



THE WELDING INSTITUTE

## **SENIOR WELDING INSPECTOR**

**COURSE REF: WIS10**



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## **SENIOR WELDING INSPECTOR**

### **COURSE DETAIL**

#### **ALL COURSE MEMBERS PLEASE READ CAREFULLY**

1. The general working programme is attached.
2. Any alterations will be announced by the course tutor.
3. The lectures and tutorials etc are supported by the course text, please read as appropriate.
4. Question papers are included at both welding and senior inspector level and will be used to reinforce most sessions please attempt the questions.
5. The end of course assessments are marked and the results recorded.
6. CSWIP 3.2 examination candidates are reminded that examination success is based not only on course attendance, but also previous experience, (i.e. CSWIP require a minimum of five years experience as a Senior Welding Inspector, or hold a CSWIP 3.1 qualification for two years). Candidates are therefore advised to attend other courses in welding inspection or NDT (if appropriate) in order to improve their knowledge and competence. Discussion with the course tutor is advised.

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## **KEY KNOWLEDGE FOR WELDING INSPECTION PERSONNEL**

The information contained in this course text supplements the lectures given in courses WIS 5 and WIS 10.

Terminology given in the test is that recommended in BS 499 Pt.1:1983; Weld Symbols to BS 499 Pt 2: 1980. To supplement this further, however, an indication of both International (ISO) and American standards is given.

The sections are written in general terms and do not include all of the conditions that may apply to a specific fabrication or product.

The examining body, CSWIP, expect candidates, for the Senior Welding Inspectors' Examination, to have sufficient knowledge of both 3:1 and 3:2 levels. Because of this, the text is based on the established Welding Inspectors' course and additional information required for the senior level has been included.

It is assumed course members have previously attended course WIS 5.

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## TERMINOLOGY

Use of the correct terminology is important. This course uses BS 499.

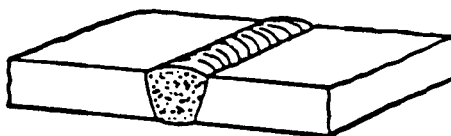
### GENERAL TERMINOLOGY

#### WELDS and JOINTS

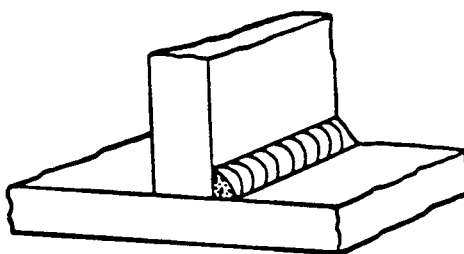
Frequently the terms 'weld' and 'joint' are used incorrectly. Exact definitions are given in BS 499 'Welding terms and symbols'.

#### TYPES OF WELD

##### BUTT WELD



##### FILLET WELD



##### EDGE WELD



##### SPOT WELD

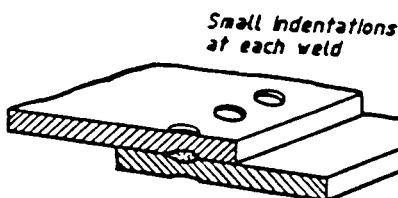


Illustration depicts resistance weld. Spot welds can be made with MIG or TIG processes.

## TYPES OF JOINT

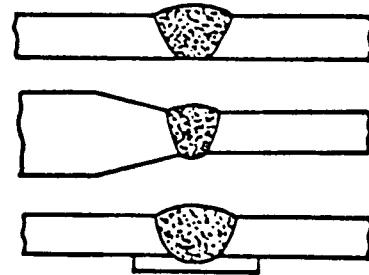
The four basic welds can be used to join various types of joints.

The following are some typical joints

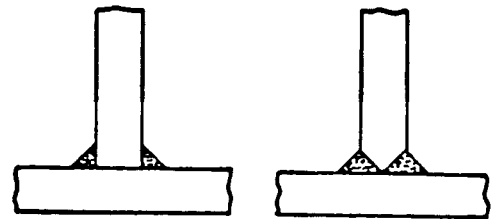
### TYPE OF JOINT

### EXAMPLES

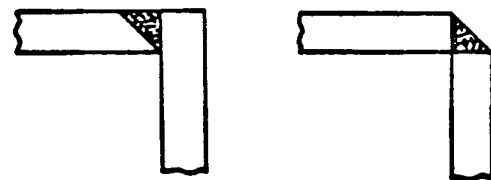
#### BUTT



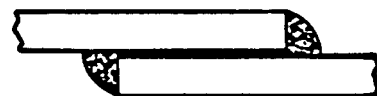
#### TEE



#### CORNER



#### LAP



## PLATE EDGE PREPARATION FOR BUTT WELDS

The illustrations show standard terminology for the various features of plate edge preparations.

Single – V



Double – V



Single bevel

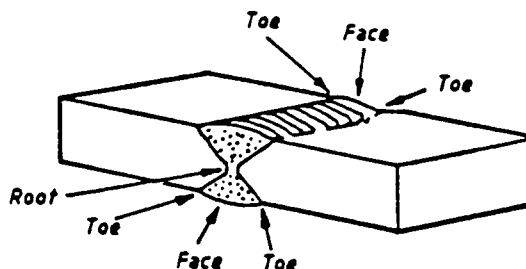


Single – U



## FEATURES OF COMPLETED WELD

A butt weld in a plate, made by welding from both sides, has two weld faces, four toes. In a full penetration weld made from one side, the protruding weld on the underside is the penetration bead.



If a weld is sectioned, polished and etched, the fusion boundary can be established. Metal lying between the two fusion boundaries is weld metal, a mixture of deposited metal and plate material that has been melted. Adjacent to the fusion boundary is the heat affected zone (HAZ), in which the plate material has a metallurgical structure modified by the heat of welding.

Fillet welds also have

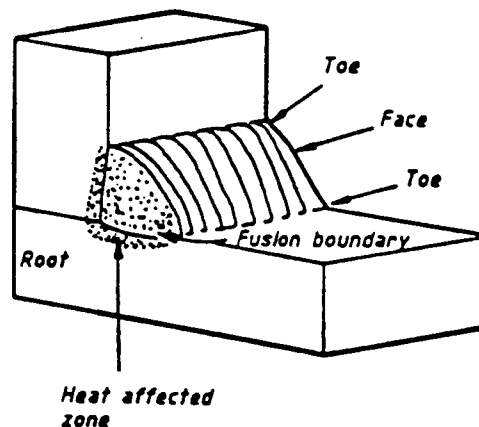
Toes

A weld face

A root

A fusion boundary

A heat affected zone

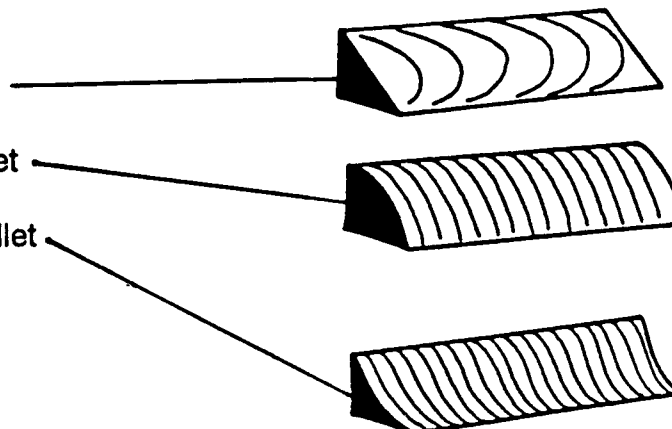


The shape of a fillet weld in cross-section is described by three terms

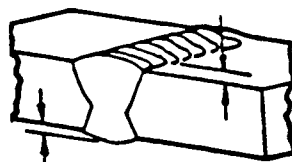
Mitre fillet

Convex fillet

Concave fillet



Excess weld metal, as illustrated, is often referred to as 'weld reinforcement'. This does not necessarily mean it strengthens a joint.

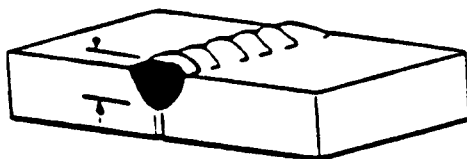


## SIZE OF WELDS

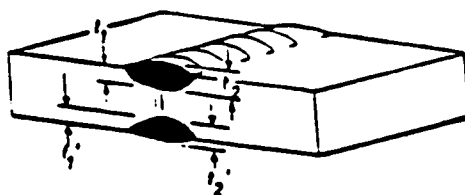
For full penetration butt welds, the general rule is: design throat thickness,  $t_1$  = thickness of the thinner part joined.

### Partial penetration butt welds

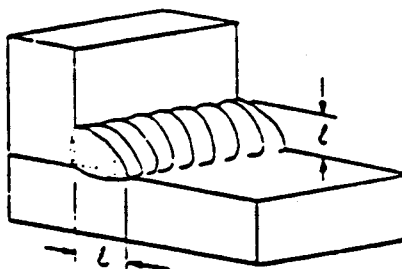
The term partial penetration strictly implies butt welds that are designed to have less than full penetration. Failure to achieve full penetration when it is wanted should be listed as the defect INCOMPLETE PENETRATION.



The throat thickness of a partial penetration weld made from both sides is  $t_2 + t_2$ , and the design throat thickness  $t_1 + t_1$ . Note that the degree of penetration must be known.



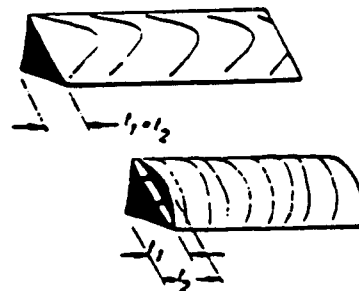
Fillet weld sizes are calculated by reference to allowable shear stress on the throat area, i.e. throat area = design throat thickness x length of weld. The size required is specified on drawings in terms of leg length ( $l$ ).



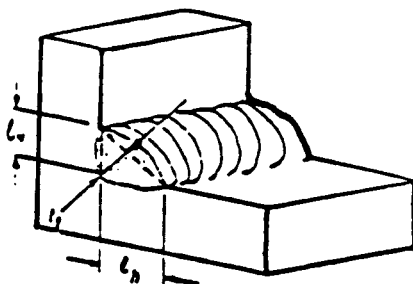
For fillet welds with equal leg lengths:

$$l = 1.4t_1$$

where  $t_1$  is as defined for mitre and convex fillets.



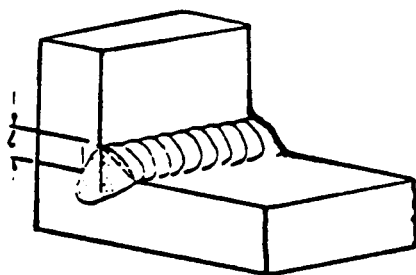
If an asymmetrical fillet weld is required, both leg lengths are specified and  $t_1$  is taken as the minimum throat dimension.



### Deep penetration fillet weld

With high current density processes, e.g. submerged arc and MIG (spray), penetration along the joint line can be produced.

This gives an increase in throat thickness with no change in leg length.



# THE DUTIES OF THE WELDING INSPECTOR

## VISUAL INSPECTION

At any point in the course of welding, i.e. tacking, root pass, filler pass or capping pass, but particularly for the root and cap, a detailed inspection may be required. British Standard 5289 : 1976 gives guidance on tools and responsibilities together with sketches of typical defects.

The inspector at this point must –

- a) observe, identify and perhaps record the features of the weld.
- b) decide whether the weld is acceptable in terms of the particular levels which are permitted; defect levels may be 'in-house' or National Codes of Practice.

When the defect size is in excess of the permitted level then either a concession must be applied for (from a competent person) or the weld rejected.

## CODE OF PRACTICE FOR VISUAL INSPECTION

A code of practice for an inspection department could take the form outlined below. It is appreciated that full implementation of the code would be extremely costly and therefore it may be necessary to reduce the amount of inspection to less than is theoretically required.

## AIDS OF VISUAL INSPECTION

|                           |                                                                                                                        |
|---------------------------|------------------------------------------------------------------------------------------------------------------------|
| <b>Illumination:</b>      | Good lighting is essential                                                                                             |
| <b>Inspection lenses:</b> | The magnification should not exceed 2–2½ diameters.<br>If higher magnification is required use a binocular microscope. |

Optical viewing devices are a progressive development from the use of a hand torch and mirror, frequently with the addition of a magnifier and light source.

In order to achieve accessibility probe units are available down to a diameter, properties for which are:

1. Large field of vision.
2. Freedom from distortion of image.
3. Accurate preservation of colour values.
4. Adequacy of illumination.

## **VISUAL INSPECTION PRACTICE**

The inspector should be familiar with the following:

1. All applicable documents.
2. Workmanship standards.
3. All phases of good workshop practice.
4. Tools and measuring devices.

## **INSPECTION BEFORE WELDING**

### **Before assembly:**

- Check:
1. Application standard
  2. Welding procedure sheets
  3. Drawings
  4. Welder qualifications
  5. Material composition
  6. Condition of material
  7. Type of edge preparation, method and finish
  8. Consumables, i.e. type of electrodes, filler wires, fluxes, shielding and backing gases (composition) and special drying requirements for electrodes
  9. Welding process/processes

### **After assembly:**

- Check:
1. Clearance dimensions, tolerances, type of backing (if any)
  2. Alignment, tack welds, bridging pieces, etc.
  3. Cleanliness
  4. Preheat (if any)

Note: Good inspection prior to welding could eliminate conditions that lead to the formation of defects.

## **INSPECTION DURING WELDING**

- Check:
1. Welding process
  2. Preheat and interpass temperatures
  3. Inter-run cleaning
  4. Joint preparation
  5. Filler metals
  6. Control of distortion
  7. Root and subsequent runs
  8. Welding current and voltage
  9. Chipping, grinding, gouging
  10. Fluxes and shielding gases
  11. Compliance with weld procedure sheet and application standard

## **AFTER WELDING**

- Check:
1. Dimensional accuracy
  2. Conformity of drawings and standard requirements
  3. Acceptability of welds regarding appearance
  4. Post-heat treatment (if any)
  5. Repairs

## **REPAIRS**

1. Mark out area positively and clearly.
2. Use a method established and understood by all inspection and repair personnel.
3. Check when partially removed (visual and NDT).
4. Check when fully removed (visual and NDT).
5. Check rewelding.
6. Reinspect.

## **QUESTIONS**

### **RESPONSIBILITIES AND DUTIES OF A WELDING INSPECTOR**

- Q1.** Give three (3) main responsibilities of a welding inspector
- Q2.** Give three (3) attributes which all welding inspectors must possess
- Q3.** What documents or records should be referred to by the welding inspector?
- Q4.** What are the duties of the welding inspector?
- Q5.** Should the most up to date code or specification be used?

## THE DUTIES OF THE SENIOR WELDING INSPECTOR

The fabrication industry has come to accept the need for detailed inspection of welding for a combination of two reasons:

1. The quality of a manually made weld is critically dependent on the skill of the welder.
2. Much fabrication is made under sub-contracting conditions.

There has developed, therefore, a system which is quite general, but is more obvious in the fabrication field, of client appointed inspectors who may work independently or alongside the fabricators own inspectors with or sometimes without the full co-operation of the welding supervisors and welders.

Welding inspection in the general sense is the monitoring of the formation of the weld, i.e. materials, equipment, consumables, approvals of staff and procedures, examination of the completion, i.e. size, excess metal, undercut, surface defects, spatter etc., and the compilation of the documents into the fabrication file.

Many quality welds are required to be examined by a non-destructive testing technique and operatives with the required skills are called in as required and the welding inspector obtains the NDT reports for the fabrication file.

The senior welding inspector grade is able to assess and control welding inspection with a wide perspective because of his wider qualifications and experience. In addition he must have a knowledge of the practice of supervision and to have the necessary personal quality of leadership.

It is not possible to be a senior welding inspector without technical knowledge BUT the quality of leadership is an essential addition.

It is sometimes said that leadership cannot be taught and there is a lot of truth in this. But the ability to lead can be improved by teaching./

The technical skills required are:

1. Knowledge of technology
2. Knowledge of Codes of Practice
3. Knowledge of Planning
4. Knowledge of Organisation
5. Knowledge of Auditing

Leadership requires :

1. Ability to do if so required
2. Willingness to direct
3. Acceptance of responsibility
4. Understanding of problems
5. Ability to delegate
  - willingness to trust staff
6. Commitment to ones staff

#### Knowledge of Technology:

The scope and level of the technical aspects of welding with which the senior welding inspector needs to be familiar are similar to those of the welding inspector with slightly more depth but in addition a good appreciation of NDT is required together with (for CSWIP) a proven ability in radiographic interpretation.

#### Knowledge of Codes of Practice:

Neither welding inspectors or senior welding inspectors would be expected to have a detailed recall of the requirements of a code of practice. What is expected is at the senior level an appreciation of the commonly used codes and degree of stringency implied. That is what the product type is and what the general quality requirements are.

