints 09.47

Lap Joints

A *fillet* welded Lap joint 

A *spot* welded Lap joint 

A *compound* welded Lap joint* 

Welded Joints 09.48

Closed Corner Joints

A *fillet* welded Closed Corner joint 

A *butt* welded Closed Corner joint 

A *compound* welded Closed Corner joint* 

Welded Joints
09.49

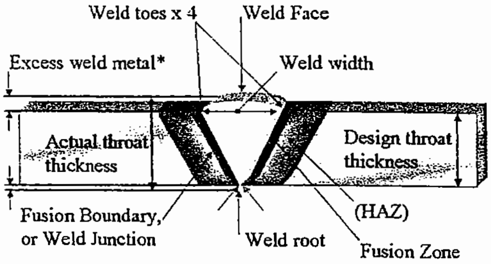
Open Corner Joints

An *inside fillet* welded Open Corner joint

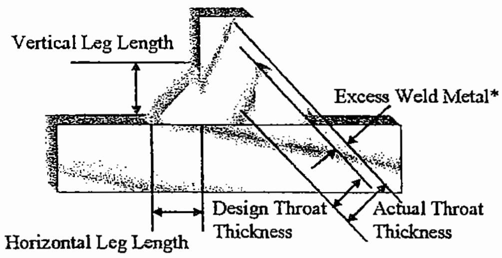
An *outside fillet* welded Open Corner joint

A *double fillet* welded Open Corner joint*

A Butt Welded Butt Joint
09.55

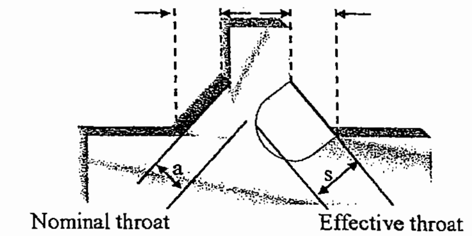


Sizing of Fillet Welds
09.57



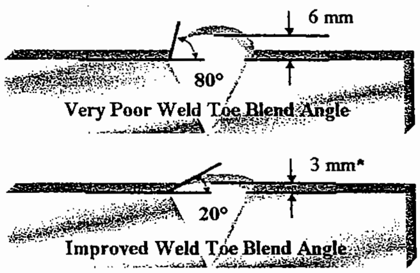
Nominal & Effective Throat Thickness
10.00

Same leg length

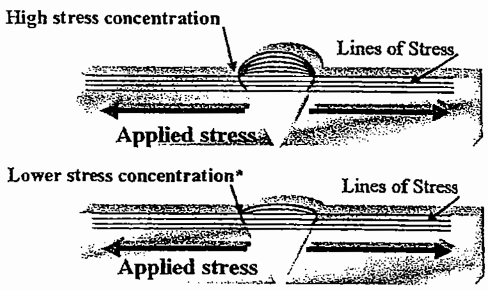


Deep throat fillet welds from FCAW & SAW etc*

Effect of a Poor Toe Blend Angle
10.02

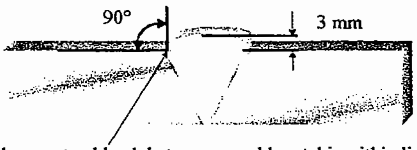


Effect of a Poor Toe Blend Angle
10.05



Effect of a Poor Toe Blend Angle 10.07

It is also possible that the height of excess weld metal is **within the accepted limit** of an applied standard, but the toe blend is **unacceptable**, as shown below



Extremely poor toe blend, but excess weld metal is within limits*

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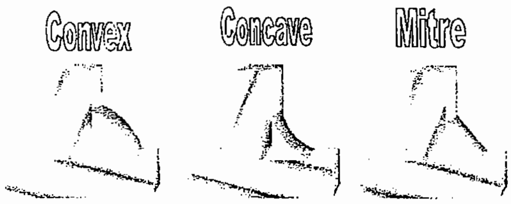
Fillet Weld Profiles 10.10



Concave is preferred for joints subject to fatigue loading*

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Summary of Basic Terms 10.15

Weld:	A Union of materials
Joint:	A Configuration of members
Weld Preparation:	Preparing a joint to allow access and fusion.
Types of Weld:	Butt. Fillet. Spot. Seam Plug. Slot. Edge.
Types of Joint:	Butt. T. Lap. Corner (Open & Closed)
Types of Preparation:	Bevel's. V's. J's. U's. Single & Double.
Preparation Terms:	Bevel/included angle. Root face/gap. Land/Radius
Weldment Terms:	Weld face & root. Fusion zone & boundary. HAZ. Weld toes. Weld width
Weld Sizing (Butts):	DTT. ATT. Excess weld metal.
Weld Sizing (Fillets):	DTT. ATT. Excess weld metal. Leg length*

 27

Terms Associated with QA/QC 10.18

Quality Assurance: All the planned and systematic actions and activities, required to provide adequate confidence in a product

What is wanted!!*

Quality Control: The operational techniques and activities used to fulfil quality.

What must be done, in order achieve what is wanted*

 28

Terms Associated with QA/QC 10.22

In process inspection: Inspection & surveillance carried out during production*

Non – Compliance: A written report, that states that a clause or instruction in the contract documents, code or standard cannot be, or was not met*

Concession: An agreed deviation (with the customer) from a pre-agreed path, or specification*

 29

Terms Associated with QA/QC 10.25

Inspection Specification: A document containing, or referring to all information required in the level of inspection for a product*

Certificate of Conformance: A signed certificate, declaring that a product has been produced in accordance with a specification*

 30

Attributes of an Effective Supervisor 11.25

Attributes/Skills of an effective Senior Welding Inspector*

- •Honesty
- •Planning skills
- •Organisational skills
- •Responsible
- •Delegation skills
- •Motivation skills
- •Decisiveness
- •Analytical*
- •Knowledgeable
- •Experienced
- •Leadership skills
- •Communication skills
- •Record keeping skills
- •Impartial & fair
- •Problem solving skills
- •Diplomatic etc. etc.*

 37

Auditing 11.28

Audit: To carry out a periodic and systematic "check" on a system/process to ensure that it has been carried out as specified*

- Staff
- Equipment
- QA/QC/Inspection
- Documentation (**i.e.NDT reports**)
- Health & Safety

 38

Responsibilities of a Senior Inspector 11.30

For a supervisor the principles are:

Identify: Find the facts!

Measure: Assess the facts!

Observe: Implement & monitor!

 39

Non Destructive Testing 14.02

We use Non Destructive Testing (NDT) when we wish to assess the integrity of a structure without destroying it

The 4 of the common types of NDT used when assessing weldments are:

- Penetrant Testing.
- Magnetic Particle Testing.
- Ultrasonic Testing.
- Radiographic Testing*

 40

Penetrant Testing 14.05

Procedure

First the work must be cleaned thoroughly, then a penetrant is applied for a specified time*

Once the contact time has elapsed, the penetrant is removed and a developer is then applied*

Any penetrant that has been drawn into a crack by capillary action will be drawn out into the developer*

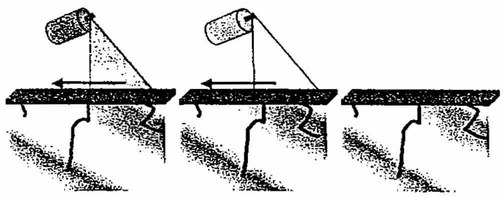
Two types of penetrants are:

1) Colour contrast 2) Fluorescent Penetrant*

 41

Colour Contrast Penetrant 14.07

Method



Apply Penetrant — Clean then apply Developer — Result*

 42

Advantages and Disadvantages 14.10

Advantages	Disadvantages
1) Low operator skill level	1) Highly clean metal
2) All materials	2) Surface flaws only
3) Low cost method	3) Extremely messy
4) Simple equipment	4) No permanent record*

 43

Magnetic Particle Testing 14.12

Procedure

First the work must be cleaned and a whitener applied for contrast. A magnetic flux is then applied by permanent magnet, electro magnet, or straight current*

A magnetic ink is applied which will concentrate in areas of flux leakage, as those caused by flaws*

The weld length must be crossed at 90° by the magnetic field*

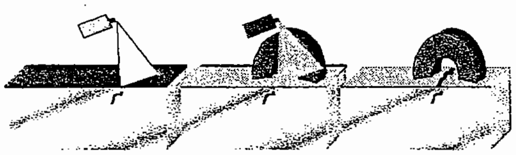
The types of magnetic media used are:
1) Wet ink 2) Dry powder 3) Fluorescent ink*

 44

Magnetic Particle Testing 14.15

Method

Contrast paint Magnet & Ink Result*



 45

Advantages and Disadvantages 14.18

Advantages	Disadvantages
1) Low operator skill level	1) Fe Magnetic metal only
2) Sub surface flaws	2) De-magnetize after use
3) Relatively cheap	3) Can cause arc strikes #
4) Simple equipment	4) No permanent record*

When using the straight current prod technique

 46

Ultrasonic Testing 14.20

Procedure

First the work must be cleaned thoroughly, then a couplant is applied to increase sound transmission*

A probe is then applied with the correct angle for the weld preparation and sound waves are transmitted*

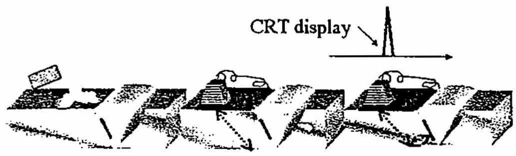
Any imperfections will rebound the sound waves causing a signal to occur on the cathode ray tube*

 47

Ultrasonic Testing 14.22

Method

Apply Couplant Sound wave Result*



Signal rebounded from Lack of fusion

 48

Advantages and Disadvantages 14.20

Advantages	Disadvantages
1) Can find lack of fusion	1) High operator skill
2) Most materials	2) Difficult to interpret
3) No safety requirements	3) Requires calibration
4) Portable/instant results	4) No permanent record*

Radiographic Testing 14.22

Procedure

A film is placed inside a cassette between lead screens.
It is then placed to the rear of the object to be radiographed
A radiographic source, is exposed to the work and film for a pre-calculated time*

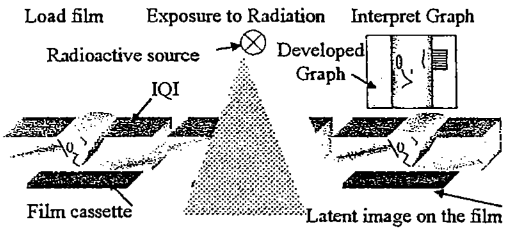
Any imperfections in line with the beam of radiation will be shown on the film after exposure and development*

The 2 types of radiation used in industrial radiography:

1) X rays (from Cathode Ray Tube)
2) Gamma rays (from a Radioactive Isotope)*

Radiographic Testing 14.25

Method



Advantages and Disadvantages 14.28

Advantages	Disadvantages
1) A permanent record ?	1) High operator skill
2) Most materials	2) Difficult interpretation
3) Assess root pen' in pipe	3) Lack of sidewall fusion
4) Gamma ray is portable	4) Safety requirements*

Auditing 14.40

Part of your duties as a Senior Welding Inspector, and therefore also part of your 3.2 final exam, is to audit (or scrutinize) reports for missing, or incorrect information.