#### As a first check list:

1. Standards for consumables  
BS 639      DIN 1913      AWS A:5:81
2. Standards for welding procedure approval  
BS 4870      ASME IX
3. Standards for welder approval  
BS 4871 & 4872      ASME IX      DIN 8560
4. Standards for quality of fabrication  
BS 5500      ASME VIII      AWS Structural Code

It is to be noted that standards are merely convenient collections of good practice data. As such a client who is commissioning the manufacture may incorporate this into the legal contract: but a client can (and often will) add requirements of his own devising. Most major fabrications and many smaller ones are in fact controlled by a code plus a special client requirement.

# **SENIOR WELDING INSPECTOR**

## **THE DUTIES OF A SENIOR WELDING INSPECTOR (SWI)**

### **QUESTIONS:**

1. In general terms what are the duties of a Senior Welding Inspector.
2. State the five technical skills which are required by the Senior Welding Inspector.
3. State the six essential elements which comprise Leadership.

## NOTES ON INSPECTION, QUALITY CONTROL & QUALITY ASSURANCE

It must be said that these terms, although they are all widely used and definitions of their meanings defined in many documents, are not sufficiently precise for really general application. It is not uncommon to find that these functions overlap or that in particular instances QA is planned and organised as a department which in practice covers inspection and quality control. Again many UK and USA manufacturing plants are organised with a Project Office dealing with the aims of quality and an Inspection Office dealing with the attainment of quality.

Hence these notes are written in terms of functions rather than departments, that is they attempt to identify WHAT is done, not the title of the person performing the job or function.

DEFINITIONS: Extract BS 4778 Pt 1 1987  
(Quality Vocabulary)

- |                          |   |                                                                                                                                                                                         |
|--------------------------|---|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Quality Assurance</b> | – | "All those planned and systematic actions necessary to provide adequate confidence that a product or service will satisfy given requirements for quality."                              |
| <b>Quality Control</b>   | – | "The operational techniques and activities that are used to fulfill requirements for quality."                                                                                          |
| <b>Inspection</b>        | – | Activities such as measuring, examining, testing, gauging one or more characteristics of a product or service and comparing these with specified requirements to determine conformity." |

In basic terms an alternative way of putting this is:

- |                          |   |                                                                         |
|--------------------------|---|-------------------------------------------------------------------------|
| <b>Quality Assurance</b> | – | States what is wanted in general terms                                  |
| <b>Quality Control</b>   | – | States what to observe and measure in order to meet the QA requirements |
| <b>Inspection</b>        | – | Observes and measures specific details                                  |

# **SENIOR WELDING INSPECTOR**

## **INSPECTION, QUALITY CONTROL & QUALITY ASSURANCE**

### **QUESTIONS:**

1. In an organisation which has departments of Production Engineering and Design Engineering, how may the functions of Inspection, Quality Control and Quality Assurance be organised.
2. In an organisation with departments of Inspection, Quality Control and Quality Assurance which departments would be responsible for the following functions:
  - a) Measuring excess metal
  - b) Deciding on the appearance requirements of a weld
  - c) Setting the level of toughness
  - d) Setting the limits of amperage variation
  - e) Collecting and analyzing inspection documents
  - f) Granting concessions with respect to defects
  - g) Setting inspection requirements
3. Briefly describe two methods by which the Quality Control department can control the level of inspection (i.e. the details etc.)

## NOTES FOR PLANNING

The planning function may be taken to mean the consideration of the necessary arrangements which must be made from the general notification of the job requirement through to the final advice of completion.

It is usual to find that this falls into three (3) stages.

1. Preparation and dispatch of staff i.e. collection of codes, tickets, hotels, travel time.
2. The inspection and documentation:
  - i.e. Equipment
  - Personnel approvals
  - Procedure approvals
  - Material
  - Consumables
  - Edge preparations
  - Tacks
  - Pre-heat
  - Welding
3. Collection of test data and certificates and return to base.

There are various methods of dealing with the planning function and the three (3) most common are:

1. Allocate staff on a block basis
  - i.e. send an inspector on to the site and allow and expect him to make a useful return on his time
2. Use of charts in which each job function (or group of job functions) is estimated for time. In some instances this enables a considerable saving of staff time to be made, but by implication the inspector works "harder" and tends to travel more.

3. Use of critical path analysis in which a detailed assessment is made or obtained of the overall production plan and the inspection function is meshed into this.

Which of these approaches is used will depend on the nature of the work flow and the number of calibre of the available inspection and back-up staff. Also critical is the degree of competition, which may be the driving force for economic use of staff and hence low tendering.

# SENIOR WELDING INSPECTOR

## QUESTIONS

1. A fabricated product is required to be made with "increased" toughness. Outline the QA, QC and Inspection requirements which must be undertaken in order to attain this requirement.
2. In an organisation which has departments of QA, QC and Inspection, which department(s) would be responsible for sanctioning "small" deviations in:
  - a) size of weld
  - b) welding parameters A, V, S
  - c) material specifications
  - d) mechanical properties
3. A product being made to a pressure vessel code has a QC requirement that defects should be limited to 80% of the stated values, but that defects between 80% and 100% values should be referred to QC for approval.

Give your appreciation of the reasons for this.

## **PLANNING ASPECTS**

Planning can be taken to mean 'to make the general arrangements'. There are many ways of increasing productivity. Amongst them, production or project planning is high on the list. Apart from improving the utilization of resources it also forms the basis for effective production or project control, and thereby reduces the risk of over spending budgets and for failing to achieve delivery targets.

### **Some advantages of planning**

- (a) Jobs are planned and issued in correct sequence thereby reducing unnecessary work-in-progress and minimising the need for overtime or subcontractors.
- (b) Men and machines are supplied with the correct materials and tools at the right time.
- (c) The correct quality standards are achieved for minimum cost.
- (d) Completed goods are despatched to customers as promised.
- (e) Adequate stock levels of materials and components are maintained.
- (f) Greater job satisfaction for employees.
- (g) Greater job security.

A sound system of planning should clearly show the stages of manufacture and inspection. It should draw attention to bottlenecks and areas of unused resources, and show what, and where, additional resources are needed. The system and methods of planning must be fully understood by the supervisor, and prove capable of coping with sudden changes to programme. Simplicity should be foremost in the mind of the planner when developing a system, or selecting a planning technique. Reverse Scheduling and Network Planning are two principal planning techniques.

### **Reverse Scheduling**

Most jobs consist of a sequence of operations and in most cases it is essential that the correct sequence and a brief description of each operation is determined before work is issued. In addition a time estimate should be made for each operation. By fixing the very last operation at the required completion date, and working back in reverse sequence, the target dates for all operations can be determined. This is called "Reverse Scheduling" and is a well proven method of planning. Figure 1 shows part of a reverse scheduling plan. The target date for the last operation 'Ship' is week 26. Provided the operation sequence and time estimates are known it is then

|                               |             |      |      |      |
|-------------------------------|-------------|------|------|------|
|                               | Final Build | Test | Insp | Ship |
| 14 15 16 17 18 19 20 21 22 23 |             |      |      |      |

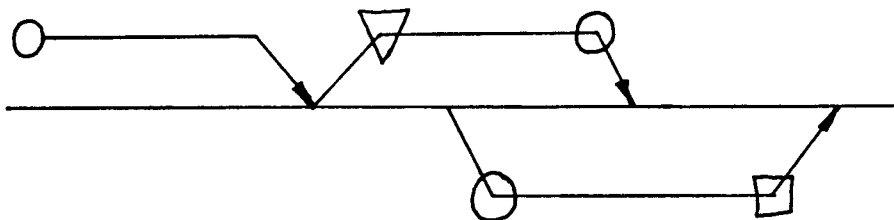
**Figure 1** Part of a reverse scheduling plan showing completion target dates

## Network Planning (Forward Scheduling)

About twenty years ago a few British firms began to experiment with a planning technique developed by the U.S. Navy called 'Programme Evaluation Review Technique' (Pert), and a more simple but similar technique called Critical Path Analysis (C.P.A). Both techniques are based on a single idea of showing the correct sequence of jobs by means of links or arrows in a network. An example is shown in Figure 2. A project is broken down into major tasks or work packages called 'activities'. The junction between the finish of one and the start of another activity is shown by a circle. The planner defines the very first job (in this example Design) and would shown this as an arrow at the extreme lefthand side of a sheet of paper. The immediate succeeding jobs (their start being controlled by the finish of the preceding job) are drawn in a similar fashion as shown in Figure 2. Hence 'Order Materials', 'Determine Methods' and 'Order Components' cannot start until the 'Design' is finished. 'Inspection' follows immediately after 'Order Material' and 'Order Components' and so on. The very last activity is 'Test and Final Inspection'.

Many components involved with projects now use this method of planning, and the supervisor is often called upon to estimate the duration time for the job, or work package, for which he will be responsible. The estimate should be based on normal practice and methods i.e. the most efficient methods.

If the supervisor finds he is unable to complete a job according to schedule he must report this immediately to the project manager or co-ordinator. Any delay may cause the project to run late which could cause unsatisfactory customer relations and the possible loss of future contracts.



# **SENIOR WELDING INSPECTOR**

## **PLANNING**

### **QUESTIONS:**

1. Give a brief definition of the planning function.
2. Planning may be taken to mean the sequential combination of three sub-functions. What are these?
3. The planning function may be approached in three ways. Briefly describe these.
4. You are to prepare data for tendering on an unusual offshore inspection job at a distance of 2 days travel from your base office. Draw up a preliminary check list of items which must be considered.
5. Give two advantages of the use of "BAR" charts when planning.
6. Give two advantages of the use of "Critical Path Analysis" when planning.

## **NOTES FOR ORGANISATION**

The organisation function may be taken to mean the fitting of staff to the plan which must then be supervised to completion.

In these terms the organisation function means the ability to assess the detailed requirements of the plan and to gauge the ability of individual staff to be technically competent, available and temperamentally able to perform the tasks involved.

As a preliminary check list organisation involves :

1. Total man hours of inspection required
2. Maximum time allowed
3. Number of inspectors required
4. Analysis of job functions (see planning)
5. Estimation of job times
6. Analysis of job sequences
7. Preparation time
8. Travel time
9. Leave

# **SENIOR WELDING INSPECTOR**

## **ORGANISATION**

### **QUESTIONS:**

1. Give a brief description of the organisation function.
2. What should be completed before attempting to organise.
3. What function is used to ensure that the plan and organisation is proceeding correctly AND that deviations are recognised and corrected.
4. What are the personal aspects of an Inspector which should be considered and perhaps assessed when attempting to organise him/her into the plan.
5. In the context of welding inspection of heavy fabrications what is the aspect which most commonly causes the "time" assessment made in the plan and organisation to be invalid. How can this problem be dealt with during tendering.

## **NOTES FOR AUDITING**

The term audit has been taken from accounting practice and means:

- a) An overall check of inspection
  - b) A detailed check of a very limited area of inspection
- a) In the overall check the general content of the fabrication file is examined for:
- (i) completeness
  - (ii) presentation
- and a general impression is formed as to the visual quality of the product.
- b) For the detailed check the requirements of a very limited zone is examined with great care and (as appropriate) the code requirements are checked against the documents in the fabrication file.

## **Auditing**

There are three types of audits currently used in the fabrication industry.

1.    **Pre-production**
  - this is usually undertaken to assess ability in terms of staff and facilities to perform a task.
  
2.    **In-production**
  - this is to confirm that welding and the related activities are being conducted according to the requirements specified or to an acceptable workshop standard.
  
3.    **Post-production**
  - the objective in this instance is to ensure that the welding and the welding inspection are satisfactory.

## **SUPERVISION**

### **What is a supervisor?**

A supervisor is any person who is given authority and responsibility for planning and controlling the work of others with whom they are in close touch.

### **Supervisors and Operators**

The difference between a supervisor and an operator is that an operator performs his own work but the supervisor gets work done through his operators.

### **Supervisors and Managers**

Supervisors are part of the management structure. The term "supervision", however, generally implies overseeing and controlling a working group on the spot dealing with situations and details as they arise.

The term "management" implies planning ahead and controlling work more remotely using administrative procedures and reporting systems.

### **"The man in the middle"**

The supervisor is in a key position between operators and management able to encourage smooth working or cause disruption (wilfully or unintentionally). He is also subject to pressures from both sides who each expect him to support their views. He must seek to earn the respect and support of managers and operators, carrying out sometimes unpopular orders and duties at the same time as looking after the interests of the group he leads.

### **Working with others**

The job of the supervisor is enhanced and becomes more satisfying if he makes use of the assistance of specialist advisers on personnel, work scheduling, work study, finance, etc. thereby allowing him to spend more time on organising and dealing with his staff.

The supervisor should also recognise the role of the shop steward and endeavour to promote a good working relationship through a straightforward exchange of information and explanations on plans, problems, changes and complaints. Strict adherence to agreed procedures, fairness in dealings and a joint effort to settle problems at supervisor/shop steward level should produce mutual respect and improve the working "atmosphere".

### **Responsibilities of a Supervisor**

A supervisor is responsible for his subordinates, the activities and the work place which he is given formal authority to control. This usually includes:

1. Staff – morale, consultation, discipline, welfare, safety, employment induction, training
2. Work – maximum economy
3. Cost – maximum economy
4. Machines and equipment – maintenance, loading, operation
5. Materials – supplies, suitability, economic use
6. Workplace – layout, tidiness, good housekeeping

### **Qualities of a good supervisor**

Particular circumstances will give different emphasis to the following essential basic qualities required in the good supervisor.

1. Technical skill and knowledge – ability to explain why and how jobs are to be performed to eliminate faults, dangerous practices, wastage, to keep up to date.
2. Intelligence – judgement, sound common sense, ability to determine priorities.
3. Drive – vitality, energy, enthusiasm and general good health. Vigour is as infectious as fatigue is demoralising.
4. Leadership – maintenance of high personal standards, goal setting, trustworthiness, reliability, consistency, fairness, stability, persistence and a sense of humour.

### **Motivation**

Some of the better-known theories on what induces people to work more purposefully have been put forward by Abraham Maslow, Frederick Hergberg and Douglas McGregor. The main features of their research findings are :

#### **Abraham Maslow**

People will strive to satisfy basic human needs. These needs have an ascending order of importance so that when one need is satisfied it no longer acts as an effective motivator. The need that is next in the order of importance becomes the motivator. Hence, the theory is sometimes referred to as "Maslow's Ladder of Needs".

Five levels of need (or rungs on the ladder) are identified. In ascending order of importance they are :

1. Survival – e.g. hunger, thirst
2. Safety – e.g. security, protection
3. Social – e.g. belonging, acceptance in a group
4. Esteem – e.g. success, respect
5. Self fulfilment – e.g. achievement, inner satisfaction

Whilst striving to satisfy the next level of need, if a lower order of need is at risk, attention reverts to satisfying that level (e.g. illness, loss of job etc. will temporarily at least, affect ambition and alter a person's priorities).

Maslow's theory helps our understanding of what people are seeking from their work. In today's welfare state, many of the lower order needs are satisfied by social legislation and attention is therefore concentrated on the higher levels (e.g. social, respect etc.)

### **Frederick Herzberg**

Herzberg's contribution to understanding what induces people to work is the identification that what satisfies people at work is not the opposite of the same factors that cause dissatisfaction.

Satisfaction, according to Herzberg, comes from the job itself through interest in the work, a feeling of achievement, of meeting a challenge, of effort recognised, or responsibility carried and of professional growth. Dissatisfaction arises more from the work environment and conditions, relationships with supervisors and others, policies and organisations pay, status and security.

Attention paid to removing causes of dissatisfaction is important if the contribution of people at work is not to fall below a "fair days effort". However, in order to induce an increased effort, more attention needs to be paid to involving people in their work improving the interest and challenge of the job.

Concern for the context in which the job is done may reduce the complaints but improving the content of the job is necessary if greater effort is to be induced. (Ref. The Motivation to Work by F. Herzberg).

### **Douglas McGregor**

McGregor's work is based on his idea that effective leadership depends on a supervisor's assumptions about the nature of supervision and about people in general – summarised by theory "X" and theory "Y" in his book "The Human Side of Enterprise".

Theory "X" applies where a supervisor considers his operators inherently dislike work, will attempt to avoid assuming responsibility whenever possible and are generally not

ambitious. They therefore need to be coerced, controlled directed and if necessary punished.

Theory "Y" assumes that work is a natural activity and that if encouraged through reward involvement and respect people will work well, exercise self discipline or have potential for development.

Both theories recognise that much work as organised in the modern world is an unnatural form of behaviour and some kind of pressure is needed. Theory "X" leads to submission to orders, compulsion and threats whilst theory "Y" involves coaxing and the creation of opportunities for achievement and personal improvement.

### **Motivation and the Supervisor**

These and other theories on behaviour of people at work emphasise the need for a supervisor to take an interest in his operators, to try to understand their attitudes and reactions, to treat them responsibly and with respect for their views, efforts and skills. Responsible treatment includes correcting or reprimanding those who fail to respond responsibly. Good operators expect the supervisor to act justly when dealing with those who do not conform to working requirements.

### **Staff Assessment**

Linking motivation with the responsibility of a supervisor to achieve targets of performance is the assessment of staff and the development needs of the supervisor's section.

Whatever policy an organisation applies to staff assessment, a supervisor inevitably forms judgements on the varying capabilities and attributes of his operatives. Assessment procedures only differ in the degree to which they are formalized.

If no other agreed system applies, a supervisor should first decide the factors that are important in constituting a good worker. These usually include such factors as quantity of output, quality of output, versatility (range of capabilities) co-operation, timekeeping, conduct, relationships with others etc. On the basis of factual records where possible, each operative can be assessed against each factor using for instance a three or five grading scale. The five grades might show AVERAGE performance with two levels above average and two levels below:

|      |                  |         |                  |           |
|------|------------------|---------|------------------|-----------|
| POOR | BELOW<br>AVERAGE | AVERAGE | ABOVE<br>AVERAGE | EXCELLENT |
|------|------------------|---------|------------------|-----------|

A simpler three grade scale may be :

|       |         |       |
|-------|---------|-------|
| BELOW | AVERAGE | ABOVE |
|-------|---------|-------|

Operatives should be made aware of those factors which are satisfactory and by discussion methods should be agreed for improving those aspects which are not satisfactory.

### **Assessing Section Development Needs**

Similar principles of assessment can be applied to the needs of the section over the whole range of the supervisor's responsibilities.

For this purpose it is useful to construct a simple grid, listing a heading to the columns the tasks or jobs for which the supervisor is responsible. The rows of the grid carry the names of the operatives in the supervisor's section.

The grid is then completed by indicating in the squares the tasks each operator is capable of performing and how well he performs that particular task. Different colour marks could be used to indicate ability to perform a task averagely well, above average, exceptionally well or poorly.

Such a grid is a valuable document for a supervisor. In compiling it, the supervisor is compelled to consider the full range of present and known future commitments and the abilities of each member of his team. The completed grid exposes weaknesses in job coverage, limitations of staff versatility and highlights development and training needs, to make best use of labour resources.

### **Discipline**

The aim in exercising industrial discipline is not to punish but to obtain co-operation in achieving the company's targets, but ensuring that personal behaviour confirms to the company's rules and standards.

In dealing with offenders, a supervisor should consider the likely reaction not only on the offender but on others in the working group.

By his influence and example, a supervisor should try to encourage self-discipline, a responsible attitude (making requirements known and why; giving responsibility; involving workers).

To be accepted, discipline must be seen to be fair:

- a) Rules and standards expected should be known
- b) The consequences of failure should be known
- c) Consistent application of discipline – no favourites, no scapegoats; in accordance with custom and practice

- d) Impartial administration – a natural and expected consequence; in the company's interest – not a personal vendetta.
- e) In accordance with agreed procedure.

To be effective discipline needs to be progressive – repetition being considered more serious. It is therefore necessary to consider the levels available e.g.

1. Continuous checking and correcting of performance and behaviour (being "on the ball")
2. Reprimand (in private)
3. Reprimand with written warning
4. Suspension, transfer, demotion, with-holding privileges, etc.
5. Dismissal with notice (e.g. incompetence)
6. Dismissal without notice (e.g. serious misconduct)

Some general tips for the supervisor:

Know the extent of your authority (how far can you go)

Know company practice in similar cases

Find out all the facts of the case

Act promptly – do not let things slide

Avoid frequent reprimands (they lose effect and encourage suppression of faults)

Mean what you say – no idle threats

### Elements of a Supervisor's Authority

A supervisor responsible for achieving specific company objectives within the framework of company policy, can rely on :

1. **"Formal authority"** – delegated (stemming from ownership).  
the right to make decisions.  
the right to give orders and require compliance.  
power to reward or punish.  
(consumable? Submission?)
2. **Authority of knowledge** – ability to inform.  
ability to solve problems.  
ability to correct errors.  
("authority" on a subject)
3. **Personal Influence** – acceptance by subordinates based on :  
  
**Trust** – "means what he says".  
"a man of his word" – keeps promises.  
reliable – "you know where you stand with him".

- |                                |   |                                                                                                                                                                                                                                                       |
|--------------------------------|---|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Confidence</b>              | – | in his ability to cope with situations.<br>facing up to problems – not passing the buck.<br>making effective decisions.<br>taking action.                                                                                                             |
| <b>Fairness</b>                | – | Objective in dealing with people.<br>consistent within department and company.<br>consistent over time.<br>no favourites: no scapegoats.                                                                                                              |
| <b>Respect</b><br>(reciprocal) | – | involvement, participation, consultation.<br>delegation of responsibility.<br>setting of targets.<br>accountability ("on the ball")<br>keeping people informed, explaining reasons.<br>regular staff assessment.<br>invites suggestions and comments. |

The measure of a supervisor's leadership is the response of the subordinates. Co-operation is an attitude formed from experience.  
In his dealings a supervisor should anticipate likely reactions.

## **The Supervisors Role in Project Planning**

To make an effective contribution to project planning the supervisor should be able to answer the following question :

### **WHAT IS THE CURRENT FORWARD WORK LOAD IN YOUR DEPARTMENT?**

If the supervisor can answer this question he should be able to deal with the following:

- (i) Can additional work be confidently accepted and a reliable completion date be given.
- (ii) If it is necessary to accept a 'rush job' what will be the effect on other orders.
- (iii) How much additional work must be found to avoid resources from being under utilized.
- (iv) If an order is cancelled how will it effect the department budget.

If an answer is to be found to the former question some form of work load record is essential.

This may be in the form of :

- (a) a written record
- (b) visual display
- (c) a computer file and print out

### **Written Records**

A written record may take the form of a 'Department Work Load Summary Sheet' as shown in Figure 3. The average man hours (capacity) available for a given period is first determined, and as orders for work are received this is taken away from the available capacity and the balance shown. Looking at the example Fig.3 the Inspection Department has a capacity of 200 man days per period (say a month). A number of jobs need inspecting in connection with contract ZU/76/107. The first requires 2 days therefore the balance is 198, the next job requires 7 days so the balance drops to 191 and so on. The method is very simple and takes very little time to maintain. The effect of order cancellation or re-scheduling can be readily determined.

A further innovation would be to provide an additional column showing actual time taken so the supervisor could, over a period, check the accuracy of the estimates.

Fig. 3 Department Work Load Summary Sheet

| Inspection Department |                           |                   |                                 |
|-----------------------|---------------------------|-------------------|---------------------------------|
| Period:7              | Section & Control Systems |                   | Capacity<br>200 days/<br>period |
| Contract<br>Number    | Activity<br>Number        | Estimated<br>Days | Available<br>Capacity           |
| ZU/76/107             | 3 – 7                     | 2                 | 198                             |
|                       | 3 – 9                     | 7                 | 191                             |
|                       | 12 – 13                   | 10                | 181                             |
| ZU/76/201             | 4 – 10                    | 12                | 169                             |
| ZX/76/159             | 5 – 7                     | 20                | 149                             |
|                       | 8 – 10                    | 16                | 133                             |
|                       | 8 – 14                    | 4                 | 129                             |
|                       | 8 – 17                    | 5                 | 124                             |
| ZX/76/187             | 5 – 11                    | 34                | 90                              |
|                       |                           |                   |                                 |

## **CODES AND STANDARDS**

### **CLASS OF WORK**

There are many types of work which require engineering materials to be joined by welding, for example:

- pressure vessels
- bridges
- oil rigs
- earth moving equipment
- aero-engines
- ventilation systems
- storage tanks
- heavy vehicle chassis
- car bodies
- food processing plant

The quality requirements of the joints in these fabrications depend on their fitness-for-purpose and differ significantly from one application to the next.

Pressure vessels require welds which can withstand the stresses and high temperatures experienced in operation.

Bridges must take into account the effect of differing vehicle loads and wind loading.

Oil rigs are designed to withstand the effect of wave formation and wind loads.

Earth moving equipment has to accommodate differences in terrain and earth conditions and is subject to fatigue loading.

Welds in food processing plants must withstand corrosion by hot acidic liquors.

On the next page some typical Codes of practice and Standards which cover various types of constructions being fabricated by welding are listed.

Note: Throughout this text, the term Code is used to cover Code of Practice, Standard and Specification.

| <b>Code</b> | <b>Class of Work</b>                                               |
|-------------|--------------------------------------------------------------------|
| BS 5500     | Unfired fusion welded pressure vessels                             |
| ASME VIII   | American boiler and pressure vessel code                           |
| BS 2633     | Class 1 Arc welding of ferritic steel pipework for carrying fluids |
| BS 4515     | Process of welding steel pipelines on land and offshore            |
| BS 5950     | Structural use in steelwork in building                            |
| AWS D1.1    | Structural welding code (American)                                 |
| BS 5400     | Steel concrete and composite bridges                               |
| BS 6235     | Code of Practice for fixed offshore structure                      |
| API 1104    | Standard for welding pipelines and related facilities              |

These documents can also provide a useful source of data for applications where Codes do not exist. It should be remembered, however, that the principal criterion in the Codes listed is the quality of the joint in relation to the service conditions. There are other applications where success is judged by different criteria, such as dimensional accuracy.

Another important consideration is controlling the cost of welding. Variations in weld times and quantities of consumables can readily result if the method of making a weld is left to the welder to decide.

The continuous and satisfactory performance of weldments made to various Codes requires that specific guidelines are laid down to cover materials, design of joints, welding processes, welding consumables, acceptance criteria and inspection techniques.

These guidelines are usually grouped under the general heading of a Weld Procedure.

## SENIOR WELDING INSPECTOR

### "SIGNING OFF A PRODUCT"

In many fields of fabrication it is a requirement that on completion of a product a review is made of all documentation to ensure conformity to the specification, code and drawing requirements. Usually until this review is completed and perhaps a Release Note or Shipping Note is signed, the product is not complete with possible late payments and penalties on delivery being incurred.

It could be part of the Senior Welding Inspector's duties to carry out this task. The requirements for such a check would normally be stated in the client's specification although some standards, e.g. BS5500, lay down what documents must be available and checked. Some, if not all, of these documents may have to be incorporated into a Data Book on completion of the contract.

In order to perform this task, a check list of all documents used on the product must be prepared. The task is made easier if Quality Plans or at least Inspection Check lists are in use on the job. The numbers and types of documents will obviously depend upon the complexity and quality standard of the product, but among the documents to be reviewed could be:

|                              |                                                                                                           |                                            |
|------------------------------|-----------------------------------------------------------------------------------------------------------|--------------------------------------------|
| <b>Quality Plan</b>          | All stages complete and signed off                                                                        |                                            |
| <b>Inspection Check List</b> | All stages complete and signed off                                                                        |                                            |
| <b>Materials</b>             | All certificates checked. In some cases this may include tests carried out by the consumable(s) supplier. |                                            |
| <b>Procedures for:</b>       | Cutting<br>Welding<br>Repair<br>NDT<br>PWHT<br>Testing<br>Coating                                         | All have to be approved                    |
| <b>Qualification of:</b>     | Welders<br>NDT Personnel<br>Inspectors                                                                    | All have to be approved and are up to date |

|                                                      |                                                                                    |                                                         |
|------------------------------------------------------|------------------------------------------------------------------------------------|---------------------------------------------------------|
| <b>Inspection Reports for:</b>                       | Visual<br>NDT<br>Dimensional                                                       | Ensure they cover all appropriate joints and structures |
| <b>Calibration Certificates:</b>                     | for those items of equipment deemed necessary, e.g. pressure gauges for Hydro Test |                                                         |
| <b>PWHT Charts:</b>                                  | Ensure all necessary information is on records, e.g. job descriptions, chartspeeds |                                                         |
| <b>Hydro Test:</b>                                   | Reports are complete                                                               |                                                         |
| <b>As Built Drawings:</b>                            | All are completed                                                                  |                                                         |
| <b>Materials &amp; Weld Map:</b>                     | All are completed                                                                  |                                                         |
| <b>Nameplate Rubbings:</b>                           | When applicable                                                                    |                                                         |
| <b>Concessions/Deviations/Site Query sheets</b>      |                                                                                    |                                                         |
| <b>Permits to work/Degas certificates applicable</b> |                                                                                    |                                                         |
| <b>Coating Reports</b>                               |                                                                                    |                                                         |

## **QUESTIONS**

### **CODES AND STANDARDS**

- Q1. List the typical items to be found in a Code of Practice
- Q2. Explain the meanings of the terms:
- a) 'Shall'
  - b) 'Should'
- Q3. What is meant by the term 'concession'?
- Q4. Does a Code of Practice contain all relevant information?
- Q5. State the three (3) parties generally mentioned in Codes or Standards

# **SENIOR WELDING INSPECTOR**

## **QUESTIONS**

### **CODES AND STANDARDS**

- Q1. List the contents of a typical Code of Practice.
- Q2. Are the requirements legally binding
- Q3. At what point of production should the inspector ensure the correct use of consumables.
- Q4. Can a non-approved welder be employed on production work.
- Q5. Long question (300 words)  
Write in an essay format a "signing off of product" to your respective code.

## THE WELDING PROCEDURE

The task of collecting the data and drafting the documentation is often referred to as *writing* a weld procedure. In many ways this is an unfortunate term as the writing of documents is the last in a sequence of tasks.

Producing a weld procedure involves:

- 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

In each Code reference is made to how the procedures are to be devised and whether approval of these procedures is required. In most Codes approval is mandatory and tests to confirm the skill of the welder are specified. Details are also given of acceptance criteria for the finished joint.

The approach used depends on the Code, for example:

BS 2633 : (Class 1 arc welding of ferritic steel pipework for carrying fluids) provides general comments on various aspects of a suitable weld procedure.

AWS D.1.1 (Structural welding code – steel) favours more specific instructions for different joints and processes which are, in effect, pre-qualified procedures.

Other Codes do not deal specifically with the details of the weld procedure but refer to published documentation, e.g. BS 5135 'process of arc welding carbon and carbon manganese steels'.

## COMPONENTS OF A WELD PROCEDURE

Items to be included in the procedure can be some of the following:

### 1. Parent metal

- 1.1 Type
- 1.2 Thickness (for pipe this includes outside diameter)
- 1.3 Surface condition
- 1.4 Identifying marks

### 2. Welding process

- 2.1 Type of process (MMA, TIG, MAG etc)
- 2.2 Equipment
- 2.3 Make, brand, type of welding consumables
- 2.4 When appropriate the temperature and time adopted for drying and baking of electrode/consumables

### 3. Joint design

- 3.1 Welding position
- 3.2 Edge preparation
- 3.3 Method of cleaning, degreasing etc
- 3.4 Fit up of joint
- 3.5 Jigging or tacking procedure
- 3.6 Type of backing

### 4. Welding position

- 4.1 Whether shop or site welding
- 4.2 Arrangement of runs and weld sequence
- 4.3 Filler material, composition and size (diameter)
- 4.4 Welding variables – voltage, current travel speed
- 4.5 Weld size
- 4.6 Back gouging
- 4.7 Any specific features, e.g. heat input control, run-out length

### 5. Thermal treatment

- 5.1 Preheat and interpass temperatures including method and control
- 5.2 Post weld treatment including method and control

## **APPROVING THE PROCEDURE**

When the data has been collected, the procedure must be validated by producing and testing a trial weld.

If the procedure is to be used on a fabrication which has been designed to meet the requirements of a Code, the test weld is done under the supervision of an independent witness. The detailed arrangements for the test are subject to agreement between the contracting parties.

A number of British Standards make cross reference to another Standard which covers approval testing.

Other Codes of practice include their own weld procedure/welder approval information.

In general they include a standard format which can be used to report the results of an approval test.

# MANUFACTURER'S WELDING PROCEDURE SPECIFICATION (WPS)

(see EN 288-2)

Location: .....TWI TRAINING WORKSHOP.....  
 Manufacturer's Welding Procedure: .....pWPS 001/A.....  
 Reference No: .....41920.....  
 WPAR No: .....0223.....  
 Manufacturer: .....FRED BLOGGS INDUSTRIES.....

Examiner or test body:.....B.D.I LTD.....

DEGREASE &

Method of Preparation and Cleaning:.....MACHINE...

Parent Material Specification: ..316L STAINLESS STEEL

C .03% Cr 17% Mn 1.5% Mo 2.5%

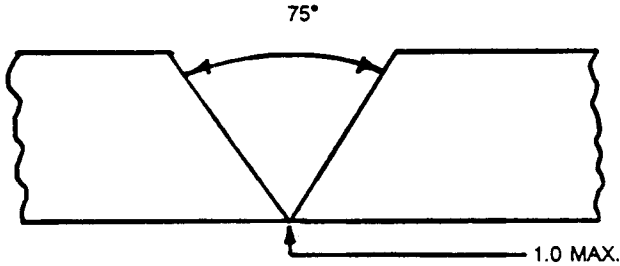
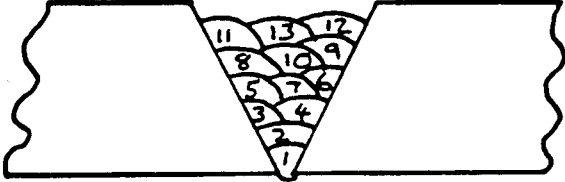
Ni 11% Si 0.5% + Residuals

Material Thickness (mm): .....15mm

Outside Diameter (mm):.....155mm.....