A knowledge of NDT is of course essential to carry out this task for NDT reports.

Make a list of the elements that you would consider would need checking on an NDT report, prior to accepting it? (10 Min's)*

Steps for Auditing of NDT Reports 14.45

1 **Check:** Welding process/material/position/preparation.
2 **Check:** NDT method/and technique.
3 **Check:** NDT process parameters.
4 **Check:** All elements relevant to NDT process/materials.
5 **Check:** The NDT procedure & all BS numbers are correct.
6 **Check:** All units are correct for application i.e. mm/cm
7 **Check:** All imperfections identified/sized and located.
8 **Check:** The operators name/qualifications are entered.
9 **Check:** Report has been signed, dated & stamped correctly.
10 **Check: Everything again, "*Carefully*"!!!! ***

R. SANKAR

(3)

Classification of Steels

10.55

Steels are classified into groups as follows:*

Plain Carbon Steels:*

1) **Low Carbon Steel 0.01 – 0.3% Carbon***

2) **Medium Carbon Steel 0.3 – 0.6%** Carbon*

3) **High Carbon Steel 0.6 – 1.4% Carbon***

Plain carbon steels contain only iron & carbon as main alloying elements, traces of Mn Si Al S & P may also be present*

 1

Classification of Steels

11.00

An Alloy steel is one that contains more than Iron & Carbon as a main alloying elements*

Alloy steels are divided into 2 groups:*

Low Alloy Steels< 7% extra alloying elements*

High Alloy Steels> 7% extra alloying elements*

 2

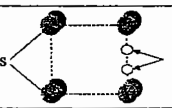
Basic Atomic Structure of Steels

11.05

The following basic foundation information on metallurgy <u>will not</u> form any part of your CSWIP examination*

A most important function in the metallurgy of steels, is the ability of iron to dissolve carbon in solution*

The carbon atom is very much smaller than the iron atom and does not replace it in the atomic structure, but fits between it*



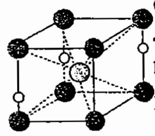
Iron is an element that can exist in 2 types of cubic structures, depending on the temperature. This is an important feature*

 3

Basic Atomic Structure of Steels

11.10

At temperatures below Ac/r 1, (LCT) iron exists like this*



α Alpha iron

This structure occurs below 723 °C and is body centred, or BCC in structure

It can only dissolve up to **<u>0.02% Carbon</u>**

Also known as **Ferrite or BCC iron***

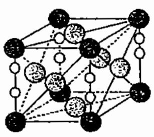
Compressed representation could appear like this

 4

Basic Atomic Structure of Steels

11.15

At temperatures above the Ac/r 3, (UCT) iron exists like this*

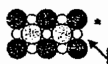


γ Gamma iron

This structure occurs above the UCT in Plain Carbon Steels and is FCC in structure.

It can dissolve up **<u>2.06% Carbon</u>**

Also called **Austenite or FCC iron***



Compressed representation could appear like this

 5

Basic Atomic Structure of Steels

11.17

If steel is heated and then cooled slowly in equilibrium, then exact reverse atomic changes take place*

If a steel that contains more than 0.3% Carbon is cooled quickly, then the carbon does not have time to diffuse out of solution, hence trapping the carbon in the BCC form of iron.

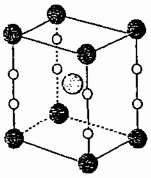
This now distorts the cube to an irregular cube, or tetragon*

This supersaturated solution is called **Martensite** and is the hardest structure that can be produced in steels*

 6

Basic Atomic Structure of Steels 11.20

If some steels are cooled quickly their structure looks like this*



Martensite can be defined as:

A supersaturated solution of carbon in BCT iron (Body Centred Tetragonal)

It is the hardest structure we can produce in steels*

Compressed representation could appear like this

The Important Points of Steel Microstructures 11.22

Solubility of Carbon in BCC & FCC phases of steels*

Ferrite: α Low carbon solubility. Maximum 0.02%*

Austenite: γ High carbon solubility. Maximum 2.06%*

Martensite: The hardest phase in steels, which is produced by rapid cooling from the Austenite phase
It only occurs below 300 °C*

Hardenability in Steels 11.25

This is a term used to describe the ability of a steel to harden through a cross section. We now understand the mechanism of hardening and its reliance on the rate of cooling from above the UCT of the steel*

The **Hardenability** of a steel is affected by the influence of the alloying elements in delaying the transformation temperatures of a steel *

Each alloying element has a different severity on this effect and from thus was borne the following formulae

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

Time Temperature Transformation 11.30

The Fe/C equilibrium diagram is of little use to the engineer when it comes to practical heat treatments, as all phases are shown in equilibrium cooling*

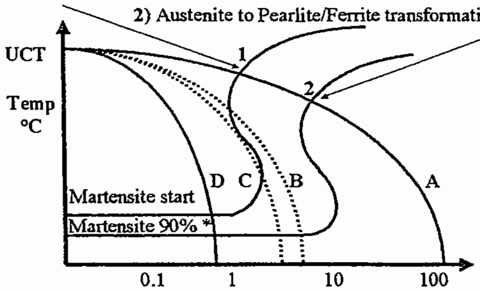
To understand the relative phases of a steel under differing cooling conditions we need to produce a diagram that gives this information*

A Time Temperature Transformation diagram shows us this information, and a different diagram is produced for any one type of steel. The following diagrams show how the effect of carbon and alloying elements effect the hardenability and hence the depth of hardening of steels*

TTT Curve for a Medium Carbon Steel 11.35

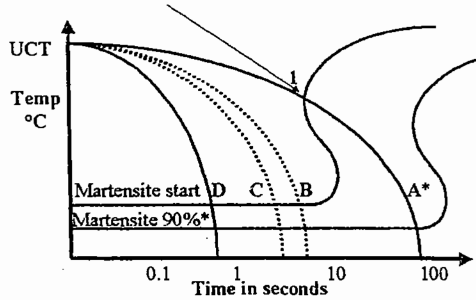
1) Austenite to Pearlite/Ferrite transformation begin*

2) Austenite to Pearlite/Ferrite transformation end



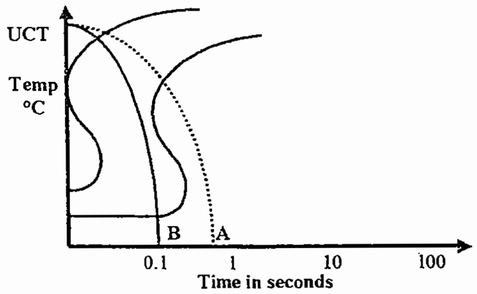
TTT Curve for a Low Alloy Steel 11.40

1) Austenite to Pearlite/Ferrite transformation begin.



TTT Curve for a Low Carbon Steel

11.45



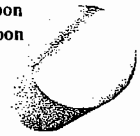
Effect of Hardenability

11.50

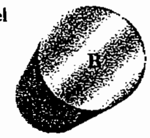
Hardenability has a major effect on the weldability of steels*

Consider 2 round bars of the same cross sectional area:

Plain Carbon
0.4% Carbon



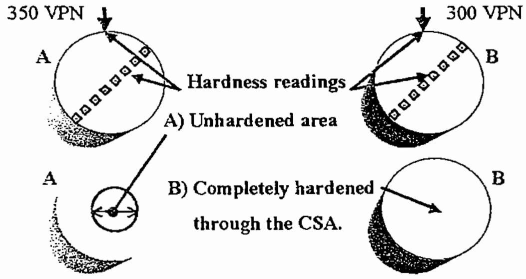
Low Alloy Steel
0.1 % Carbon
1.6% Mn
2.25%Cr
0.5% Mo



After heating above the UCT and quench cooling, they are sectioned and hardness tested across the area*

Effect of Cooling Rate

11.55



Summary of Hardenability

11.58

On analysing this experiment, it can be determined that the only difference between these two specimens is their composition*

By substituting the values in the Ceq formulae we can see that the hardenability of specimens as follows:

A as % C =	Ceq 0.4
B as % C + 0.26 + 0.45 + 0.05 =	Ceq 0.76*

It can be determined from this experiment that both; chemical composition and material thickness have a major effect on the hardenability of steels*

Summary of Steel Microstructures

12.00

To summarize the effect of increasing the hardness of steels by thermal treatment, it can be said that the formation of Martensite is caused by the <u>entrapment of carbon in solution</u>, produced by rapid cooling from temperatures above the Upper Critical*

In plain carbon steels there must be sufficient carbon to trap. In low alloy steels however, the alloying elements play a significant part in the thermal hardening of steels*

In medium, high carbon steels and alloy steels, the formation of Martensite is very dependant on chemical composition and the cooling rate. It is also very dependant on section thickness*

This foundation in metallurgy is for information only and will not form any part of your CSWIP examination*

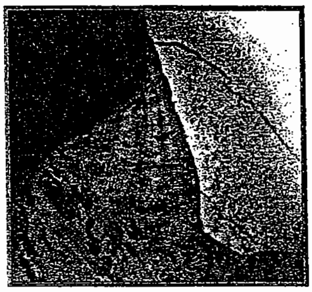
The Weldability of Steels for CSWIP 3.2

13.05

- # 1) Hydrogen induced HAZ cracking in Low Alloy Steels
- # 2) Hydrogen weld metal cracking in Micro Alloy Steels
- 3) Hydrogen cracking in Quenched & Tempered steels
- # 4) Solidification cracking in Ferritic steels
- # 5) Shrinkage cavities in Ferritic steels
- 6) Liquation cracks and Shrinkage Cavities in Fe steels
- # 7) Lamellar tearing in Ferritic steels
- 8) Solidification cracking in Austenitic Stainless Steels
- # 9) Inter-granular corrosion in Stainless Steels
- 10) Re-heat cracking in Creep Resistant Steels

Studied at 3.1 level

Hydrogen Induced Cracking 13.10



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Hydrogen Induced Cracking 13.15

Crack type: H^2 HAZ & weld metal cracking
Location: a. HAZ (Longitudinal)
b. Weld metal (Transverse)
Steel types: a. All hardenable steels including:
b. HSLA steels
c. Quench & Tempered steels
Microstructure: Martensite*

Occurs when:
Hydrogen is above 15 ml/100 gm weld metal
Hardness is above 350 VPN
Stress is greater than 0.5 of the yield stress
Temperature is below 300 °C*

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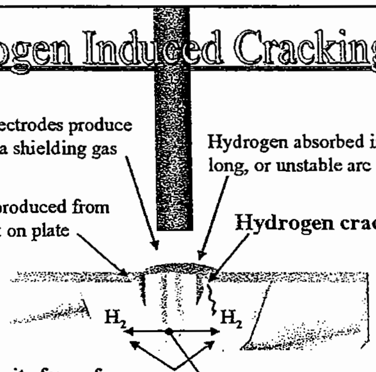
Hydrogen Induced Cracking 13.20



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Hydrogen Induced Cracking in HSLA Steels 13.25

HSLA or Micro-Alloyed Steels are high strength steels that derive their high strength from finite alloying*

Typically the level of alloying is in the region of 0.05% and elements such as vanadium molybdenum and titanium. are used. It would be impossible to match this micro alloying in the electrode due to the effect of losses across an electric arc*

It is however important to match the strength of the weld to the strength of the plate, and so a simple way of matching weld strength must be found and utilised*

To find a simple method we would need to look at the effect of increasing carbon content on the properties of iron*

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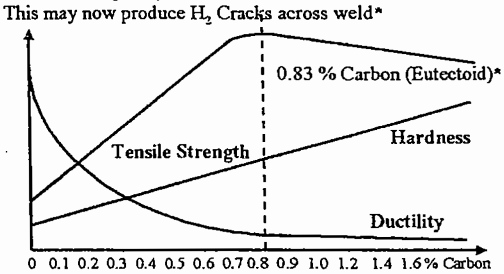
Effects of Carbon on the Properties of Iron 13.30

Increasing the carbon content will increase the strength, but will also increase greatly the formation of martensite in the weld. This may now produce H_2 Cracks across weld*



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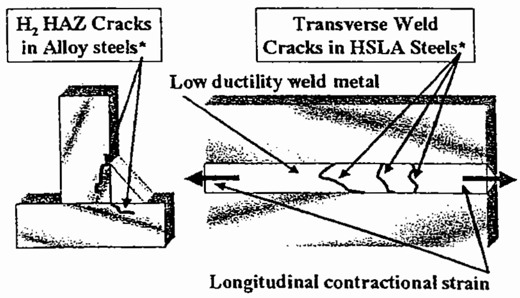
H2 Cracking in Plain Carbon and Low alloy Steels 13.35



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H2 Cracking in Q T Steels 13.40

Quench and tempered steels are highly alloyed steels to produce a Martensitic structure on cooling (> 90%) *

A typical chemical composition of this type of steel is:

Carbon	0.4%	Manganese	1.0%
Chromium	0.8%	Molybdenum	0.3%

+ Aluminium (As a grain refiner) + Titanium. Ceq > 0.78 *

The carbon equivalent will need to increase as the thickness of the steel increases, to allow for the slower cooling, or mass effect. This is to increase the "Hardenability" or ruling section *

H2 Cracking in Q T Steels 13.45

Quench & Tempered, or Q/T steels are steels that are produced specifically with high hardenability to produce a fine martensitic grain structure during manufacture. These steels are then fully tempered to remove the Martensite and retain the fine grain structure, which is of high strength and toughness*

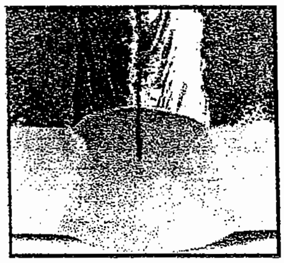
In order that these steels can harden throughout their thickness, their chemical composition changes as the plate thickness increases. This is to maintain the ruling section of the plate, or in other words, to increase the hardenability of the steel*

The resultant weldability is extremely low, and great care must be taken to avoid H² cracks in Weld & HAZ. Careful consideration must be given to keeping any stress concentration at weld toes and the H_2 content in the weld as low as possible*

Prevention of Hydrogen Induced Cracking 13.50

1) Maintain calculated preheats, and never allow the inter-pass temperature to go below the pre-heat value*
2) Use Low Hydrogen processes with short arcs & ensure consumables are correctly baked & stored as required*
3) If using a cellulosic E 6010 for the root run, insert the "Hot pass" as soon as possible. (Before HAZ < 300 °C)*
4) Remove any paint, oil or moisture from the plate or pipe*
5) Carry out any specified PWHT as soon as possible*
6) Avoid any restraint, and use high ductility weld metal*
7) For Q/T Steels minimize H_2 and Stress concentrations*

Solidification Cracking Fe Steels 13.55



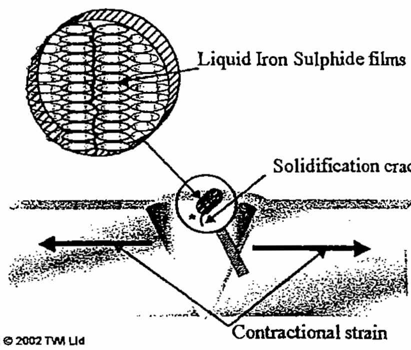
Solidification Cracking Fe Steels 14.00

Crack type:	Solidification cracking
Location:	Weld centre (longitudinal)
Steel types:	High sulphur & phosphorus steels.
Microstructure:	Columnar grains In direction of solidification*

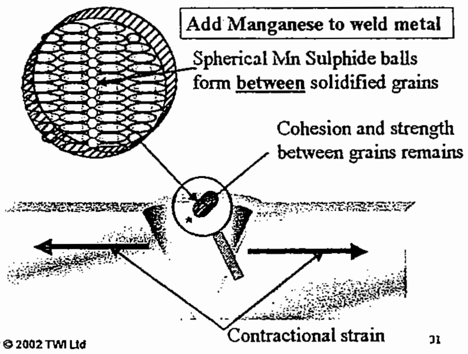
Occurs when:

Liquid iron sulphides are formed around solidifying grains. High contractional strains are present
High dilution processes are being used.
There is a high carbon content in the weld metal*

Solidification Cracking Fe Steels 14.05



Prevention of Solidification Cracking 14.10



Control of Solidification Cracking 14.12

1) The first step in eliminating this problem would be to choose a low dilution process, and change the joint design*

2) Grind and seal in any lamination and avoid further dilution*

3) Add Manganese to the electrode to form spherical Mn/S which form between the grain and maintain grain cohesion*

4) As carbon increases the Mn/S ratio required increases exponentially and is a major factor. Carbon content % should be a minimised by careful control in electrode and dilution*

5) Limit the heat input, hence low contraction, & minimise restraint*

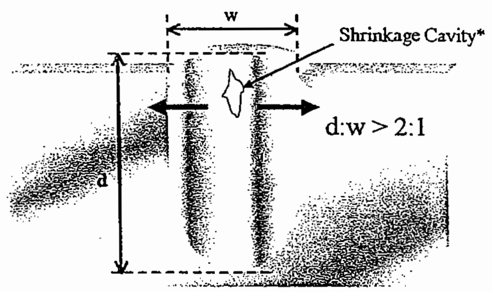
Shrinkage Cavities in Fe Steels 14.15

Crack type:	**Shrinkage cavity**
Location:	**Weld centre (Sub Surface)**
Steel types:	Ferritic Steels.
Microstructure:	Columnar grains*

Occurs when:

High contractional strains are present in welds having a d:w > 2:1 The solidifying weld metal cannot support this high level of strain and a plastic tear results just below the weld surface on the centreline. This resultant tear has sharp edges and may cause failure of the weld during service, as it is a high stress concentration. It may also progress to the surface during/after the solidification process to appear like a solidification crack*

Shrinkage Cavities in Fe Steels 14.20



Controlling occurrence of shrinkage cavities: Keep d:w < 2:1*

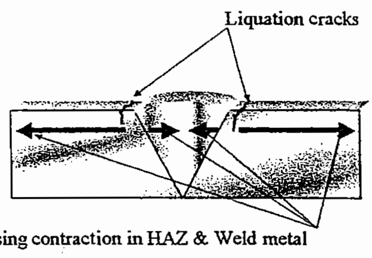
Liquation Cracking Fe Steels 14.25

Crack type:	**Liquation cracking**
Location:	**HAZ (longitudinal)**
Steel types:	**High sulphur & phosphorus steels.**
Microstructure:	**Areas containing high S content***

Occurs when:

When welding low quality, high sulphur content steels, it is possible that areas containing Fe/S in the HAZ will liquify. This low melting point liquid Fe/S will form around the grain boundaries in the HAZ. Opposing strains in the weld and HAZ may result in a crack in the HAZ, caused by the high contractional strain in these areas *

Liquation Cracking Fe Steels 14.30



Control of Liquation Cracking 14.35

1) Use higher quality, refined steels*

2) Minimise heat input*

3) Use pre-heat to control contraction rate*

4) Minimise restraint*

Lamellar Tearing 14.40

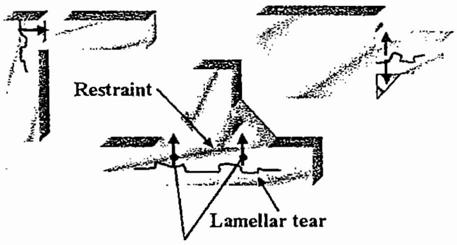
Lamellar Tearing 14.45

Crack type:	Lamellar tearing
Location:	Below weld HAZ
Steel types:	High sulphur & phosphorous steels
Microstructure:	Lamination & Segregation*