Welding Position: .....HL045.....

Welder's Name: .....A N OTHER.....  
 Welding Process: .....141(TIG ROOT)/111(MMA FILL & CAP).....  
 Joint Type: .....SINGLE VEE BUTT.....

| Weld Preparation Details/Joint Design (Sketch)*                                   | Welding Sequences                                                                  |
|-----------------------------------------------------------------------------------|------------------------------------------------------------------------------------|
|  |  |

## Welding Details

| Run        | Process | Size of Filler Metal | Current A | Voltage V | Type of current/ Polarity | Wire Feed Speed | Travel Speed* | Heat Input* |
|------------|---------|----------------------|-----------|-----------|---------------------------|-----------------|---------------|-------------|
| 1          | 141     | AUTOGENEOUS          | 60-70     | 10-12     | DCEN                      | -               | 40mm/mn       | 1.0Kj/mm    |
| 2-4        | 111     | 3.2mm                | 110-120   | 20-22     | DCEP                      | -               | 140mm ROL     | 1.0Kj/mm    |
| 5-10       | 111     | 3.2mm                | 95-110    | 20-22     | DCEP                      | -               | 130mm ROL     | 1.0Kj/mm    |
| 10 to      | 111     | 2.5mm                | 70-90     | 20-22     | DCEP                      | -               | 100mm ROL     | 1.0Kj/mm    |
| completion |         | 2.5mm                | 70-90     | 20-22     | DCEP                      | -               | 100mm ROL     | 1.0Kj/mm    |
| -          | -       | -                    | -         | -         | -                         | -               | -             | -           |

Filler Metal Classification and trade name:.....SOUOMETAL SUPERCROM 316L to ISO 3581-E19:12:3:LR23.....

Any Special Baking or Drying: .....DRY AT 100°C FOR 2 HOURS QUIVER AT 75°C.....

Gas/Flux: shielding: .....ARGON - COMMERCIAL PURITY .....

backing : .....ARGON - COMMERCIAL PURITY .....

Gas Flow Rate - Shielding: .....8 LITRES/MINUTE.....

Backing: .....4 LITRES/MINUTE.....

Tungsten Electrode Type/Size: .....2% THORIUM 2.5 φ.....

Details of Back Coupling/Backing: .....RETAIN UNTIL RUN 5 ONWARD..

Preheat Temperature: .....NONE.....

Interpass Temperature: .....150°C MAXIMUM.....

Other information\*.....

e.g. weaving (maximum width of run): .....2 x φ.....

Oscillation: amplitude, frequency, dwell time: .....as required

Pulse welding details: .....NOT REQUIRED .....

Stand off distance: .....NOT REQUIRED .....

Plasma welding details: .....NOT REQUIRED .....

Torch angle: .TILT 90° SLOPE 70°.....

Post-Weld Heat Treatment and/or Ageing: .....NONE.....

Time, Temperature, Method: .....NOT REQUIRED.....

Heating and Cooling Rates\*: .....AS PROCEDURE.....

Manufacturer

Name .....FREDERICK BLOGGS.....  
 Date ..00-00-199-.....  
 Signature .....*Frederick Bloggs*.....

Examiner or test body

Name .....I.C. ITCANBE.....  
 Date .....00-00-199.....  
 Signature .....*I.C. ITCANBE*.....

## WELDING PROCEDURE SPECIFICATION

With the information provided below check W.P.S. for contents.

### 4. Items in a welding procedure test

**4.1 General.** The items listed in 4.2 and the items in 4.3 relevant to the particular welding process shall be recorded for each welding procedure test.

NOTE. Not all of these items need be included in the approved welding procedure documentation.

**4.2 Items for all welding processes.** Details relating to the following items shall be recorded for all welding processes:

- (a) welding process, or processes when more than one is used in making a complete joint;
- (b) parent metal specification, thickness and for pipe† the outside diameter or dimension;
- (c) whether shop or site welding;
- (d) edge preparation (sketch);
- (e) cleaning, degreasing etc.;
- (f) fit-up (sketch);
- (g) jiggling or tacking, backing, etc.;
- (h) welding position (including direction for vertical position);
- (i) make, brand and type of welding consumables;
- (j) filler material composition and size (diameter);
- (k) pre-heating and interpass temperature, including method and control;
- (l) travel speed (mechanized welding);
- (m) approximate number and arrangement of runs and weld dimensions (sketch);
- (n) welding sequence;
- (o) back gouging;
- (p) post-weld heat treatment, including method and control;
- (q) when applied, the temperature and time adopted for drying/baking of welding consumables before use;
- (r) any special features, including heat input control requirements, e.g. run-out length (R.O.L.).

**4.3 Items for particular welding processes.** Details relating to the items given in 4.3(a) to 4.3(f) shall be recorded for these particular processes in addition to the items in 4.2. For pipe welding, where back purging is used, the purge gas, flow rate of purge gas, and period shall be recorded.

#### (a) *Manual metal-arc welding*

- (1) a.c. or d.c. and polarity;
- (2) current;
- (3) for pulsed welding, the pulse time, pulse current, background current and background voltage.

#### (b) *MIG welding, solid or cored wire, including cored wire CO<sub>2</sub> and gasless welding*

- (1) shielding gas and flow rate;
- (2) nozzle diameter;
- (3) arc voltage;
- (4) wire feed speed or current.

Additional for dip transfer technique:

- (5) electrode extension (mechanized welding);
- (6) circuit inductance or setting;
- (7) for pulsed welding, the pulse time, pulse current, background current and background voltage.

#### (c) *TIG welding*

- (1) tungsten electrode diameter and type;
- (2) shielding gas and flow rate;
- (3) nozzle diameter;
- (4) a.c. or d.c. and polarity;
- (5) current;
- (6) arc length or voltage for mechanized welding;
- (7) for pulsed welding, the pulse time, pulse current, background current and background voltage.

#### (d) *Submerged arc welding and continuous covered electrode arc welding with or without CO<sub>2</sub> or flux shielding*

- (1) number and configuration of electrode wires and electrical connections;
- (2) shielding gas and flow rate;
- (3) electrode extension;
- (4) a.c. or d.c. and polarity;
- (5) current;
- (6) voltage;
- (7) power source characteristic.

#### (f) *Gas welding*

- (1) oxygen pressure;
- (2) fuel gas and pressure;
- (3) nozzle size;
- (4) flame characteristic (oxidizing, reducing or neutral);
- (5) rightward or leftward technique.

**WELDING PROCEDURE APPROVAL RECORD FORM (WPAR)**  
TO EN 288

**WELDING PROCEDURE APPROVAL - TEST CERTIFICATE**

Manufacturer's Welding Procedure  
Reference No. ....41920/001/A.....

Examiner or test body BDI LTD.....  
Reference No. .BDI 71000/25 .....

Manufacturer: ...FRED BLOGGS INDUSTRIES .....

Address ....375 LONDON ROAD, CAMBRIDGE UK. ....

Code/Testing Standard:.....EN 288 .....

Date of Welding: .....00-00-199- .....

**EXTENT OF APPROVAL**

Welding Process: ....141 TIG ROOT 111 MMA FILL & CAP .....

Joint Type : ....ANY BUTT JOINT IN PIPE OR PLATE/FILLET WELDS IN PIPE/PLATE & T BUTT WELDS .....

Parent metal(s): .....AUSTENITIC STAINLESS STEELS..... Conditions of tempered: .NOT APPLICABLE.....

Metal thickness (mm): .....12mm - 16.5mm .....

Outside Diameter (mm): .....78mm - 310mm .....

Filler Metal type : .....316L SOUDOMETAL SUPERCROM TO ISO E19:12:3:L R 2:3 ONLY .....

Shielding Gas/Flux: .....ARGON .....

Type of Welding Current: .....DIRECT CURRENT 141 DCEN 111 DCEP .....

Welding Positions: .....ALL POSITIONS EXCEPT P.G. (VERTICAL DOWN) .....

Preheat: .....NOT REQUIRED.....

Post-Weld Heat Treatment and/or ageing: .....NOT REQUIRED.....

Other Information: .....TACK WELDING NOT PERMITTED LINE UP CLAMPS ONLY .....

Certified that test welds prepared, welded and tested satisfactorily in accordance with the requirements of the code/testing standard indicated above.

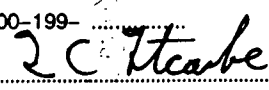
Location .....

Date of Issue .00-00-199- .....

Examiner or test body

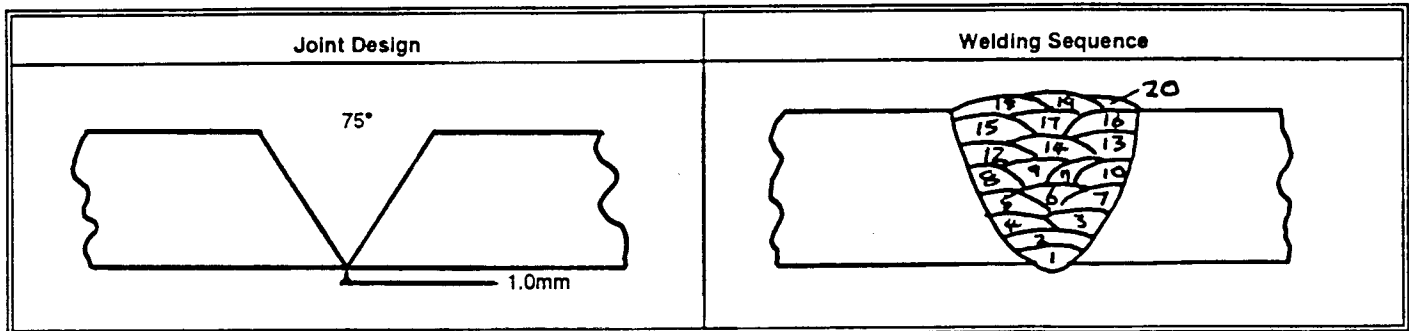
Name... B.D.I. LTD. I.C. ITCANBE

Date...00-00-199- .....

Signature  .....

# DETAILS OF WELD TEST

Location: .....SHOP - TWI TRAINING WORKSHOP..... Examiner or test body: ....B.D.I. LTD.....  
 Manufacturer's Welding Procedure  
 Reference No.: .....41920 .....  
 WPAR No: .....WPAR 001/A..... Method of Preparation and Cleaning: ..M/C & DEGREASE  
 Parent Material Specification: ..316L STAINLESS STEEL  
 Manufacturer: .....FRED BLOGGS INDUSTRIES .....  
 Welder's Name: .....A N OTHER .....  
 Welding Process: .....141 (TIG) 111 (MMA).....  
 Joint Type : .....SINGLE VEE BUTT.....  
 Weld Preparation Details (Sketch)\*: .....NO ROOT FACE..... Material Thickness (mm): ....15mm .....  
 Outside Diameter (mm) : ....155mm .....  
 Welding Position : ..h1045 .....



## Welding Details

| Run        | Process | Size of Filler Metal | Current A | Voltage V | Type of current/ Polarity | Wire Feed Speed | Travel Speed* | Heat Input* KJ/mm |
|------------|---------|----------------------|-----------|-----------|---------------------------|-----------------|---------------|-------------------|
| 1          | 141     | AUTOGENEOUS          | 65        | 11        | DCEN                      | -               | 45mm          | 0.95              |
| 2-4        | 111     | 32mm                 | 115       | 21        | DCEP                      | -               | 150mm         | 0.96              |
| 5-10       | 111     | 3.2mm                | 105       | 21        | DCEP                      | -               | 150mm         | 0.88              |
| 10 to      | 111     | 3.2mm                | 80        | 21        | DCEP                      | -               | 110mm         | 0.96              |
| completion |         | 3.2mm                | 80        | 21        | DCEP                      | -               | 110mm         | 0.96              |

Filler Metal Classification and trade name: ....SOU DOMETAL SUPERCROM 316L .....  
 Any Special Baking or Drying:.....DRIED AT 100°C - 2 HRS. ....  
 Gas/Flux: shielding: .....BOC ARGON.....  
 backing: .....BOC ARGON.....  
 Gas Flow Rate - Shielding: .....6 LITRES/MIN.....  
 Backing: .....4 LITRES/MIN.....  
 Tungsten Electrode Type/Size: .....2% THORIUM 2.5mm.....  
 Details of Backing: .....RETAINED UNTIL RUN 6.....  
 Preheat temperature: .....NONE APPLIED.....  
 Interpass Temperature: .....MAXIMUM 130°C.....  
 Other information\*:  
 e.g. weaving (Maximum width of run): ..NONE..  
 Oscillation: amplitude, frequency, dwell time  
 Pulse welding details: ..NONE .....  
 Stand off distance:.....NONE .....  
 Plasma welding details: ..NONE.....  
 Torch angle: .....AS REQUIRED .....

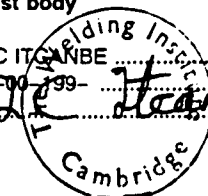
Post-Weld Heat Treatment and/or Ageing:.....NONE .....  
 Time, Temperature, Method: .....NONE.....  
 Heating and Cooling Rates\*: .....NONE.....

## MANUFACTURER

Name: .....FREDERICK BLOGGS.....  
 Date: .....00-00-199-.....  
 Signature: .....Frederick Bloggs.....

## Examiner or test body

Name: .....I C IT CANBE.....  
 Date: .....00-00-199-.....  
 Signature: .....I C IT CANBE.....



# TEST RESULTS

## Manufacturer's Welding Procedure

Reference No.: 41920/001A

## Examiner or test body

Reference No.: BDI 71000/25

Visual Examination:

Radiography\*: ACCEPTABLE

Penetrant/Magnetic Particle Test\*

Ultrasonic Examination\*: NOT REQUIRED

## Tensile Tests

Temperature: +20°C

| Type/No.   | Re<br>N/mm <sup>2</sup> | Rm<br>N/mm <sup>2</sup> | A % on | Z % | Fracture Location | Remarks    |
|------------|-------------------------|-------------------------|--------|-----|-------------------|------------|
| TRANSVERSE | 448                     | 550                     | 40%    | -   | PARENT            | ACCEPTABLE |
| TRANSVERSE | 477                     | 550                     | 38%    | -   | PARENT            | ACCEPTABLE |
| -          | -                       | -                       | -      | -   | -                 | -          |
| -          | -                       | -                       | -      | -   | -                 | -          |

## Bend Tests

Former Diameter: 60mm

| Type/No.     | Bend Angle | Elongation*  | Result     |
|--------------|------------|--------------|------------|
| ROOT (UPPER) | 120°       | NOT REQUIRED | ACCEPTABLE |
| FACE (UPPER) | 120°       | "            | "          |
| ROOT (LOWER) | 120°       | "            | "          |
| FACE (LOWER) | 120°       | "            | "          |
| -            | -          | -            | -          |
| -            | -          | -            | -          |

Macro Examination:  
Micro Examination\*:

## Impact Test\* CHARPY

Type: VEE NOTCH

Size: 0.25mm

Requirement:

| Notch Location/Direction | Temp.°C | Values |    |    | Average | Remarks    |
|--------------------------|---------|--------|----|----|---------|------------|
|                          |         | 1      | 2  | 3  |         |            |
| WELD METAL               | -100°C  | 37     | 41 | 40 | 39      | ACCEPTABLE |
| H.A.Z.                   | -100°C  | 35     | 39 | 38 | 37      | ACCEPTABLE |
| PARENT METAL             | -100°C  | 32     | 36 | 35 | 35      | ACCEPTABLE |

## Hardness Tests\*

Type/load: NOT REQUIRED

Location of Measurements(Sketch\*)

Parent Metal: NOT APPLICABLE

H.A.Z.:

Weld Metal:

Other Tests:

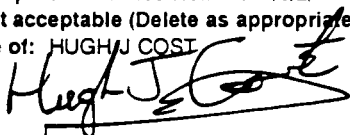
Remarks: ACCEPTABLE TO EN 288

Tests carried out in accordance with the requirements of:

Laboratory Report Reference No.: 7654/3/2/1

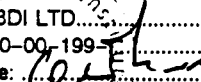
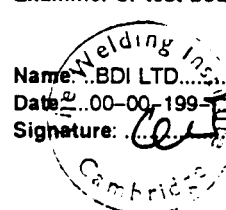
Test results were acceptable/not acceptable (Delete as appropriate)

Test carried out in the presence of: HUGH J COST



\* If required

Examiner or test body

Name: BDI LTD  
Date: 00-00-199-  
Signature: 