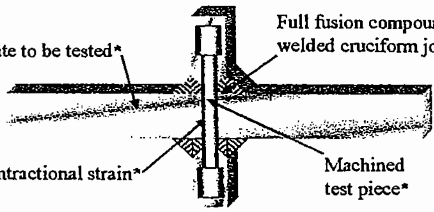
Occurs when:

High contractional strains are through the short transverse direction. There is a high sulfur content in the base metal.
There is low through thickness ductility in the base metal.
There is high restraint on the work*

Lamellar Tearing 14.50

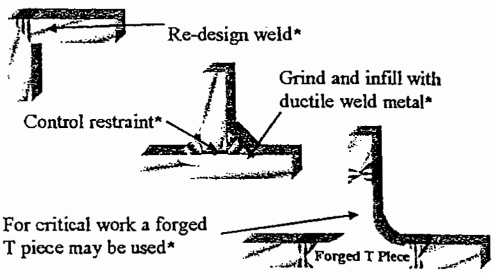


Testing for Lamellar Tearing 14.55



The test piece is machined from the cruciform joint and placed under tension. If Lamellar tearing was present it would fail at a low value*

Control of Lamellar Tearing 15.00



Checking for Lamellar Tearing Susceptibility 15.05

Assessment of susceptibility to Lamellar Tearing:

- Carry out through thickness tensile test
- Carry out Ultra-sonic testing
- Carry out penetrant testing of plate edges
- Carry out full chemical analysis ($S < 0.05\%$)*

Control of Lamellar Tearing 15-10

Methods of avoiding Lamellar Tearing:*

1)	Avoid restraint*
2)	Use controlled low sulfur plate *
3)	Grind out surface and butter *
4)	Change joint design *
5)	Use a forged T piece (Critical Applications)*

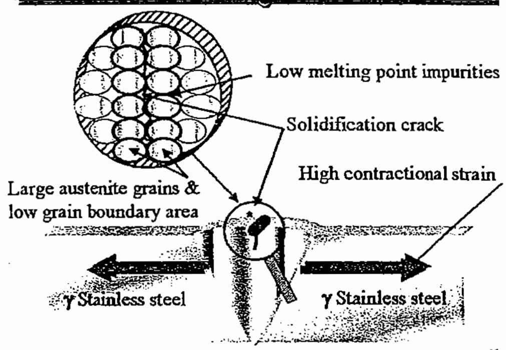
Solidification Cracking Austenitic Stainless 15.15

Crack type:	Solidification cracking
Location:	Weld centre (longitudinal)
Steel types:	Austenitic Stainless Steels.
Microstructure:	Columnar grains In direction of solidification*

Occurs when:

Low melting point impurities form around the large solidifying austenitic grain structure on the weld centreline.
High contractional strains are present
High dilution processes are being used.
There is a low, or no ferrite content in the weld metal*

Solidification Cracking Austenitic Stainless 15.20



Control of Solidification Cracking in S/S 15.25

1) Select a low dilution process, and modify the joint design*

2) As delta ferrite has a mush smaller grain size it is often used to increase the grain boundary area during the welding of austenitic stainless steels in amounts of between 5 – 15%*

3) Limit the heat input, hence low contraction, & minimise restraint*

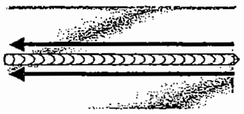
Intergranular Corrosion 15.30

Crack type:	Inter-granular corrosion
Location:	Weld HAZ. (longitudinal)
Steel types:	Stainless steels
Microstructure:	Sensitised grain boundaries*

Occurs when:

An area in the HAZ has been sensitised by the formation of chromium carbides. This area is in the form of a line running parallel to and on both sides of the weld.
This depletion of chromium will leave the effected grains low in chromium oxide which is what produces the corrosion resisting effect of stainless steels.
If left untreated corrosion and failure will be rapid*

Intergranular Corrosion 15.35



During the welding of stainless steels, a small grain area in the HAZ, parallel to the weld will form chromium carbide at the grain boundaries. This depletes this grain of the corrosion resisting chrome oxide

We say that the steel has become "Sensitised" or has become sensitive to corrosion*

Control of Intergranular Corrosion 15.40

1) Use Stabilised Stainless Steels*
2) Use Low Carbon Stainless Steels (Below .04%)*
3) A sensitised Stainless Steel may be de-sensitised by heating it to above 1100 °C where the Chrome carbide will be dissolved. The steel is normally quenched from this temperature to stop re-association*

Re-Heat Cracking 15.45

Re-Heat Cracking 15.50

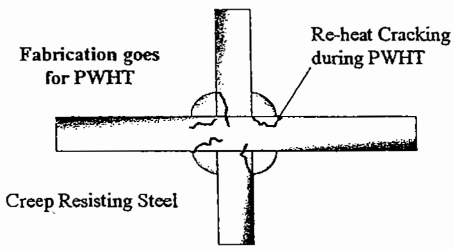
Crack type:	Re-heat cracking.
Location:	Coarse grained HAZ & weld.
Steel types:	Low alloy creep resistant steel
Microstructure:	Embrittled coarse grains.

Occurs when:

During Stress relief. As the alloy has been strengthened against plastic slip, the slip occurs in concentrated areas of low strength during stress relieving at temperatures between 450 –550 °C.

As a result, all the plastic strain is occuring in a concentrated area & the UTS of the steel is easily reached, forming a crack. This usually occurs in areas of high stress concentration, such as the weld toes

Re-Heat Cracking 15.55



Control of Re-Heat Cracking 16.00

1) Heat quickly through the susceptible temperature range. *

2) Using a higher preheat temperature, and the use of PWHT during the stages of welding large fabrications, to reduce the risks of re-heat cracking during final stress relieving *

3) Dressing of fillet weld toes and nozzle attachments welds, on completion of the weld before it cools to reduce stress concentrations *

4) The use of weld metal with high ductility will also reduce the risk of re-heat cracking *

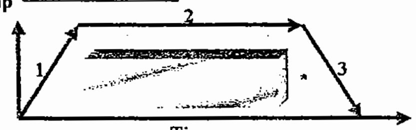
1

R. SANKAR
A. [illegible]

Heat Treatments 09.20

All heat treatments applied to metals are cycles of 3 elements

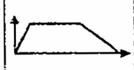
1) Heating
2) Soaking
3) Cooling



 1

Heat Treatments 09.30

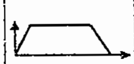
Annealing:



Used to make metals soft and ductile

For steels, the component is heated above its UCT, or upper critical temperature, soaked for 1 hour/25mm of thickness and left in the furnace to cool
Produces a coarse grain structure & low toughness*

Normalising:



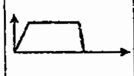
Used to make steels tough

As for annealing, but the steel is removed from the furnace after soaking to cool in still air
Produces a fine grain structure with good toughness*

 2

Heat Treatments 09.40

Hardening:



Used to make some steels harder

Used to increase the hardness of some plain carbon & alloy steels. Plain carbon > 0.3%
The cycle is the same as previously but the cooling is rapid i.e. Quenched in water, oil, but sometimes air*

Tempering:

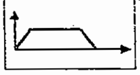
Used after hardening to balance the properties of Toughness & Hardness

The temperature range is from 220 – 723 °C
The cooling part of the cycle should not be too rapid, but over heating will over temper the steel*

 3

Heat Treatments 09.50

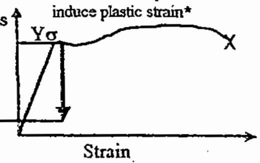
PWHT:



Used after welding to release residual stresses, caused by welding operations*

Force/Stress required to induce plastic strain*

The effect of heat on the position of the yield point*

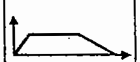


By heating the steel, the yield point is suppressed/reduced relieving residual stresses as plastic strain at a much lower level of stress*

 4

Heat Treatments 10.00

Pre-Heating:



Used mainly on steels to retard the cooling rate of a hardenable steel and reduce the hardening effect (Martensite formation)

Is also used to help diffusion of Hydrogen from the HAZ of hardenable steels to avoid hydrogen cracking. Typically < 350 °C

Is also used to produce a more uniform rate of cooling, and control distortion, or effects of high contractional strains*

 5

In Service Modes of Failure 10.20

The 3 mechanisms, or modes that cause in service failures that will be covered on this course are as follows:*

- Fatigue Fracture*
- Brittle Fracture*
- Ductile Fracture*

It is important to note that all failures require an initiation point, which are invariably stress concentrations*

 6

Fatigue Failures

10.25

Fatigue fractures are initiated like all fractures, from areas where the stresses are higher than other areas. We call these areas Stress Concentrations and they occur at points where there is an abrupt change in CSA such as the toes of welds or an arc strike*

Fatigue failures occur due to cyclic loading and at stress levels well below the materials UTS*

So that weld designers can have safe limits to work within, graphs have been produced for welded joints to give factors to apply with certain joint designs.

Other graphs have been produced for most metals giving safe limits of stress for materials under cyclic loading*

Fatigue Failures

10.30

Designers use curves called S/N curves to produce structures, where applied stresses must be below the fatigue limit.

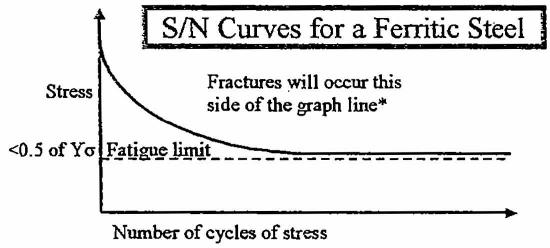
In welded fabrications factors are further applied for specific joint designs*

When a welded member is exposed to fatigue and also a corrosive condition, then corrosion fatigue will occur and the fatigue limit will be further reduced*

The graph shown on the next slide is for a typical Ferritic steel. A graph for Non Ferrous alloys is shown on the following slide*

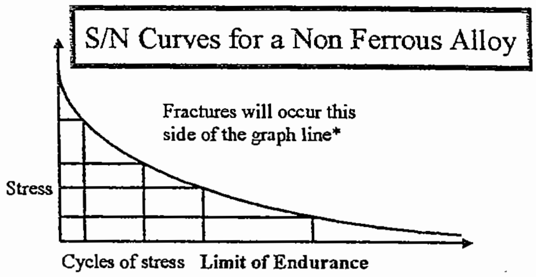
Fatigue Failures

10.32



Fatigue Failures

10.35



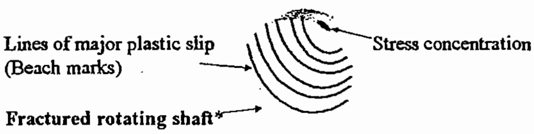
Observations of Fatigue Fractures

10.40

Fatigue fractures are initiated from stress concentrations and then progress slowly through the section in ductile materials until there is insufficient CSA to support the applied load*

Areas of sudden plastic slip are characterised by beach marks, which can be observed on the final fracture surface.

The epicentre of the radii always points to the crack start*



Summary of Fatigue Failures

10.45

1) Fatigue failures are always initiated from stress concentrations*
2) The final fractured surface is characterised by areas of plastic slip, these are known as beach marks*
3) The epicentre of the radii is the initiation point of the fracture*
4) The fracture generally continue to move until insufficient CSA is available to carry the increased level of stress *
5) Fatigue will not be the final mode of fracture, but it is very often the first*

Brittle Fracture Failures 10.50

Brittle fractures are rapid failures of metallic structures that occur when a metal has become brittle and in the presence of some kind of stress and on most occasions a low temperature*

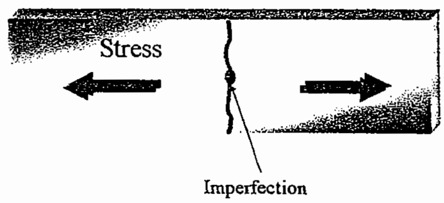
This stress can be static or dynamic stress, or the final mode of failure associated with another form of fracture*

The fractured surface is characterised by its flat and featureless appearance that is always at <u>90° to the plain of the stress</u>*

The surface is marked with chevrons (>>>#<<<<) which point in the direction of the fracture initiation point*

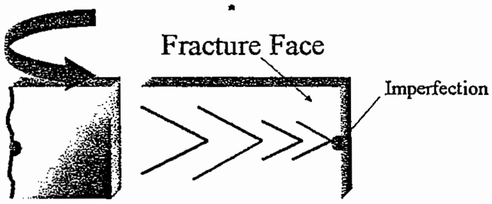
Brittle Fracture Failures 10.53

*



Observations of Brittle Fractures 10.55

*



Chevrons point to the fracture initiation point

Summary of Brittle Fractures 11.00

1) Brittle fractures occur from areas of stress concentration*
2) They may also be the final mode of fracture in a fatigue fracture*
3) Brittle fractures always occur at 90° to the applied load*
4) Brittle fractured surfaces are crystalline, flat & featureless*
5) Areas indicating brittle fracture may be observed in otherwise ductile specimens caused by the plain strain effect*
6) Ductile ferritic steels tend to become brittle when exposed to sub zero temperatures (Acute Ductile/Brittle Transition)*

Ductile Fracture Failures 11.05

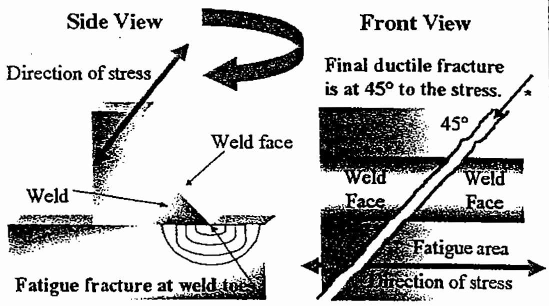
Ductile fractures are generally a final mode of fracture and are more often associated with final failure of fatigue cracks*

The final fracture is characterised by a distinct failure at 45° to the line of applied stress This is often accompanied by shear lips on the fracture face*

Ductile tears are often identified in fabrications well before final fracture and are regularly monitored by NDT*

Ductile tears can often arrest themselves in a metal structures*

Observations of Ductile Fractures 11.10



Summary of Ductile Fractures 11.15

1) Ductile fractures occur from areas of stress concentration*
2) They may also be the final mode of fracture in a fatigue fracture*
3) Ductile fractures always occur at 45° to the applied load*
4) Ductile fractured surfaces are rough, and often show shear lips*
5) It is possible to find areas of all 3 modes mentioned in this presentation on a single fractured surface*

 19

Summary of Brittle Fracture Analysis 11.20

Factors to be considered when investigating Brittle Fractures*

Brittle fractures are likely to occur in steels that exhibit good toughness at normal room temperatures after they have been exposed to sub zero temperatures for any length of time. (At temperatures below the transition range)*

The presence of sudden impact will cause the steel to undergo brittle fracture with characteristic sudden failure. This is most often accompanied by a sharp and loud noise*

Factors to be ascertained would include eyewitness accounts of these elements and further investigative work to establish other possible contributory factors, such as the carrying of cryogenic liquid gases under pressure*

 20

Summary of Fatigue Failure Analysis 11.25

Factors to be considered when investigating Fatigue Fractures* Fatigue fractures are initiated from areas of high stress concentration such as a sharp toe blend, or undercut, or convex fillet weld toes. They are initiated by the action of cyclic stresses at much lower stress levels that the UTS*

In analysing fatigue failures, the presence of cyclic stress is a prime requirement in the initiation and further propagation of fatigue cracks. It would therefore play an important part of the investigation to establish the nature of such a loading, which may be as simple as a degree of vibration*

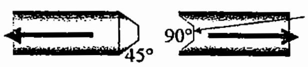
Analysis of the fracture surface and identification of epicentres of the plastic slip will lead to the discovery of the fracture initiation point*

 21

Summary of Ductile Failure Analysis 11.30

Factors to be considered when investigating Ductile Fractures*
Ductile fractures are initiated from areas of high stress concentrations*
When analysing the failure pattern of ductile failures, the propagation rate of the crack may have been extremely slow, but final fracture will be rapid if the component is loaded*
Analysis of the fracture surface will initially show that the fracture occurred at 45° to the load, and the surface and may be accompanied by shear lips, or areas of plastic movement*
Ductile materials may very often show indications associated with brittle fracture, which have been caused by the plain strain effect*

Tensile test
Cup & Cone



 22

In Service Modes of Failure 12.00

TWI Video Presentation on

Fatigue Fracture 15 mins*

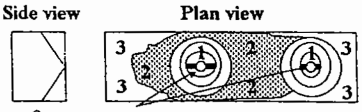
Brittle Fracture 15 mins*

 23

Practical Failure Analysis 13.10

Example Fracture Report Specimen number 001
Double V butt weld

Side view Plan view



a) O Initiation points. Fatigue at weld root due to lack of root fusion in 2 positions.

1 Fatigue area 1st mode of fracture (35%)
2 Brittle area showing plain strain effect. (35%)
3 Final ductile area showing shear lips. (30%)

Signed JG Plenty 09/09/02 *

 24

Summary of Weldability of Steels:

H_2 induced HAZ or weld metal cracks. Key words:

Cause:

H^2 HAZ cracks	Process	Consumables	Paint, Rust, Grease
Delayed inspection.	Solubility	σ concentrations	HAZ
Diffusion	Transformation	Martensite	**Critical factors =**
Hardness> 350VPN	**Hydrogen >15ml**	**σ > 0.5 Re (YS)**	**Temp > 300 °C**

HSLA weld cracks	High strength metal	High carbon weld	Low ductility
Weld contraction	Transverse crack	Micro alloy Nb T V	Longitudinal σ

Q/T Steels	Thickness	σ concentrations	**High hardenability**
HAZ or Weld metal	Martensite	Low ductility	High risk cracking

Prevention: (Q/T Steels in bold)

Pre-heat	**Control of H_2**	**Bake consumable**	**Low H^2 Process**
Minimise restraint	Remove coatings	**Control σ concnt**	γ S/S Weld metal
Arc energy	Use low Ceq plate	Hot pass ASAP	**Use low H^2 Cons'**

Solidification cracking in C/Mn steels. Keywords:

Cause:

Sulphur.	Fe/Sulphides	Weld centreline	Contraction
Low m.p. films	Contraction forces	Loss of cohesion	Hot shortness

Prevention:

High manganese %	Use low restraint	Control carbon %	Use low dilution
Control heat input	Control sulphur %	Change Prep	Seal laminations

Lamellar tearing in C/Mn steels. Key words:

Cause:

Poor ductility	Plastic strain	Sulphur	Laminations
Contraction	Short transverse	Stepped crack	Segregation

Prevention:

NDT for laminations	Through t tensile	Buttering layers	Contraction gap
Re-design joint	Forged T piece	Chem analysis	Control heat input

Solidification cracks in γ stainless steels.

Key words:

Cause:

Austenite grains	Coarse structure	Boundary area	Low m.p Sulphur
Contractional force	Co-ef conduction	Co-ef contraction	Last solidification
Weld centreline	Plastic strain	Hot shortness	

Prevention:

Ferrite content	Inc boundary area	Minimise dilution	10-15% Ferrite
Reduce restraint	Duplex S/S	Contraction rate	Consumables

Inter - crystalline corrosion in stainless steels.

Key words:

Cause:

Chromium depletion	Temp gradient	Cr Carbide	Sensitisation
Parallel to weld	In HAZ	Loss of resistance	Stress CC

Prevention:

Low Carbon .04%	Stabilising elements	Niobium	Molybdenum
Tantalum	Titaniumfor plate	Solution anneal	Rapid cooling

Re-heat cracking in alloy steels.