Page 3 of 3

# SENIOR WELDING INSPECTOR

## PROCEDURE QUALIFICATION RECORD OR WELD PROCEDURE APPROVAL RECORD

With the information provided below, check W.P.A.R. for "Range of Approval"

| Type of joint in approval test piece |                        |                                                                                     | Butt welds on plate  |            |                        |            | T butt welds on plate |                        | Fillet weld on plate | Butt welds on pipe   |            | Fillet weld on pipe |
|--------------------------------------|------------------------|-------------------------------------------------------------------------------------|----------------------|------------|------------------------|------------|-----------------------|------------------------|----------------------|----------------------|------------|---------------------|
|                                      |                        |                                                                                     | Welded from one side |            | Welded from both sides |            | Welded from one side  | Welded from both sides |                      | Welded from one side |            |                     |
|                                      |                        |                                                                                     | with backing         | no backing | with gouging           | no gouging |                       |                        |                      | with backing         | no backing |                     |
| Butt weld on plate                   | Welded from one side   | with backing                                                                        | ✓                    | -          | ✓                      | ✓          | -                     | ✓                      | ✓                    | -                    | -          | ✓                   |
|                                      |                        | no backing                                                                          | ✓                    | ✓          | ✓                      | ✓          | ✓                     | ✓                      | ✓                    | -                    | -          | ✓                   |
|                                      | Welded from both sides | with gouging                                                                        | -                    | -          | ✓                      | ✓          | ✓                     | ✓                      | ✓                    | -                    | -          | ✓                   |
|                                      |                        | no gouging                                                                          | -                    | -          | -                      | ✓          | -                     | ✓                      | ✓                    | -                    | -          | ✓                   |
| Butt weld on pipe                    | Welded from one side   | with backing                                                                        | ✓                    | -          | ✓                      | ✓          | -                     | ✓                      | ✓                    | ✓                    | -          | ✓                   |
|                                      |                        | no backing                                                                          | ✓                    | ✓          | ✓                      | ✓          | ✓                     | ✓                      | ✓                    | ✓                    | ✓          | ✓                   |
| T butt weld on plate                 | Welded from one side   |    | -                    | -          | -                      | -          | ✓                     | ✓                      | ✓                    | -                    | -          | ✓                   |
|                                      | Welded from both sides |   | -                    | -          | -                      | -          | -                     | ✓                      | ✓                    | -                    | -          | ✓                   |
| Fillet weld                          | Plate                  |  | -                    | -          | -                      | -          | -                     | -                      | ✓                    | -                    | -          | ✓                   |
|                                      | Pipe                   |  | -                    | -          | -                      | -          | -                     | -                      | ✓                    | -                    | -          | ✓                   |

Key:  
 ✓ indicates the weld for which the WPS is approved in the approval test  
 ✓ indicates those welds for which the WPS is also approved  
 - indicates those welds for which the WPS is not approved

| Group | Type of steel                                                                                                                                                                                                                                                                                      |
|-------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1     | Steels with a minimum specified yield stress $R_e \leq 355 \text{ N/mm}^2$ or $R_m \leq 520 \text{ N/mm}^2$ and with analyses not exceeding in %:<br>C = 0.24<br>Si = 0.85<br>Mn = 1.60<br>Mo = 0.65<br>S = 0.045<br>P = 0.045<br>Any other single element = 0.3<br>All other elements total = 0.8 |
| 2     | Normalized or thermo-mechanically treated fine grain steels with a specified minimum yield stress $R_e > 355 \text{ N/mm}^2$                                                                                                                                                                       |
| 3     | Quenched and tempered fine grain steels with a specified yield stress $R_e > 500 \text{ N/mm}^2$                                                                                                                                                                                                   |
| 4     | Steels with Cr max. 0.8 %, Mo max. 0.5 %, V max. 0.25 %<br>See note 1                                                                                                                                                                                                                              |
| 5     | Steels with Cr max. 9 %, Mo max. 1.2 %<br>See note 1                                                                                                                                                                                                                                               |
| 6     | Steels with Cr max. 12 %, Mo max. 1 %, V max. 0.5 %<br>See note 1                                                                                                                                                                                                                                  |
| 7     | Steels with Ni max. 9 %<br>See note 1                                                                                                                                                                                                                                                              |
| 8     | Ferritic or martensitic stainless steels from 12 % to 20 % Cr.<br>See note 1                                                                                                                                                                                                                       |
| 9     | Austenitic stainless steels                                                                                                                                                                                                                                                                        |

NOTE 1: For groups 4 to 8: the alloy content relates to nominal ladle analysis.

| Thickness of the test piece t | (Dimensions in mm)                           |                       |
|-------------------------------|----------------------------------------------|-----------------------|
|                               | Range of approval (1) (2)                    |                       |
|                               | for single run or single run from both sides | for multi-run welding |
| $t \leq 3$                    | 0.8 t to 1.1 t                               | t to 2 t              |
| $3 < t \leq 12$               | 0.8 t to 1.1 t                               | 3 to 2 t              |
| $12 < t \leq 100$             | 0.8 t to 1.1 t                               | 0.5 t to 2 t max. 180 |
| $t > 100$                     | 0.8 t to 1.1 t                               | 0.5 t to 1.5 t        |

1) For tests below the impact limit (12 mm) approval is  $\leq 12 \text{ mm}$ , without impact testing.  
2) The range of approval may have to be reduced in order to avoid hydrogen cracking.

| Diameter of the test piece D (1) (2)<br>mm | Range of approval           |
|--------------------------------------------|-----------------------------|
| $D \leq 168.3$                             | 0.5 D to 2 D                |
| $D > 168.3$                                | $\geq 0.5 D$ and plates (3) |

1) D is the outside diameter of the pipe or outside diameter of the branch pipe.  
2) Approval given for plates also covers pipe when the outside diameter is  $> 500 \text{ mm}$ .  
3) See also 8.4.2.

## DOCUMENTATION

The objectives of a procedure or welder approval test are:

- a) to prove the procedure meets the necessary requirements with reference to feasibility, mechanical strength etc
- b) to prove the welders are competent to work in a particular job

If a customer queries it, evidence can and would be supplied to prove validity, even though the approval tests might have been some considerable time ago.

Approval Test Specifications call for a paper record which can be known as either:

- procedure/welder approval certificate
- procedure/welder approval record
- procedure/welder approval report

The following records should also be kept:

- a) NDT reports
- b) records of visual examination or mechanical testing
- c) test pieces from destructive testing

Other records which are equally important are:

- a) PROOF of regular employment on a job
- b) for scheduling re-tests
- c) to avoid duplication on procedure approval

## TEST CERTIFICATE

Should state clearly that it is a welder approval; and not a PROCEDURE approval, and, depending on the particular Standard, should contain the following:

- a) welder's name and identity number – could be his/her clock or payroll number, or possibly a photograph
- b) date of the test
- c) Standard of Code in full, i.e. BRITISH STANDARD 4872 PT 1 : 1982
- d) testpiece details including material specification
- e) equipment and consumable details: welding equipment, type of filler etc
- f) extent of approval
- g) sketch of run sequence, preparation and dimensions

- h) other factors, operating parameters etc
- i) the test results (visual, NDT, DT etc)
- j) remarks
- k) witnessed by
- l) test supervisor
- m) location

Most Standards give an example of the test certificate.

**SIGNATURES ON CERTIFICATES MUST BE ENDORSED WITH COMPANY STAMP.**

### **STORAGE AND RETRIEVAL**

Most companies prefer to store the records in a conventional filing system. With larger companies it may be useful to use a computer filing system or register which could automatically give an indication of re-approval.

# WELDER APPROVAL TEST CERTIFICATE

Designation: .....EN 287.....

Manufacturer's Welding Procedure Specification.....41920 .....

Examiner or test body .....BDI LTD. ....

Reference No.(if applicable)..... 0223 .....

Reference No. ....0223 .....

Welder's Name: .....P COCK .....

Photograph

Identification: ..... 54321 .....

(if required) NOT REQUIRED

Method of Identification: ..... PASSPORT .....

Date and place of birth: .....25 DECEMBER 1952 .....

Employer: .....FRED BLOGGS INDUSTRIES .....

Code/Testing Standard: ..... EN 287 .....

Job Knowledge: Acceptable ~~Not tested~~ (Delete as necessary)

|                               | Weld test details      | Range of approval                     |
|-------------------------------|------------------------|---------------------------------------|
| Welding process               | 141 (TIG) 111 (MMA)    | 141 TIG / 111 MMA                     |
| Plate or pipe                 | PIPE                   | PIPE & PLATE                          |
| Joint type                    | SINGLE VEE BUTT        | ANY BUTT OR FILLET WELD               |
| Parent metal group(s)         | W11                    | W01/W02/W03/W04/W011/                 |
| Filler metal type/Designation | ISO 3581 E19:12:3:LR23 | ABOVE APPROVAL USING SPECIFIED FILLER |
| Shielding gases               | ARGON                  | ARGON                                 |
| Auxiliaries                   | ARGON BACKING          | ARGON                                 |
| Test piece thickness (mm)     | 15mm                   | 5mm AND GREATER                       |
| Pipe outside diameter (mm)    | 155mm $\phi$           | GREATER THAN 0.5 $\phi$               |
| Welding position              | HL045                  | ALL POSITIONS EXCEPT VERTICAL DOWN    |
| Gouging/ <del>Beveling</del>  | NOT REQUIRED           | REQUIRED ON DOUBLE PREPS              |

Additional information is available on attached sheet and or welding procedure specification No.:

00-00-199-

| Type of test      | Performed and acceptable | Not required |
|-------------------|--------------------------|--------------|
| Visual            | ✓                        |              |
| Radiography       | ✓                        |              |
| Magnetic particle |                          | ✓            |
| Dye penetrant     | ✓                        |              |
| Macro             |                          | ✓            |
| Fracture          | ✓                        |              |
| Bend              | ✓                        |              |
| Additional Tests* |                          | ✓            |

\* Append separate sheet if required

Name, date and signature I C ITCANBE

Examiner or test body BDI LTD

Date of issue 00-00-199-

Location TWI TRAINING WORKSHOP

Validity of approval until 00-00-199-

Prolongation for approval by employer/coordinator  
for the following 6 months (refer to 10.2)

| Prolongation for approval by examiner or test body<br>for the following 2 years (refer to 10.2) |           |                   |
|-------------------------------------------------------------------------------------------------|-----------|-------------------|
| Date                                                                                            | Signature | Position or title |
|                                                                                                 |           |                   |
|                                                                                                 |           |                   |
|                                                                                                 |           |                   |
|                                                                                                 |           |                   |
|                                                                                                 |           |                   |
|                                                                                                 |           |                   |

| Date | Signature | Position or title |
|------|-----------|-------------------|
|      |           |                   |
|      |           |                   |
|      |           |                   |
|      |           |                   |
|      |           |                   |
|      |           |                   |

# SENIOR WELDING INSPECTOR

## WELDER APPROVAL CERTIFICATE

With the information provided below check welder approval certificate for extent of approval.

### 6.3 Joint types

Depending on the test piece, the range of welds for which the welder is approved is shown in table 3; the following criteria are applicable:

- approval for butt welds in pipes includes butt welds in plates;
- approval for butt welds in plates in all relevant positions covers butt welds on pipes having an outside diameter  $\geq 500$  mm, for rotating pipes item c) applies;
- approval on test butt joints in plates welded in the flat (PA) or horizontal vertical (PC) position shall include approval for butt joints in pipes of outside diameter  $\geq 150$  mm welded in similar positions according to table 7;
- welding from one side without backing approves welds from one side with backing and welds from both sides with and without gouging;
- welding in plates or pipes with backing approves welds made from both sides, but not for welds without backing;
- butt welds approve fillet welds for similar welding conditions;
- in cases where the production work is predominantly fillet welding, it is recommended that the welder should be approved also by an appropriate fillet welding test, i.e. on plate, pipe or branch connection (see EN 288-3);
- welding from both sides without gouging approves welds from one side with backing and welds from both sides with gouging;
- approval for butt welds in pipes without backing includes approval for branch connections within the same range of approval as in tables 3 to 7. For a branch weld the range of approval is based on the diameter of the branch;
- in cases where the production work is either predominantly branch welding or involves a complex branch connection, it is recommended that the welder should receive special training. In some cases a welder approval test on a branch connection may be necessary.

Table 3: Range of approval for tests on butt joints (Details of weld type)

| Details of weld type                                                       |                                 |              |    | Range of approval          |                  |                              |                  |                            |                  |
|----------------------------------------------------------------------------|---------------------------------|--------------|----|----------------------------|------------------|------------------------------|------------------|----------------------------|------------------|
|                                                                            |                                 |              |    | Butt welds in plate        |                  |                              |                  | Butt welds in pipe         |                  |
|                                                                            |                                 |              |    | welded from one side<br>ss |                  | welded from both sides<br>bs |                  | welded from one side<br>ss |                  |
|                                                                            |                                 |              |    | with backing<br>mb         | no backing<br>nb | with gouging<br>gg           | no gouging<br>ng | with backing<br>mb         | no backing<br>nb |
| Butt weld<br>in plate                                                      | welded from<br>one side<br>ss   | with backing | mb | ★                          | –                | x                            | –                | 1)                         | –                |
|                                                                            |                                 | no backing   | nb | x                          | ★                | x                            | x                | 1)                         | 1)               |
|                                                                            | welded from<br>both sides<br>bs | with gouging | gg | x                          | –                | ★                            | –                | 1)                         | –                |
|                                                                            |                                 | no gouging   | ng | x                          | –                | x                            | ★                | 1)                         | –                |
| Butt weld<br>in pipe                                                       | welded from<br>one side<br>ss   | with backing | mb | x                          | –                | x                            | –                | ★                          | –                |
|                                                                            |                                 | no backing   | nb | x                          | x                | x                            | x                | x                          | ★                |
| 1) See 6.3b) and 6.3c)                                                     |                                 |              |    |                            |                  |                              |                  |                            |                  |
| Key                                                                        |                                 |              |    |                            |                  |                              |                  |                            |                  |
| ★ indicates the weld for which the welder is approved in the approval test |                                 |              |    |                            |                  |                              |                  |                            |                  |
| x indicates those welds for which the welder is also approved              |                                 |              |    |                            |                  |                              |                  |                            |                  |
| – indicates those welds for which the welder is not approved               |                                 |              |    |                            |                  |                              |                  |                            |                  |

# SENIOR WELDING INSPECTOR

## 6.4 Material groups

According to the material group of the test piece, the range of materials for which a welder is approved is shown in tables 4 and 5 (see 5.4). For any steel not covered by any of the steel groups the welder shall carry out an approval test, which only approves for that steel.

**Table 4: Range of approval for parent metal**

| Material group of approval test piece                                                                                                                                                                                                                                                                                                                                                                                                  | Range of approval |                 |                 |                 |      |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|-----------------|-----------------|-----------------|------|
|                                                                                                                                                                                                                                                                                                                                                                                                                                        | W 01              | W 02            | W 03            | W 04            | W 11 |
| W 01                                                                                                                                                                                                                                                                                                                                                                                                                                   | ★                 | -               | -               | -               | -    |
| W 02                                                                                                                                                                                                                                                                                                                                                                                                                                   | x                 | ★               | -               | -               | -    |
| W 03                                                                                                                                                                                                                                                                                                                                                                                                                                   | x                 | x               | ★               | -               | -    |
| W 04                                                                                                                                                                                                                                                                                                                                                                                                                                   | x                 | x               | -               | ★               | -    |
| W 11                                                                                                                                                                                                                                                                                                                                                                                                                                   | x <sup>1)</sup>   | x <sup>1)</sup> | x <sup>1)</sup> | x <sup>1)</sup> | ★    |
| <sup>1)</sup> When using filler metal from group W 11.<br><b>Key</b><br>★ indicates the material group for which the welder is approved in the approval test<br>x indicates those material groups for which the welder is also approved<br>- indicates those material groups for which the welder is not approved<br><br><b>NOTE:</b> This table applies only when parent metal indicated by ★ and filler metal are in the same group. |                   |                 |                 |                 |      |

**Table 5: Range of approval for dissimilar metal joints**

| Material group of approval test piece                                                                                                                                                     | Range of approval                                                                                                                                |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------|
| W 02                                                                                                                                                                                      | W 02 welded to W 01 <sup>1)</sup>                                                                                                                |
| W 03                                                                                                                                                                                      | W 02 welded to W 01 <sup>1)</sup><br>W 03 welded to W 01 <sup>1)</sup><br>W 03 welded to W 02 <sup>1)</sup>                                      |
| W 04                                                                                                                                                                                      | W 02 welded to W 01 <sup>1)</sup><br>W 04 welded to W 01 <sup>1)</sup><br>W 04 welded to W 02 <sup>1)</sup>                                      |
| W 11                                                                                                                                                                                      | W 11 welded to W 01 <sup>2)</sup><br>W 11 welded to W 02 <sup>2)</sup><br>W 11 welded to W 03 <sup>2)</sup><br>W 11 welded to W 04 <sup>2)</sup> |
| <sup>1)</sup> For a dissimilar metal joint the filler metal shall correspond to the group of one of the parent metals.<br><sup>2)</sup> When using filler metal from material group W 11. |                                                                                                                                                  |

## 6.5 Covered electrodes

A change in the type of electrode coating may require a change in the welder's technique. An approval test of electrode coating will confer approval of the welder for other coatings as specified in table 6.