Key words:

Cause:

Precipitation	Carbides	Grain strengthen	Stress relieve
Loss of ductility	Con' plastic strain	PWHT450–600°C	Temper embrittle
Molybdenum	Vanadium	Boron	Creep resistance

Prevention:

Control PWHT	Minimal restraint	V below 0.1%	Higher Pre heat
High ductility weld	Stage PWHT	Reduce σ areas	Use clean plate

Tony Whitaker
Manager TWI Middle East
Training and Examination Services.
Dated 25-10-02

A. Ramasubbu (2)
R. Sankar

What are Mechanical Properties? 09.25

Mechanical:* Describes the actions of **"force & motion"**

Properties:* Something that makes one material different from another. **These include the properties of:**

Hardness:* The ability of a material to resist indentation

Toughness:* The ability of a material to absorb impact energy

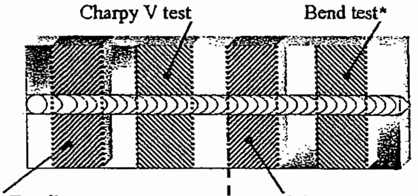
Tensile strength:* The ability to resist the action of a pulling force

Ductility:* The ability to deform plastically under tension*

 1

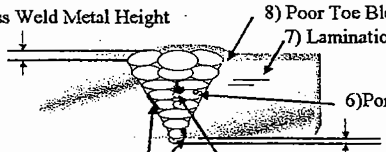
Testing the Weldment 09.30

The test weld is usually cut into sections as follows:
The location of specimens will depend upon the standard



 2

Macro Inspection 09.35



 3

Hardness Testing 09.37

The specimen may then be hardness tested

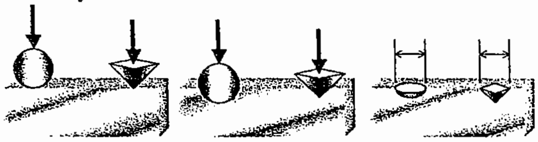
◇ = Hardness Survey

Further hardness surveys may be taken as the thickness of the specimen increases*

 4

Hardness Testing 09.40

Generally we use a diamond or steel ball to form an indentation



We measure the width of the indentation to gauge the hardness*

 5

Hardness Testing 09.42

1) **Vickers Diamond Pyramid:** Always uses a diamond
BS 427 Vickers Hardness Testing *

2) **Brinell hardness test:** Always uses a steel ball*

3) **Rockwell hardness test:** Uses a ball, or diamond depending on the scale*

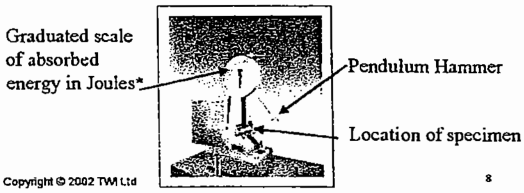
 6

Toughness Testing
09.45

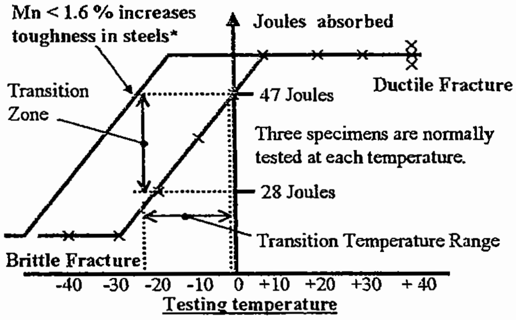
Charpy V. BS 131 Charpy V Testing.	10 x 10 mm specimen BS En 10045*
Izod.	10 x 10 mm specimen Same as Charpy V, but specimen is held vertically*
CTOD. (Crack tip opening displacement)	Specimen size and shape of actual component*

Charpy V Testing
09.50

The specimen may be tested from different areas of the weld.*

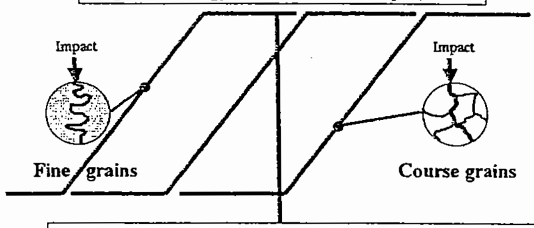


Charpy V Testing
09.45



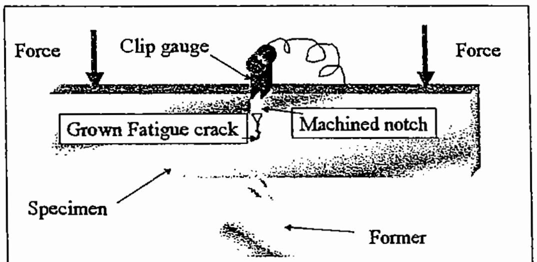
Charpy V Testing
09.50

Effect of large and small grain structures on toughness energy (Control of heat input)



A refined and clean grain structure gives much improved toughness as more energy is absorbed by the specimen!!

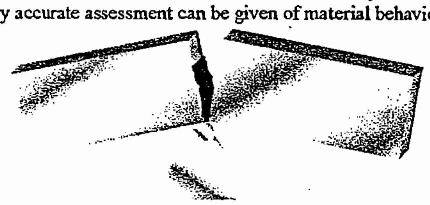
CTOD Testing
09.52



Displacement values are converted to crack tip values.

CTOD Testing
09.55

The fractured surface and stress conditions are analysed and a very accurate assessment can be given of material behaviour

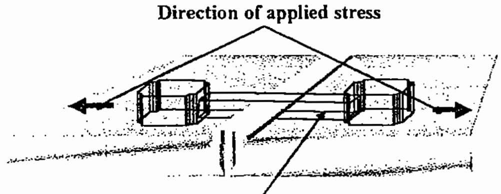


Very Accurate Results

Transverse Tensile Test

09.57

A Section of weld is cut, or machined out *across* the test piece and tested in tension to failure. The units are usually in N/mm^2

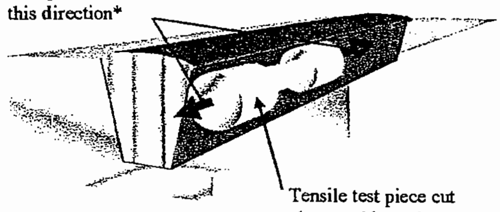


 13

All Weld Metal Tensile Test

10.00

BS 709 / BS En 10002
All Weld Metal Tensile Testing

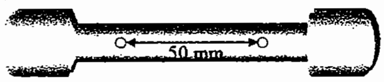


 14

Ductility Elongation %

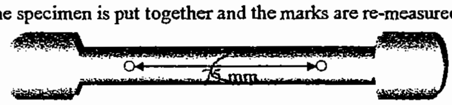
10.03

Firstly, before the tensile test 2 marks are made 50mm apart



During the test, Yield point & Tensile strength are measured

The specimen is put together and the marks are re-measured



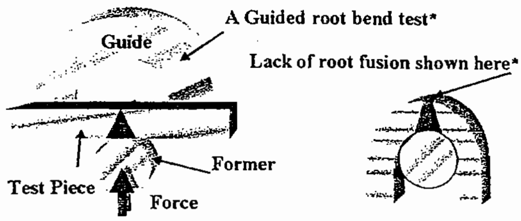
A new measurement of 75mm will indicate Elongation E50 %*

 15

Bend Tests

10.05

Bend tests are used to establish fusion in the area under test



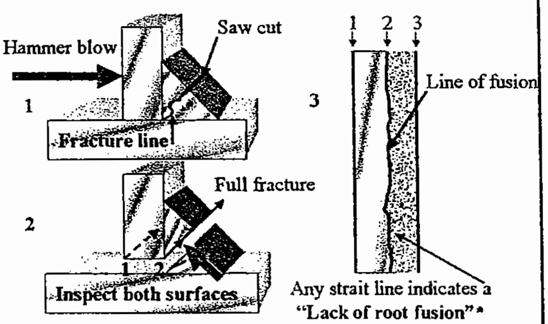
Further tests include face, side and longitudinal bend tests*

For material over 12 mm thickness, side bend test may be used*

 16

Fillet Weld Fractures

10.07

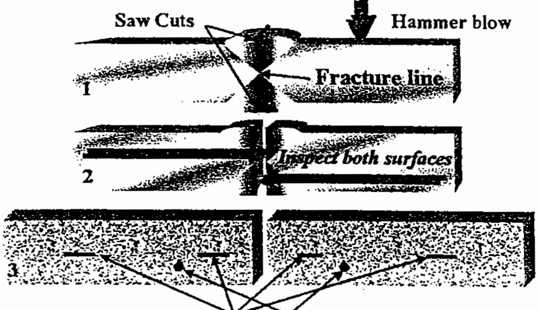


Any strait line indicates a "Lack of root fusion"*

 17

Butt Nick Break Test

10.10



Lack of root penetration — Inclusion on fracture line*

 18

Summary of Mechanical Testing 10.15

We test welds to establish minimum levels of mechanical properties, and soundness of the welded joint

We divide tests into Qualitative & Quantitative methods:

Quantitative: (Have units)	Qualitative: (Have no units)
Hardness (VPN & BHN)	Bends
Strength (N/mm² & PSI)	Fractures (Butt & Fillet)
Toughness (Joules & ft.lbs)	Macros*

 19

Welding Procedures 10.35

A definition of the term "**Procedure**"*

A systematic method of producing an aim*

Therefore, a "**Welding procedure**" is*

A systematic method of producing a sound weld*

 20

Welding Procedures 10.45

- Planning the tasks
- Collecting the data
- Writing a procedure for use or for trial
- Making test welds
- Evaluating the results of the tests
- Approving the procedure of the relevant code
- Preparing the documentation*

 21

Welding Procedures 10.50

a) Materials types and form to be welded?
Low Alloy Steel Pipe

b) Welding Position?
Fixed Vertical Pipe horizontal/weld vertical

c) Welding Process & Consumables + heat input?
MMA E8018 G. 3.25 Baked 350 ° C. @ 125 amps

d) Joint design?
60° Single V Butt welded butt joint

e) Heat treatments?
Pre heat 250° C + PWHT Stress Relieve 450°C

 22

Welding Procedures 10.52

Examples of "Extents of Approval" include:*

a) Diameter of pipe, or thickness of plate
b) Welding position, amperage range, or number of runs
c) Process (On multi process procedures only)
d) Certain material groups
e) Change of consumable to one of the same classification Only if the class is given in the original procedure
f) Heat input range (kJ/mm)*

 23

Welding Procedures 10.55

A Welding Procedure is a recipe of variable parameters, which will produce the same results of certain quality & properties if carried out in the same way each time*

To evaluate a Welding Procedure we need to check if all the parameters set will work together to produce the desired results*

Welding Procedures tests are often carried out to satisfy the feasibility of a set of unusual parameters i.e. The use of a process or consumable for a special application*

 24

Welding Procedures

10.57

Once the weld has been completed it is usually visually inspected, then Radiography or Ultrasonic testing is usually applied*

Finally, and most importantly, Mechanically tested to ensure that the desired level of mechanical properties have been met*

If all the desired properties have been met, then a procedure qualification record (WPQR) is completed with all the test results, and the procedure then becomes qualified*

Welder Approval

11.00

Once the procedure has been approved it is then important to test each welder, to ensure that he has the skill to reach the minimum level of quality in the weld, as laid down in the application standard*

There is no need to carry out the mechanical tests of the procedure, although bend tests are often used to ensure good side wall fusion

Normally visual, x ray, bends, fractures and macro's are used in welder approval tests*

Welding Processes

11.01

As a revision exercise of the common welding processes there will now follow a summary list of the requirements advantages and disadvantages of the common welding processes

Requirements of MMA

11.03

1)	A Transformer/Rectifier (Constant current type)
2)	A power and power return cable
3)	Electrode holder
4)	Electrode (To correct specification)
5)	Correct visor & glass, all safety clothing and extraction

Parameters & Inspection Points

11.05

1)	Amperage	2)	Arc Voltage
3)	Polarity	4)	Speed of Travel
5)	Electrode type & Ø	6)	Duty Cycles
7)	Electrode condition	8)	Connections
9)	Insulation / extraction	10)	Electrode treatments*

Typical Imperfections

11.07

1) Slag inclusions
2) Arc strikes
3) Porosity
4) Undercut

Most welding imperfections in MMA are caused by a lack of welder skill, the incorrect settings of the equipment, or the incorrect use, and treatment of electrodes*

Advantages & Disadvantages 11.10

Advantages:	Disadvantages:
1) Field or shop use	1) High skill factor
2) Range of consumables	2) Slag inclusions
3) All positional	3) Low operating factor
4) Very portable	4) High level of fume
5) Simple equipment	5) Hydrogen control

MMA Welding Consumables 11.12

Classification:	Main Constituent:	Shielding gas:	General Uses:
Rutile: E6013	Titania TiO_2	CO²	General Purpose
Basic: E7018	Calcium compounds	CO²	High quality work
Cellulosic: E 6010	Cellulose Ground cetonent shells	Hydrogen	Pipe root runs*

The core wire for most MMA electrodes is of a low quality steel, as this is a cheap method of manufacture and the steel will be refined during the process of welding by the refining agents and elements contained in the flux coating*

Requirements of TIG 11.25

1) A Transformer/Rectifier (Constant current type)
2) A power and power return cable
3) An Inert shielding gas. (Argon or Helium)
4) Gas hose, flow-meter, & gas regulator
5) TIG torch head with ground tungsten, collets, ceramics
6) Method of arc ignition (High frequency or lift arc)
7) Correct visor, all safety clothing and good extraction
8) Optional filler rod, to correct specification*

Parameters & Inspection Points 11.27

1) Amperage	2) Arc Voltage
3) AC or DC + Polarity	4) Speed of Travel
5) Tungsten type & Ø	6) Duty Cycles
7) Tungsten vertex angle	8) Connections
9) Gas type & flow rate	10) Insulation / extraction
11) Ceramic condition	12) Gas lens fitted*

Typical Imperfections 11.30

1) Tungsten inclusions (Low skill, or wrong vertex angle)
2) Surface porosity (Loss of gas shield mainly on site)
3) Crater pipes (Bad weld finish technique i.e. Slope out)
4) Oxidation of S/S weld bead, or root by poor gas cover

Most welding imperfections with TIG are caused by a lack of welder skill, or incorrect setting of the equipment. i.e. Current, torch manipulation, welding speed, gas flow rate, etc*

Advantages & Disadvantages 11.32

Advantages:	Disadvantages:
1) High quality	1) Very high skill factor
2) Good control	2) Range of consumable
3) All positional	3) Loss of gas shield/site
4) Lowest H_2 arc process	4) Complex equipment
5) Light slag removal	5) High ozone levels*

Gases for TIG Welding 11.34

Gases used for TIG:

Argon or Helium or a mixture of these gases*

Helium gas has higher ionization potential than argon and gives deeper penetration, whilst argon is denser than air and gives good coverage of the weld area in the down hand position. We would need 2-3 times the flow rate of helium to get the same coverage as helium is less dense than air. In the overhead position the reverse is true. We often mix these gases to get both benefits*

We sometimes use additions of nitrogen when welding some stainless steels, or copper*

 37

Requirements of MIG/MAG 11.36

1) A Transformer/Rectifier (Constant voltage type)
2) A power and power return cable
3) An Inert, active, or mixed shielding gas (Argon or CO²)
4) Gas hose, flow-meter, & gas regulator
5) MIG torch with hose, liner, diffuser, contact tip & nozzle
6) Wire feed unit with correct drive rolls (Push or Pull)
7) Electrode wire to correct specification and diameter
8) Correct visor & glass, all safety clothing and good extraction*

 38

Parameters & Inspection Points 11.38

1) WFS/Amperage	2) OCV & Arc Voltage
3) Wire type & Ø	4) Gas type & flow rate
5) Contact tip/condition	6) Roller size & pressure
7) Liner size	8) Inductance settings
9) Insulation/extraction	10) Connections
11) Duty cycle	12) Angles & travel speed*

 39

Typical Imperfections 11.40

1) Silica inclusions (Poor inter-run cleaning)
2) Lack of side wall fusion (Primarily with dip transfer)
3) Porosity (From loss of gas shield on site etc)*

Most welding imperfections in MIG/MAG are caused by lack of welder skill, or incorrect settings of the equipment

The use of low quality wires will cause wire feed problems

Worn contact tips will cause poor power pick up, or transfer

Bad power connections will cause a loss of voltage in the arc*

 40

Advantages & Disadvantages 11.42

Advantages:	Disadvantages:
1) Lower skill required	**1) Lack of sidewall fusion**
2) Easily automated	**2) Range of consumables**
3) All positional (Dip/Pulse)	**3) Loss of gas shield/site**
4) Thick/thin materials	**4) Complex equipment**
5) Continuous electrode	**5) High ozone levels***

 41

Gases for MIG & MAG Welding 11.44

Gases used for MIG: **Argon or Helium**

Gases used for MAG: CO_2 or mixtures of CO_2 and Argon*

CO_2: Very good penetration, cannot support spray transfer produces an unstable arc, with lots of spatter

Argon: Shallow penetration. Very stable arc, with low spatter

We mix both gases in mixture of between 5 – 20% CO_2 in argon to get the benefits of both gases*

For γ stainless steels we use argon with a 2% oxygen, this gives more fluidity to the weld and an improved toe blend*

 42

Wires for MIG/MAG & TIG Welding 11.46

Wires must be drawn as deposited and are therefore of very high quality. Electrode wires for MIG are the same as rods for TIG*

The quality of temper and copper coating is also very important. The copper coating on MIG wires maximises the current pick up*

Specifications for wires are as per their chemical compositions*

Grades:
Composition + Single, double, and triple de-oxidised wires*

Quality of winding:
Random wound. Layer wound. & Precision layer wound

Wires diameters:
0.6 - >2.4 mm Ø supplied on 1 kg (fine wire) & 15 kg spools*

 43

Requirements of SAW 11.48

1) A Transformer/Rectifier (Constant voltage type)
2) A power and power return cable
3) A torch head assembly
4) A granulated flux
5) A flux delivery system
6) A flux recovery system
7) Electrode wire to correct specification and diameter
8) Correct safety clothing and good extraction*

 44

Parameters & Inspection Points 11.50

1) WFS/Amperage	2) OCV & Arc Voltage
3) Flux type & mesh size	4) Flux condition
5) Wire Ø & condition	6) Wire Specification
7) Flux delivery/recovery	8) Electrode stick-out
9) Insulation/duty cycle	10) Connections
11) Tip size & condition	12) Speed of travel*

 45

Typical Imperfections 11.52

1) Lack of fusion (Caused by high levels of arc blow)
2) Solidification cracks (From S pick up from high dilution)
3) Shrinkage cavities (From high depth:width ratio)
4) Porosity (Using damp fluxes, or un-cleaned plates)*

Most welding imperfections in SAW are caused by incorrect setting of the equipment, using incorrect or wrongly dried consumables, or welding plates that have not been properly cleaned. Minor changes in the welding parameters of SAW can have a major effect on weld composition and weld quality*

 46

Advantages & Disadvantages 11.54

Advantages:	Disadvantages:
1) Low weld metal costs	1) Restricted in position
2) Easily mechanized	2) *Arc blow* with DC
3) Low Ozone production	3) Shrinkage cavities
4) Rapid weld completion	4) Penetration control
5) No visible arc light	5) Variable compositions

 47

Wires & Fluxes for SA Welding 11.56

Consumables for Submerged Arc Welding consist of a wire and a flux*

The wire is similar to that of solid wire MIG/MAG and is chosen from a table of chemical compositions*

Fluxes are varied and are classified by their method of manufacture and composition*

 48

Fluxes for SA Welding 11.58

Basicity Index*

Fluxes are grouped in BS 4165 by the amount of acid or basic elements they contain by a method called the Basicity Index

This is calculated by dividing the Basic elements by the Acid elements as follows:*

$$\text{Basic Index number} = \frac{\textbf{Basic Elements \%}}{\textbf{Acidic Elements \%}} = \textbf{BI Number*}$$

The higher the index, the more basic is the flux. (Higher quality)*

 49

Fluxes for SA Welding 12.00

In BS 4165 fluxes may be classified into:

Acidic	< 0.9 BI number
Neutral	0.9 – 1.2 BI number
Semi Basic	1.2 – 1.8 BI number
Basic	1.8 – 2.5 BI number
Highly Basic	2.5 – 3.5 BI number*

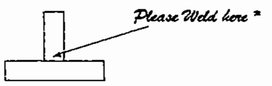
The higher the bascicity index number, then the higher the weld quality, (Higher strength & toughness in the weld metal) though the more difficult it becomes to use (Less tolerant of poor preparation etc.)