**Table 6: Range of approval for electrode coating**

| Type of covered electrodes of approval test piece                                                                                                                                                                                                                                                                                                                     | Range of approval |               |   |   |   |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|---------------|---|---|---|
|                                                                                                                                                                                                                                                                                                                                                                       | A: RA             | R: RB: RC: RR | B | C | S |
| A: RA                                                                                                                                                                                                                                                                                                                                                                 | ★                 | -             | - | - | - |
| R: RB: RC: RR                                                                                                                                                                                                                                                                                                                                                         | x                 | ★             | - | - | - |
| B                                                                                                                                                                                                                                                                                                                                                                     | x                 | x             | ★ | - | - |
| C                                                                                                                                                                                                                                                                                                                                                                     | -                 | -             | - | ★ | - |
| S <sup>1)</sup>                                                                                                                                                                                                                                                                                                                                                       | -                 | -             | - | - | ★ |
| <sup>1)</sup> S only gives approval for the specific type of electrode coating used in the test.<br><b>Key</b><br>★ indicates the covered electrode type for which the welder is approved in the approval test<br>x indicates those electrode groups for which the welder is also approved<br>- indicates those electrode groups for which the welder is not approved |                   |               |   |   |   |

## 6.6 Shielding gas and flux

A change of shielding gas or flux is permitted (see 5.5.1). However, a change from active to inert shielding gas or from inert to active shielding gas requires a new approval test for the welder.

Table 7: Range of approval according to welding position

| Welding position of approval test piece |                                      |          |    | Range of approval |        |    |    |    |              |    |    |    |    |                      |       |     |     |                  |              |     |   |   |   |   |   |
|-----------------------------------------|--------------------------------------|----------|----|-------------------|--------|----|----|----|--------------|----|----|----|----|----------------------|-------|-----|-----|------------------|--------------|-----|---|---|---|---|---|
|                                         |                                      |          |    | Plates            |        |    |    |    |              |    |    |    |    | Pipes                |       |     |     |                  |              |     |   |   |   |   |   |
|                                         |                                      |          |    | Butt welds        |        |    |    |    | Fillet welds |    |    |    |    | Butt welds           |       |     |     |                  | Fillet welds |     |   |   |   |   |   |
|                                         |                                      |          |    |                   |        |    |    |    |              |    |    |    |    | Pipe-axis and -angle |       |     |     |                  |              |     |   |   |   |   |   |
|                                         |                                      |          |    |                   |        |    |    |    |              |    |    |    |    | rotating             | fixed |     |     | 1)               | fixed        |     |   |   |   |   |   |
|                                         |                                      |          |    |                   |        |    |    |    |              |    |    |    |    |                      | 0°    | 90° | 45° |                  | 0°           | 90° |   |   |   |   |   |
| PA                                      | PC                                   | PG       | PF | PE                | PA     | PB | PG | PF | PD           | PA | PG | PF | PC | H-L045               | PB    | PG  | PF  | PD <sup>2)</sup> |              |     |   |   |   |   |   |
| Plates                                  | Butt welds                           | PA       | ★  | -                 | -      | -  | -  | x  | x            | -  | -  | -  | x  | -                    | -     | -   | -   | x                | -            | -   | - |   |   |   |   |
|                                         |                                      | PC       | x  | ★                 | -      | -  | -  | x  | x            | -  | -  | -  | x  | -                    | -     | x   | -   | x                | -            | -   | - |   |   |   |   |
|                                         |                                      | PG       | -  | -                 | ★      | -  | -  | -  | -            | x  | -  | -  | -  | -                    | -     | -   | -   | -                | -            | -   | - |   |   |   |   |
|                                         |                                      | PF       | x  | -                 | -      | ★  | -  | x  | x            | -  | x  | -  | x  | -                    | -     | -   | -   | x                | -            | x   | - |   |   |   |   |
|                                         |                                      | PE       | x  | x                 | -      | x  | ★  | x  | x            | -  | x  | x  | x  | -                    | -     | -   | -   | x                | -            | x   | x |   |   |   |   |
|                                         | Fillet welds                         | PA       | -  | -                 | -      | -  | -  | ★  | -            | -  | -  | -  | -  | -                    | -     | -   | -   | -                | -            | -   | - |   |   |   |   |
|                                         |                                      | PB       | -  | -                 | -      | -  | -  | x  | ★            | -  | -  | -  | -  | -                    | -     | -   | -   | x                | -            | -   | - |   |   |   |   |
|                                         |                                      | PG       | -  | -                 | -      | -  | -  | -  | ★            | -  | -  | -  | -  | -                    | -     | -   | -   | -                | -            | -   | - |   |   |   |   |
|                                         |                                      | PF       | -  | -                 | -      | -  | -  | x  | x            | -  | ★  | -  | -  | -                    | -     | -   | -   | x                | -            | -   | - |   |   |   |   |
|                                         |                                      | PD       | -  | -                 | -      | -  | -  | x  | x            | -  | x  | ★  | -  | -                    | -     | -   | -   | x                | -            | -   | x |   |   |   |   |
| Pipes                                   | Butt welds<br>Pipe-axis and -angle   | rotating | 0° | PA                | x      | -  | -  | -  | -            | x  | x  | -  | -  | -                    | ★     | -   | -   | -                | -            | x   | - | - | - |   |   |
|                                         |                                      |          |    | PG                | -      | -  | x  | -  | -            | -  | -  | x  | -  | -                    | -     | ★   | -   | -                | -            | -   | - | x | - | - |   |
|                                         |                                      | fixed    |    | PF                | x      | -  | -  | x  | x            | x  | x  | -  | x  | x                    | x     | -   | ★   | -                | -            | -   | x | - | x | x |   |
|                                         |                                      |          |    | 90°               | PC     | x  | x  | -  | -            | -  | x  | x  | -  | -                    | -     | x   | -   | -                | ★            | -   | - | x | - | - | - |
|                                         |                                      |          |    | 45°               | H-L045 | x  | x  | -  | x            | x  | x  | -  | x  | x                    | x     | -   | x   | x                | ★            | x   | - | x | x |   |   |
|                                         | Fillet welds<br>Pipe-axis and -angle | 1)       | 0° | PB                | -      | -  | -  | -  | -            | x  | x  | -  | -  | -                    | -     | -   | -   | -                | -            | ★   | - | - | - |   |   |
|                                         |                                      |          |    | PG                | -      | -  | -  | -  | -            | -  | x  | -  | -  | -                    | -     | -   | -   | -                | -            | -   | ★ | - | - |   |   |
|                                         |                                      | fixed    |    | PF                | -      | -  | -  | -  | -            | x  | x  | -  | x  | x                    | -     | -   | -   | -                | -            | -   | x | - | ★ | x |   |

1) PB for pipes may be welded in two versions

(1) pipe: rotating; axis: horizontal; weld: horizontal vertical

(2) pipe: fixed; axis: vertical; weld: horizontal vertical

2) This is an approved position and is covered by the other related tests.

## Key

★ indicates the welding position for which the welder is approved in the approval test

x indicates those welding positions for which the welder is also approved

- indicates those welding positions for which the welder is not approved

## QUESTIONS

### WELD PROCEDURE & WELDER APPROVAL

- Q1. State six (6) essential variables
- Q2. State the meaning of 'extent of approval' and give five (5) examples
- Q3. Explain the difference between a welding procedure specification, a procedure qualification record and a welder approval certificate
- Q4. Why are procedures and welders approved?
- Q5. State two (2) reasons for re-approval of:
- a) A weld procedure
  - b) A welder

# SENIOR WELDING INSPECTOR

## PROCEDURE AND WELDER APPROVAL

- Q1. Describe briefly 2 (two) methods of producing approved procedures.
- Q2. Can a welder be approved when welding without a procedure.
- Q3. If a welding procedure has been approved state six reasons for re-approval.
- Q4. During a welder approval test should the welder be given time to practice before attempting a "test".
- Q5. Give a typical "Extent of Approval" for
- a) thickness
  - b) diameter
  - c) process
- Q6. Sketch the following weld positions for pipe
- i) 1G
  - ii) 2G
  - iii) 3G
  - iv) 4G
  - v) 5G
  - vi) 6G
- Q7. State 4 (four) reasons for re-approving a welder.
- Q8. If a welder is approved to weld plate would he be allowed to weld pipe?
- Q9. In a welder approval test should the procedure be explained to the welder.
- Q10. Long question: State briefly the main details of conducting a procedure/welder approval.

## DESTRUCTIVE TESTING

Destructive tests on welded joints are usually made as part of the approval of a welding procedure or a welder.

The test pieces are cut from the test weld and their location is often specified in the standard.

**British Standards for Testing of Welds**  
BS 709: 1983 Methods of testing fusion welded joints and weld metal in steel

Commonly used destructive tests are:

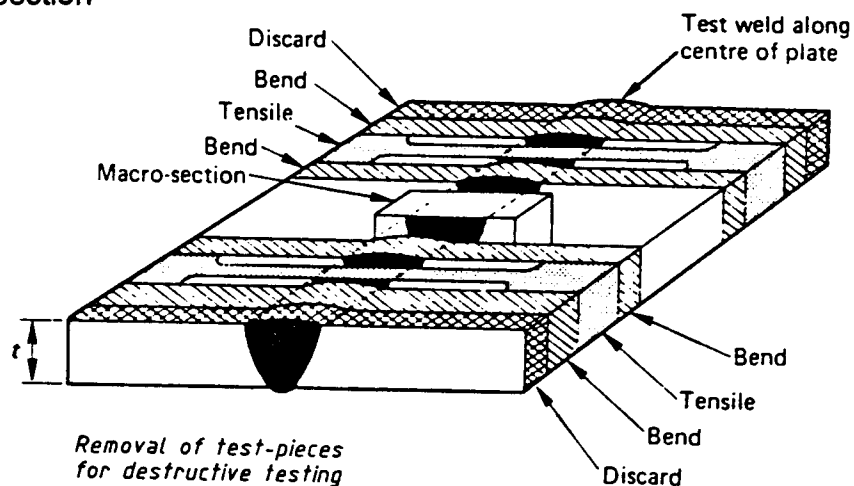
Bend

Tensile

Charpy

Fracture tests

Macro section



## BEND TESTS (transverse and longitudinal)

### Object

To determine the soundness of weld metal, heat affected zone and weld zone.

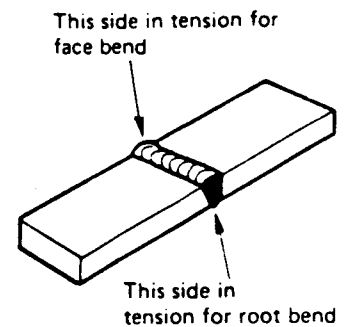
These tests may also be used to give some measure of the ductility of the weld zone. It is not usual to use longitudinal and transverse bend tests for the same application.

### Method

The specimen is bent by the movement of a former of prescribed diameter, the relevant side of the specimen to be placed in tension. Angle of bend and diameter of former should be as specified in the appropriate application standard.

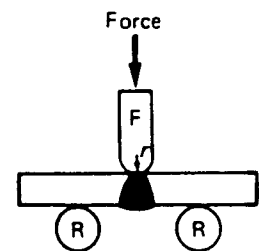
### Reporting Results

1. Thickness of specimen
2. Direction of bend (root or face)
3. Angle of bend
4. Diameter of former
5. Appearance of joint after bending, e.g. type and location of flaws.

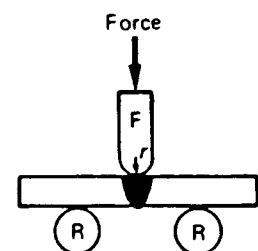


Test-piece for face or root bend

*Surface in contact with former is ground flat*



(a) Face bend



(b) Root bend

R = Roller support  
F = Former of specified radius (r) at end

## SIDE BEND TEST

### Object

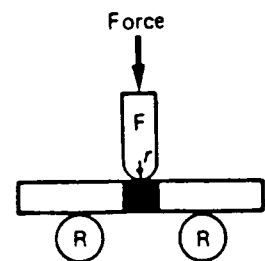
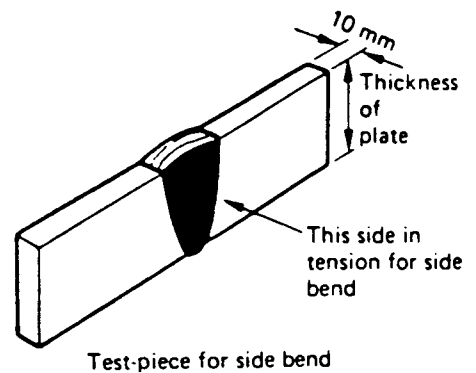
To determine the soundness of a welded joint in a cross section. This may be preferred to the transverse bend test on thick materials.

### Method

The testing method is the same as that used for transverse bends.

### Reporting Results

1. Width and thickness of specimen
2. Angle of bend
3. Diameter of former
4. Appearance of joint after bending  
e.g. type and location of flaws



(c) Side bend

R = Roller support

F = Former  
of specified  
radius  
(r) at end

## TRANSVERSE TENSILE TEST

### Object

Used to measure the transverse tensile strength under static loading of a butt joint employing butt welds.

The test is not designed to give the tensile strength of the weld metal.

### Method

The testpiece is clamped at each end and a load is applied by a hydraulic or screw mechanism. The load is increased until fracture occurs.

### Reporting Results

1. Type of specimen (e.g. reduced section)
2. Whether excess weld metal is removed or not
3. Tensile strength in  $\text{N/mm}^2$ , is calculated from maximum load and original cross sectional areas. When excess weld metal is not removed the cross sectional area shall be the product of the parent metal thickness and the width of the specimen.
4. Location of fracture, whether in parent metal, heat affected zone or weld metal. If the fracture is in the parent metal, the distance from the weld zone shall be stated.
5. Location and type of any flaws present on the fracture surfaces.

## CHARPY V NOTCH IMPACT TEST

### Object

To determine the amount of energy absorbed in fracturing a standardised testpiece at a specified temperature.

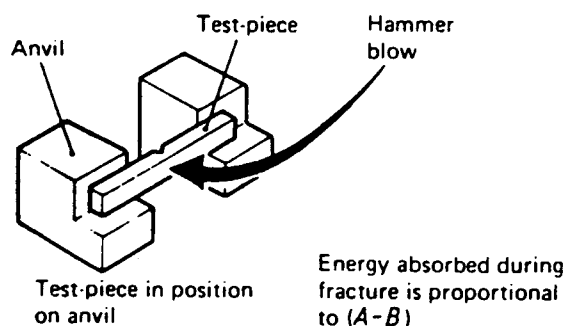
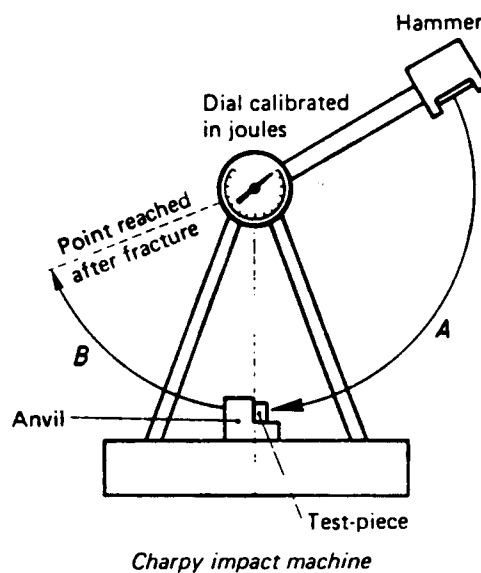
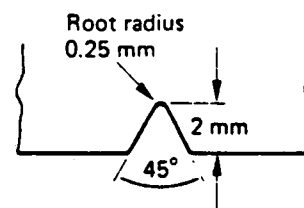
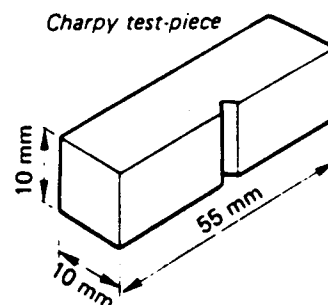
### Method

A machined, notched specimen is broken by one blow from a pendulum. Because scatter occurs in the results, at least three specimens are used to assess the joint represented.

Testing is carried out at a temperature specified in the appropriate application standard in accordance with BS 131: Pt 2: 1972.