 50

Weld Symbols on Drawings 13.05

Welding Symbols

A method of transferring information from the design office to the workshop



The above information does not tell us much about the wishes of the designer. We obviously need some sort of code which would be understood by everyone*

Most countries have their own standards for symbols.
Some of them are BS 499 Part 2. AWS A2.4 & BS En 22553*

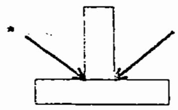
 51

Weld Symbols on Drawings 13.10

1) Convention of the arrow line:

BS. BSEn & AWS

a) **Shall** touch the joint intersection
b) **Shall** not be parallel to the drawing
c) **Shall** point towards a single plate preparation*



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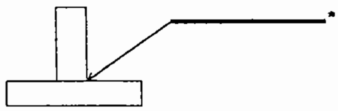
Weld Symbols on Drawings 13.15

2) Convention of The reference line:

BS 499 (UK) & AWS A 2.4 (US)

a) **Shall** touch the arrow line
b) **Shall** be parallel to the bottom of the drawing*



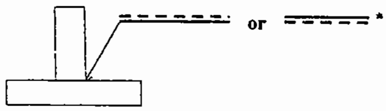
 53

Weld Symbols on Drawings 13.20

3) Convention of The reference line:

BS En 22553 or ISO 2553

a) **Shall** touch the arrow line
b) **Shall** be parallel to the bottom of the drawing
c) **There shall** be a further broken line above or beneath the reference line (Except where the weld is symmetrical)*



 54

Weld Symbols on Drawings 13.25

Symbols: BS 499 (UK) & AWS A2.4 (US)

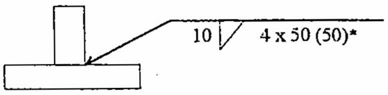
a) Welds **this side** of joint, go **underneath** the reference line

b) Welds **the other side** of the joint, go **on top** of the reference line

c) Symbols with a **vertical line** component must be drawn with the vertical line to the **left side** of the symbol

d) All **CSA** dimensions are shown to the **left** of the symbol

e) All **linear** dimensions are shown on the **right** of the symbol i.e. Number of welds, length of welds, length of any (spaces)*



 55

Weld Symbols on Drawings 13.30

Symbols: BSEn 22553. (ISO 2553)

a) Welds **this side** of joint, go on the **unbroken** reference line

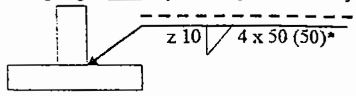
b) Welds **the other side** of the joint, go on the **broken** reference line

c) Symbols with a **vertical line** component must be drawn with the vertical line to the **left** side of the symbol

d) All **CSA** dimensions are shown to the **left** of the symbol

e) All **linear** dimensions are shown on the **right** of the symbol i.e. Number of welds, length of welds, length of any spaces

f) All leg lengths **shall** be preceded by **Z** and throat by **a** or **S***



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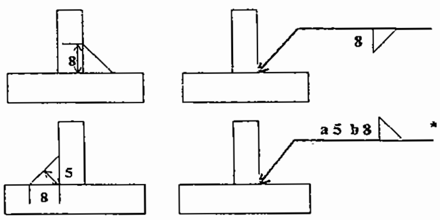
Weld Symbols on Drawings 13.35

Weld Symbols on Drawings

BS 499 & AWS A 2.4



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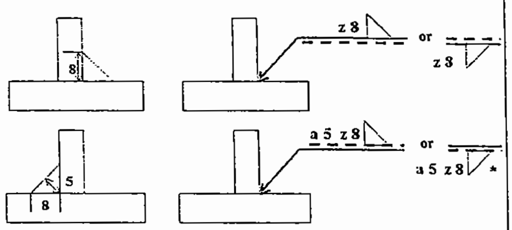
Weld Symbols on Drawings 13.40

Weld Symbols on Drawings

BS En 22553 (ISO 2553)



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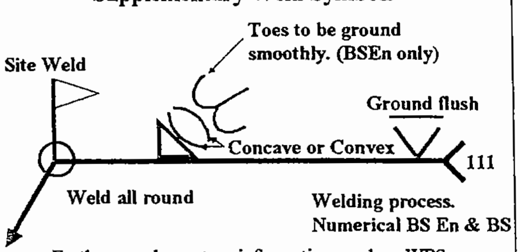
Weld Symbols on Drawings 13.45

Supplementary Weld Symbols



Further supplementary information, such as WPS number, or NDT may be placed in the fish tail*

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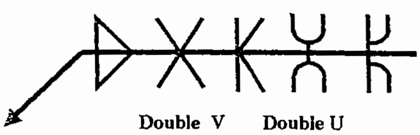
Weld Symbols on Drawings 13.50

Representation of welds done from ***both sides*** of the joint intersection, touched by the arrow head



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SENIOR WELDING INSPECTOR

(9)

A Ramasvhini

QUESTION:

You are required to visit a site on which your inspectors have been involved. The work involves the inspection of a welded structure to an application standard and is now ready for final approval.

1. What questions do you ask?
2. What documents do you review or require before submitting an inspection report to the authorities concerned?

TYPICAL ANSWER:

Prior to the site visit it is important to spend some time planning the visit, in order that a logical approach be made and that vital details are not overlooked. A knowledge of the standard that was used for fabrication, and the service conditions of the final product will be beneficial in assessing the fitness of the product for service. A list of the inspection team and the team leader will ensure that those involved with the fabrication and inspection of the product are on hand to answer pertinent questions. These questions could include the completeness of the job, repair rate during production and safety standards on site, housekeeping, etc. The standard of access and scaffolding can have a direct bearing on the quality levels attained as safe confident workers are much more likely to produce quality fit ups and welds. Certain documents can greatly assist the overall audit plan such as quality plans and inspection check lists, if used on the job.

Some standards (e.g. BS:5500) will tabulate a list of the required documentation which may be required to be included in the final data book package. If not specified by code or client specifications, then the following documents should be reviewed as a minimum prior to signing off and issuing a Certificate of Compliance.

1. A review of the quality plan and inspection check lists to ensure all stages are completed and signed off.

2. Material certificates, mill test reports and material traceability records are documented and accepted. This may include consumable certification.

3. Process control procedures should be reviewed for adequacy, accuracy and approval. These procedures should include approved cutting and welding procedures, weld repair and NDT procedures, heat treatment if required, testing, and finally, coating procedures.

4. Personnel qualification review should include welder qualifications, NDT and Inspection personnel approvals and all should be up to date and current in the particular discipline of expertise.

Terms Associated with QA/QC

10.30

A Defect: A welding imperfection that falls outside of a level of acceptance in an applied standard*

Classes of defects:

Minor: Unlikely to cause failure of the product*

Major: Likely to cause failure, but small risk of loss of life*

Critical: Extremely likely to cause failure, with high risk of loss of life*

Duties of a Senior Inspector

10.55

1) **Plan** — An agreed, pre-determined and structured pathway, that meets a specific aim

2) **Organise** — To make all necessary arrangements required to carry out, or fulfil a plan
Ensuring all things are in the correct place at the correct time

3) **Supervise** — To instruct, and control the work of staff in areas for which you are responsible

4) **Audit** — To carry out a periodic and systematic "check" on a system/process to ensure that it has been carried out as specified*

Planning

11.00

"The really nice thing about not planning is that failure comes as a complete surprise and is not preceded by long periods of worry and depression"*

We make plans every day for the most trivial of things

All delegates must have planned to come here today*

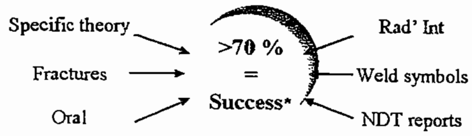
Many tools are used for production planning including: Gant Charts. Forward and Reverse Scheduling. Critical Path Analysis. etc*

Planning Task

11.10

Using the following headings and the days on which they will be covered on the course, make a reverse schedule plan to your exam date, utilising your available free time. Your plan needs to be flexible in case there are any changes to the course structure.

Remember that Radiographic Interpretation (Theory, practical, or sensitometry) is not covered on the course syllabus.



Organisation

11.15

Once an inspection plan has been made the organisation must then begin*

This may involve the following elements:

1) Any training & certification required
2) Staffing the plan
3) Procurement of equipments
4) Transport to/from site, and at site
5) Accommodation and messing
6) Any special needs (Religious etc)
7) Leave cycles etc*

Supervision

11.20

Once a plan has been organised it is essential that control is exercised so that the plan is successfully implemented

A supervisor is essentially a manager of men which requires certain specific management skills:

Each student should give an attribute/skill that they think is important for **"effective supervision of welding inspectors"**

Student names to be placed next to their choice on the white board*

Do not open next slide until this task has been carried out**

DOCUMENTATION USER GUIDE

FOLDER 1

- 1.0 Certificate of Completion
- 1.1 Inspection & Release Note (LRS)
- 1.2 Inspection and Test Plan
- 2.0 Procedures
  - 2.1 Fabrication & Execution Procedure
  - 2.2 Consumable Control Procedure
  - 2.3 Weld Visual Inspection Procedure
  - 2.4 Dimensional Control Procedure
  - 2.5 P.W.H.T procedure
  - 2.6 Hydrotest Procedure
  - 2.7 Load out Procedure
  - 2.8 Painting Procedure
- 3.0 NDT Procedures
  - 3.1 Radiography Test Procedure
  - 3.2 Ultrasonic Test Procedure
  - 3.3 M.P.I. Procedure
  - 3.4 Liquid Penetrant Inspection Procedure
  - 3.5 Equipment Calibration Certificate
  - 3.6 List of N.D.T. Operators & Certificates

FOLDER 2

- 4.0 Welding Procedures (WPS + PQR) (as per index)
- 4.1 List of Welders & Certificates (Certificates as per list)

DOCUMENTATION USER GUIDE

- 5.4 NDT Reports
  - RT Reports
  - UT Reports
  - MT Reports
- 5.5 Visual Inspection Reports
- 5.6 Dimensional Control Reports (As per DCR Register)
- 5.7 Hydrotest reports with Calibration Certificates
- 5.8 P.W.H.T. Report
- 5.9 Hardness Test Report
- 5.10 Site Query Reports / Non-conformance Reports
- 5.11 Painting Control Reports
- 5.12 Paint Warranty
- 5.13 Concrete Test Certificates

FOLDER 4

- 6.0 As-built Drawings (as per as-built drawing register)
- 6.1 As-built Weld Maps