### Reporting Results

1. Location and orientation of the notch
2. Testing temperature
3. Energy absorbed
4. Description of fracture appearance
5. Location of any defects



## FILLET WELD FRACTURE TEST

### Object

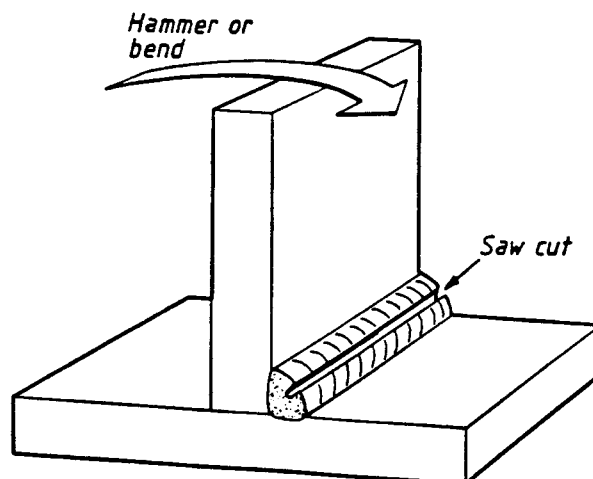
To break the joint through the weld to permit examination of the fracture surfaces.

### Method

The specimen is cut to length and a saw cut, normally 2mm deep, is made along the centre of the weld face. The specimen is fractured by bending or by hammer blows.

### Reporting Results

1. Thickness of parent metal
2. Throat thickness and leg length
3. Location of fracture
4. Appearance of joint after fracture
5. Depth of penetration/lack of penetration or fusion



## **'NICK' BREAK TEST**

### **Object**

As for fillet weld fracture

### **Method**

The specimen is cut transversely to the weld, and a saw cut is applied along the centre of the weld face. The specimen is fractured by bending or by hammer blows.

### **Reporting Results**

1. Thickness of material
2. Width of specimen
3. Location of fracture
4. Appearance of joint after fracture

## QUESTIONS

### MECHANICAL TESTING OF WELDMENTS

Q1 From a tensile test the following items were progressively recorded

- a) load
- b) extension

If the original length is also known, state what can be assessed.

Q2 State the objectives of:

- a) a reduced transverse tensile test
- b) a radius reduced transverse tensile test

Q3 What is the purpose of a Charpy test?

Q4 What is the purpose of :

- a) face bend test
- b) root bend test
- c) side bend test ?

Q5 What is the purpose of the 'nick' in a nick bend test ?

# SENIOR WELDING INSPECTOR

## MECHANICAL TESTING

Q1. What is the purpose of

- a) An "all weld" tensile test
- b) A radius reduced tensile test

Q2. Calculate the following for a transverse tensile test

- a) Yield stress
- b) % elongation

If the maximum load applied at failure is 400kN while extension at the failure was 5mm on an original length of 20mm given the specimen size is 100mm x 10mm in cross section.

Q3. Why should a macro be examined before etching.

Q4. State 10 (ten) surface defects/features.

Q5. State 10 (ten) sub-surface defects/features.

Q6. Describe briefly the method of producing a bend test.

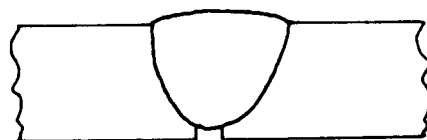
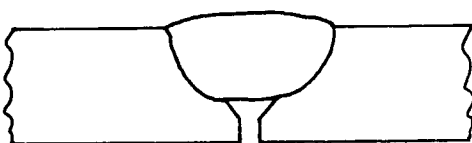
Q7. State the objective of

- a) a fillet fracture test
- b) a nick break test

Q8. If a bend test failure has occurred what would be your course of action.

Q9. In which type of tests would an assessment of ductility be made.

Q10. Below the sketches show two typical results.  
Report.



## WELD SPECIFICATIONS

Welds must be specified by clear instructions to ensure that the welder produces an acceptable result.

It may only be necessary to specify the weld size and electrode to be used.

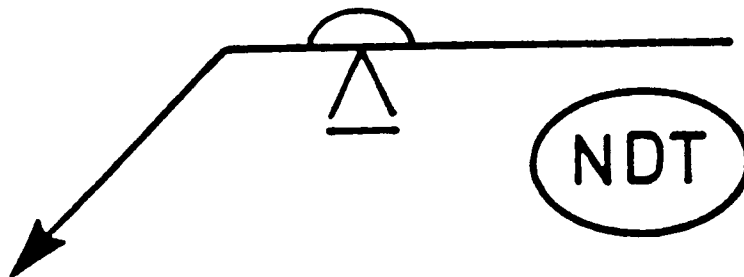
Or, the full details of a weld procedure may be needed.

Three methods are commonly used to specify a weld:

### Written statement

'Weld AZ321 is to be a single V butt welded from the outside of the vessel. The surface of the weld is to be ground flush. The root is to be sealed with a weld run deposited from inside the vessel. The completed weld is to be radiographed.'

### Symbols on a drawing



## STANDARDS FOR WELD SYMBOLS

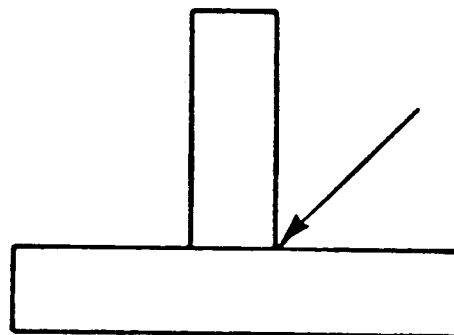
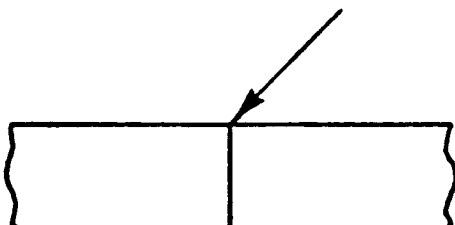
Although the main features of weld symbols are international, variations in detail occur from country to country. Symbols are specified by National Standards.

|         |                   |
|---------|-------------------|
| UK      | BS 499 Pt 2: 1980 |
| USA     | AWS2.4-79         |
| France  | NFE 04-021- 1978  |
| Germany | DIN 1912          |
| Italy   | NS1421 69-10      |

In this text, symbols are in accordance with BS 499.

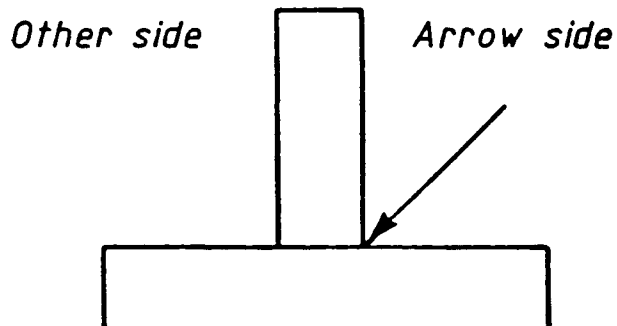
### Indicating Joint Position

The position of the joint is indicated by an arrow.



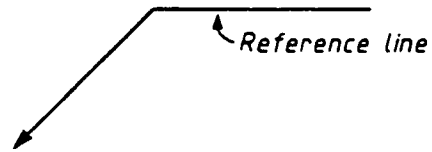
The arrow points to one side of the joint.  
This is called the **ARROW SIDE**.

The side remote from the arrow is the **OTHER SIDE**.

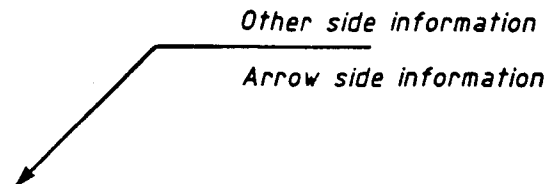


## WELD DETAILS

Information about the weld is given on a reference line attached to the arrow. The reference line is always horizontal.

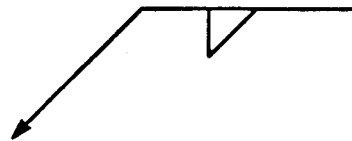


Details of the weld on the arrow side of the joint are given **below** the line.

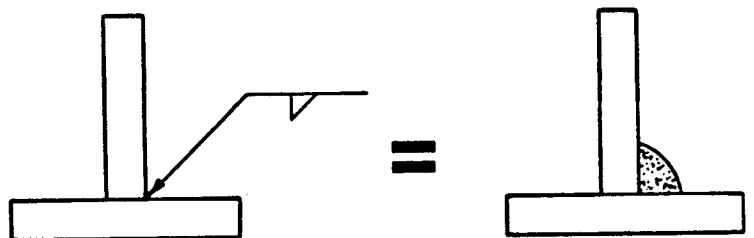


Other side information is **above** the line.

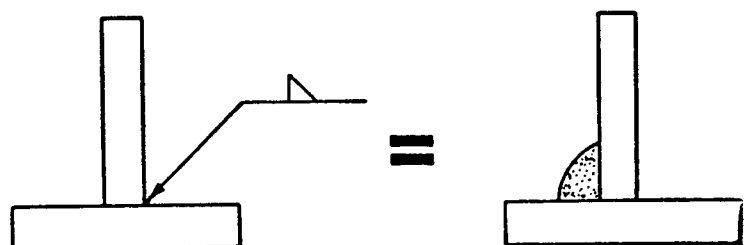
A fillet weld is indicated by a triangle placed on the reference line.



A triangle **below** the reference line specifies a fillet weld on the **arrow side** of the joint.



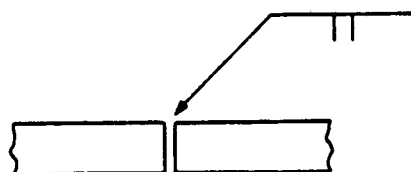
A triangle **above** the line calls for a fillet weld on the **other side** of the joint.



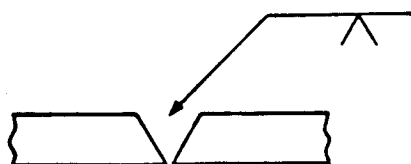
## TYPES OF BUTT WELD

The common types of edge preparation associated with a butt weld are indicated as follows :

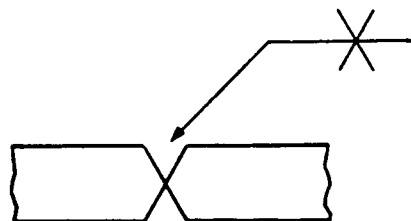
Square edge preparation



Single V preparation



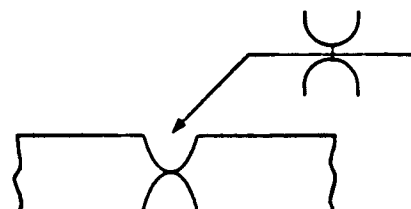
Double V preparation



Single U preparation



Double U preparation

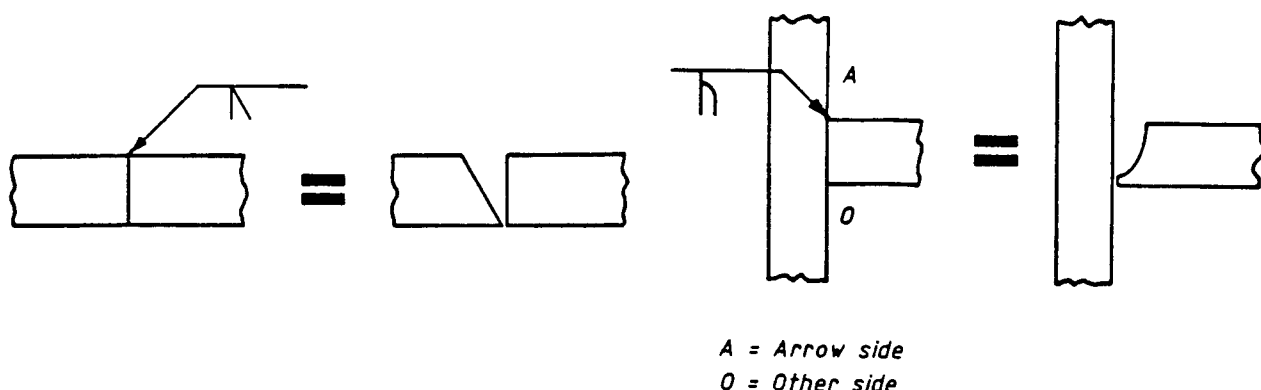


Using symbols it is not necessary to draw the shape of the edge preparation. The joint is shown as a single line.



## ASYMMETRICAL PREPARATIONS

In some joints, only one component is prepared, e.g. single bevel butt or single J butt.

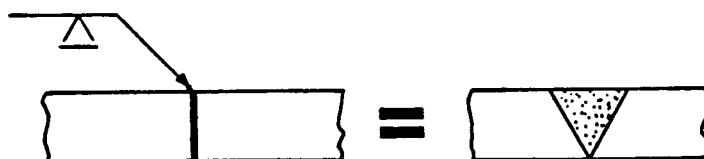


In these cases the arrow points at the edge which is to be prepared.

## SURFACE PROFILE

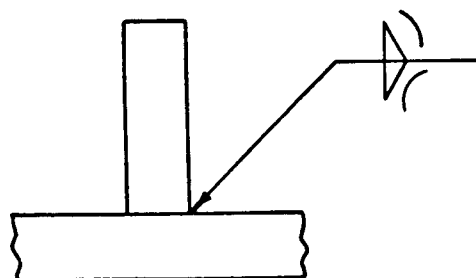
The surface profile can be indicated by an extra symbol placed on the top of the weld symbol.

Single V butt weld with a flat surface. (Flushed after welding. Usually by grinding).



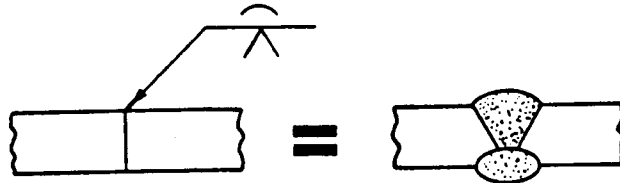
Convex fillet weld.

Concave fillet weld. (May be achieved by welding alone or by subsequent grinding).



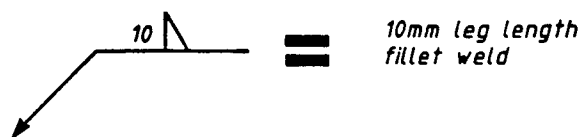
## SEALING RUN

If the root of a butt weld is to be sealed the symbol is placed on the reference line, opposite the weld symbol.

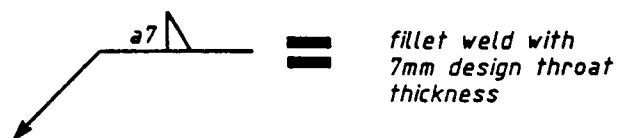


## DIMENSIONING FILLET WELDS

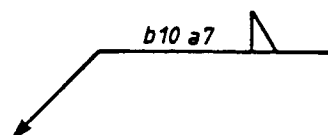
The leg length of a fillet weld is located in front of the weld symbol (triangle). The dimension is in millimetres.



Throat thickness is indicated in the same way but is preceded by the letter 'a'.

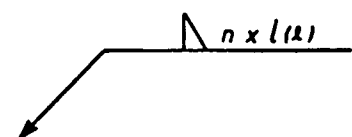


When both leg length and throat thickness are given, the dimension for the leg length is preceded by the letter 'b'.



Intermittent fillet welds are dimensioned by giving:

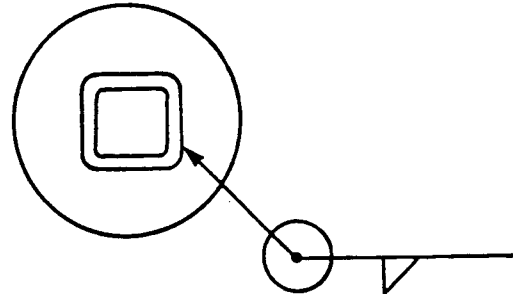
- number of weld elements (n).
- length of weld element (l).
- distance between weld elements (e).



## SUPPLEMENTARY SYMBOLS

Three supplementary symbols are in general use:

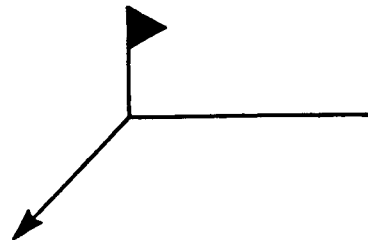
Weld all round the component



Inspect by NDT



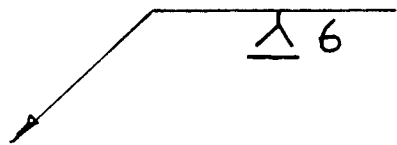
Weld this joint on site



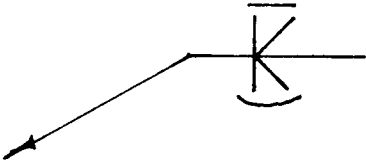
QUESTIONS

SYMBOLS FOR WELDING SPECIFICATION

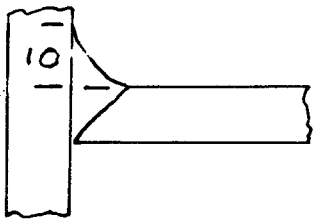
Q1 Sketch/describe the weld shown below



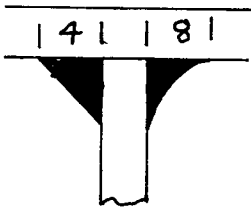
Q2 Sketch/describe the weld shown below



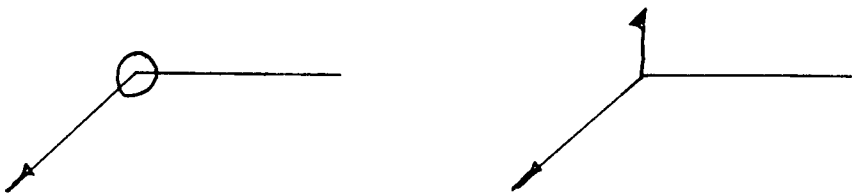
Q3 Specify the weld shown below by means of symbols



Q4 Specify the weld shown below by means of symbols



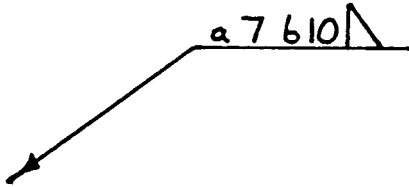
Q5 Describe the following:



# SENIOR WELDING INSPECTOR

## SYMBOLS

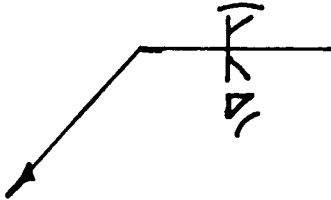
1. Describe sketch the weld shown below.



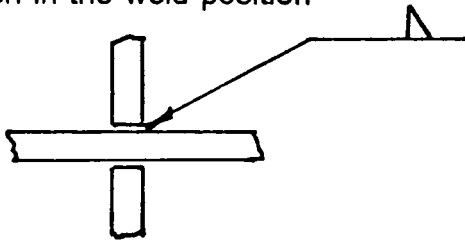
2. State the symbol for a spot weld.
3. State the symbol for a seam weld.
4. Describe/sketch the following symbol



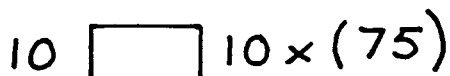
5. Describe/sketch the following weld



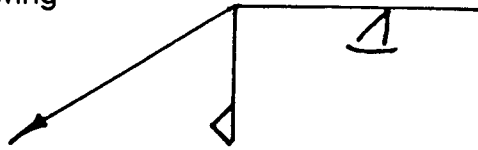
6. Sketch in the weld position



7. Describe/sketch the following



8. Comment on the following



9. Describe the following



10. What information may be placed at the end of the reference line.

## REVIEW OF STEELS AND MATERIAL DEFECTS

The term 'steel' is used to describe many different metals, they are all alloys based on iron, but the alloying additions, such as carbon, manganese, silicon and chromium, etc., singly or in combination produce a range of metals with widely differing physical and mechanical properties as well as quite different weldability.

|            |    |
|------------|----|
| IRON       | Fe |
| CARBON     | C  |
| MANGANESE  | Mn |
| SILICON    | Si |
| ALUMINIUM  | Al |
| CHROMIUM   | Cr |
| MOLYBDENUM | Mo |
| TITANIUM   | Ti |
| NIOBIUM    | Nb |
| VANADIUM   | V  |
| SULPHUR    | S  |
| NICKEL     | Ni |
| COPPER     | Cu |

### RIMMING STEEL

|             |                                 |
|-------------|---------------------------------|
| Composition | 0.09%C<br>0.9%Mn<br>+ residuals |
|-------------|---------------------------------|

|             |                                                                      |
|-------------|----------------------------------------------------------------------|
| Weldability | The weld pool will require to have added deoxidant via a filler rod. |
|-------------|----------------------------------------------------------------------|

### LOW CARBON STEEL

|             |                                |
|-------------|--------------------------------|
| Composition | 0.2%C<br>0.9%Mn<br>+ residuals |
|-------------|--------------------------------|

|             |                                                                                                                  |
|-------------|------------------------------------------------------------------------------------------------------------------|
| Weldability | The general weldability is good but the level of residuals (S) may cause weld metal/heat affected zone cracking. |
|-------------|------------------------------------------------------------------------------------------------------------------|

### MEDIUM CARBON STEEL

|             |                                  |
|-------------|----------------------------------|
| Composition | 0.45%C<br>0.90%Mn<br>+ residuals |
|-------------|----------------------------------|

|             |                                                                                             |
|-------------|---------------------------------------------------------------------------------------------|
| Weldability | The high carbon content induces hydrogen cracking in the HAZ as the section size increases. |
|-------------|---------------------------------------------------------------------------------------------|

**HIGH CARBON STEEL**

Composition      0.8%C  
                         0.9%Mn  
                         + residuals

Weldability        The weld pool is subject to solidification type cracking and the HAZ suffers hydrogen cracking.

**CARBON-MANGANESE STEEL**

Composition      0.2%C  
                         1.5%Mn  
                         + residuals  
                         may also contain Ti, Nb and V.

Weldability        These high Mn steels have good toughness, particularly the Ti, Nb and V grades, and the main weldability problem is to maintain these.

**QUENCHED AND TEMPERED STEEL**

Composition      0.4%C  
                         1.0%Mn  
                         0.8%Cr  
                         0.3%Mo  
                         + Ti or Al  
                         + residuals

Weldability        These steels are difficult to weld, and defect free welds with good mechanical properties are only attained by using the greatest care.

**HIGH TEMP. STEEL**

Composition      0.25–9%Cr  
                         0.25–3%Mo  
                         etc.

Weldability        The weldability of the low Cr is difficult.

**LOW TEMP. STEEL**

Composition      3.5–9%Ni  
                         etc.

Weldability        The higher Ni are subject to solidification cracking.

### **MICRO ALLOYED STEEL (HSLA)**

Composition      0.25%C  
                          1.5%Mn  
                          0.002%V )  
                          0.005%Nb ) min.  
                          0.003%Ti )

Weldability              These steels may suffer hydrogen cracking in the weld metal.

### **STAINLESS STEELS**

#### **1. MARTENSITIC SS**

Composition      11%Cr  
                          0.08%C  
                          + residuals

Weldability              Poor due to hydrogen cracking.

#### **2. FERRITIC SS**

Composition      12–27%Cr  
                          0.08%C  
                          + residuals

Weldability              Poor due to cracking, brittleness and temper embrittlement.

#### **3. AUSTENITIC SS (NB NON-MAGNETIC)**

Composition      18–27%Cr  
                          8–22%Ni  
                          0.08%C  
                          + residuals

Weldability              Problems with solidification cracking and weld decay.

A great variety of materials may require to be inspected with a view to satisfactory welding.

Inspection points are:

Specification/supplier – to mill sheet or reference number.

**Quantity:**

|            |   |                                      |
|------------|---|--------------------------------------|
| Size       | – | length, breadth, thickness, diameter |
| Distortion | – | flatness/ovality                     |
| Condition  | – | rust/paint, heat treatment           |
| Defects    | – | laps, bands, laminations             |
| Storage    |   |                                      |

**SPECIFICATION**

It is not, in general, safe for the inspector to identify materials by composition from mill sheet, since very small variations or additions to the metal may give rise to significant changes in properties and weldability. However, limited selectivity is permissible, such as % carbon maximum, etc.

The procedure is for the mill sheet to be submitted for approval and then the inspector records and transfers the reference number.

**SUPPLIER**

This can be found on the Goods Inwards documents or the receipt documents, or occasionally on packaging or even marked on the metal.

**QUANTITY**

The quantity being inspected should always be noted as well as the sample size, if 100% inspection is not being employed.

**SIZE**

Sizes must be checked for secondary identification as well as conformance. The inspector will, as appropriate, be given tolerances on size which are permissible.

## **DISTORTION**

A check is often required on the degree of distortion, i.e.

- Flatness
- squareness
- straightness
- ovality
- consistent wall thickness

## **CONDITION**

Rust, paint and grease on the surface of the metal are all harmful to welding and must usually be removed at least near to the actual weld. Guidance is normally given to the inspector regarding acceptable levels or the treatment which is required. An inspector should be alert to gradual changes, such as increased corrosion. Carefully maintained specimens showing acceptable conditions are often the best method. Heat treatment condition, annealed, normalised etc.

## **DEFECTS**

In wrought products the most common defects are laps and laminations. Both these will normally be subsurface so unless NDE is being employed only, the edges of plate, and particularly cut edges, can be inspected. The lap/lamination will appear as a narrow black line parallel to the surface.

## **STORAGE**

After inspection and approval for use it is essential that the metal is stored in such a way as to maintain its good condition. Protect from corrosion and mechanical damage.

### **Questions to be asked:**

1. Do the markings on the material match those on the procedure sheet or drawing?
2. Are the dimensions correct?
3. Is the surface condition satisfactory for welding?

## **QUESTIONS:**

### **REVIEW OF STEELS AND MATERIAL DEFECTS**

- Q1     Name two (2) wrought plate defects.
- Q2     Give examples of composition
- a)     A rimming steel
  - b)     A low carbon steel
  - c)     A tool steel
- Q3     Give an example by composition of a stainless steel
- Q4     What is the purpose of the increased Mn content of a carbon–manganese steel
- Q5     State the features/defects which should be noted when inspecting wrought plate

# SENIOR WELDING INSPECTOR

## MATERIALS

- Q1. What is the metallurgical/production cause of lamellar tearing?
- Q2. Why is it desirable to 'seal' in a lamination which is found to break into an edge preparation?
- Q3. Does wrought plate contain residual stresses due to manufacture?
- Q4. What is a LAP in a steel?
- Q5. State three (3) factors which contribute to or control the mechanical properties of wrought steel.
- Q6. What feature(s) of a steel determine its weldability?
- Q7. List six (6) different types of steel by type name and approximate composition.
- Q8. For each of the steels given in state the main weldability problem.
- Q9. During an inspection audit, no material mill sheet can be found. How would you proceed?
- Q10. Long question: During preweld inspection you require an inspector to check the actual material. Draw up a check list/schedule.

## CONSUMABLES

Welding consumables are the:

Electrodes  
Wire (lengths or rolls)  
Fluxes  
Gases.

Each consumable is critical in respect to –

Specification/supplier  
Condition  
Treatment (if any)

Take as an example a common MMA covered electrode. This will be to a specified type but an additional requirement may be that only one or two suppliers/manufacturers are acceptable. The electrode must be in good condition with regard to corrosion and mechanical damage and so storage and mechanical handling are important. If the electrode requires heat treatment for low hydrogen potential then the temperature, time and oven condition require attention. The issue of electrodes to the welder for use and the procedures for recycling and scrap must often be dealt with care.

There are many codes in existence which cover the various consumables. The only reasonable rule is to keep to what is specified unless (and only unless) a written order for variation is received.

### **Covered Electrodes**

BS 639  
AWS A5 1  
ISO 2560  
BS 2493  
BS 2926

### **Gas-shielded wires**

BS 2901, Part 1–5

### **Gases**

BS 4365  
BS 4105

## Identification of covered electrodes

In the BS system for carbon and carbon manganese steels the electrode may be partially or completely specified by a letter/number.

The summary sheet gives details.

## British Standards System

BS specification: BS 639: 1986

### FIRST GROUP

| Electrode designation | Tensile strength, N/mm <sup>2</sup> | Minimum yield stress, N/mm <sup>2</sup> |
|-----------------------|-------------------------------------|-----------------------------------------|
| E43                   | 430-550                             | 330                                     |
| E51                   | 510-650                             | 380                                     |

### COVERING

|    |                        |
|----|------------------------|
| B  | basic                  |
| BB | high efficiency        |
| C  | cellulosic             |
| O  | oxidising              |
| R  | rutile (medium coated) |
| RR | rutile (heavy coated)  |
| S  | other types            |

### EFFICIENCY

% recovery to nearest 10% ( $\geq 110$ )

### (H)

Indicates hydrogen controlled ( $\leq 15\text{ml}/100\text{g}$ )

E 51 33 B 160 2 0 (H)

### SECOND GROUP

| First digit  | Temperature for impact value of 28J, °C |
|--------------|-----------------------------------------|
| 0            | Not specified                           |
| 1            | +20                                     |
| 2            | 0                                       |
| 3            | -20                                     |
| 4            | -30                                     |
| 5            | -40                                     |
| Second digit | Temperature for impact value of 47J, °C |
| 0            | Not specified                           |
| 1            | +20                                     |
| 2            | 0                                       |
| 3            | -20                                     |
| 4            | -30                                     |
| 5            | -40                                     |
| 6            | -50                                     |
| 7            | -60                                     |
| 8            | -70                                     |

### POSITION DIGIT

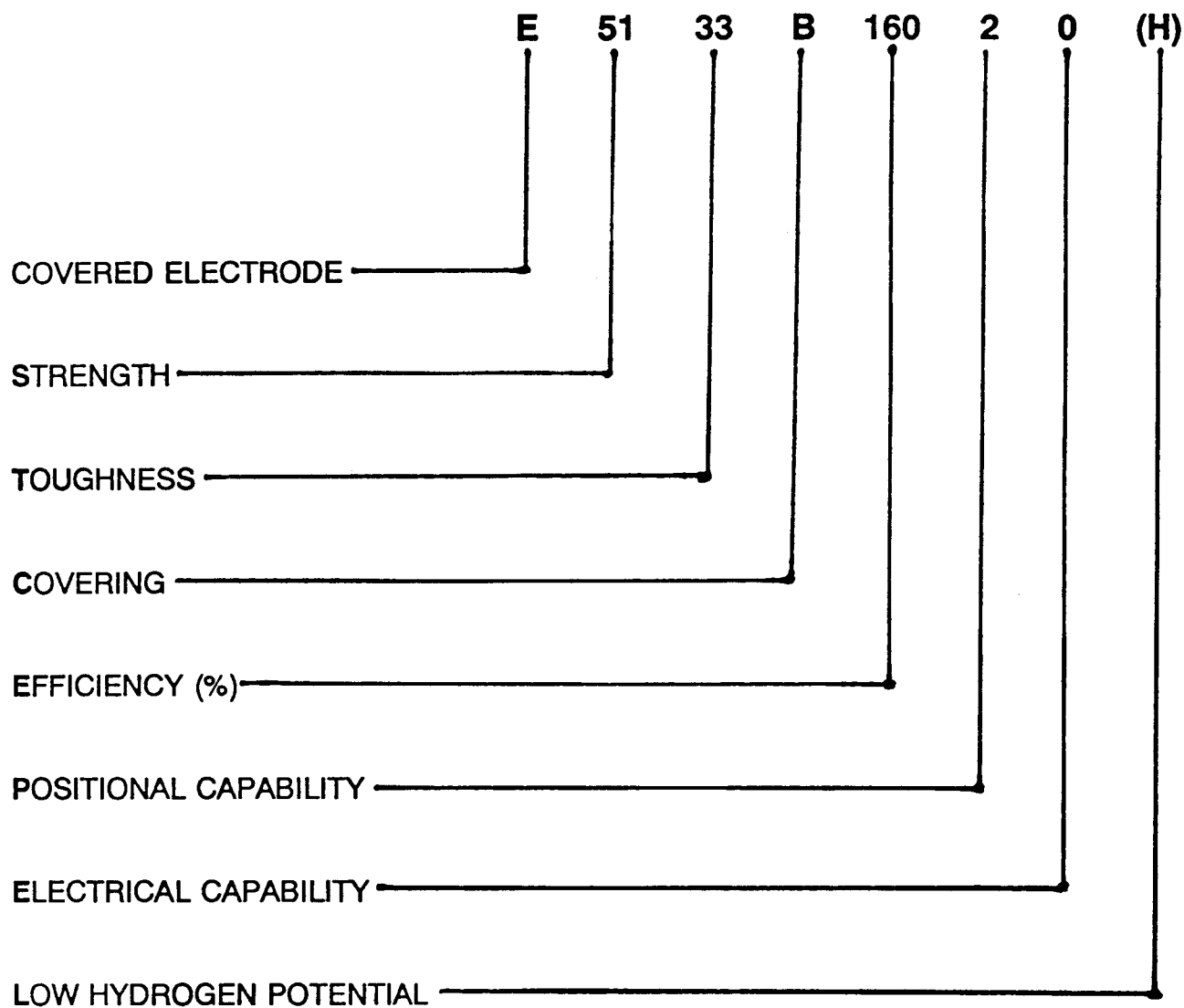
|   |                                                                |
|---|----------------------------------------------------------------|
| 1 | all positions                                                  |
| 2 | all positions except vertical down                             |
| 3 | flat and, for fillet welds, horizontal vertical                |
| 4 | flat                                                           |
| 5 | flat, vertical down and, for fillet welds, horizontal vertical |
| 9 | any position or combination of positions not classified above  |

### ELECTRICAL DIGIT

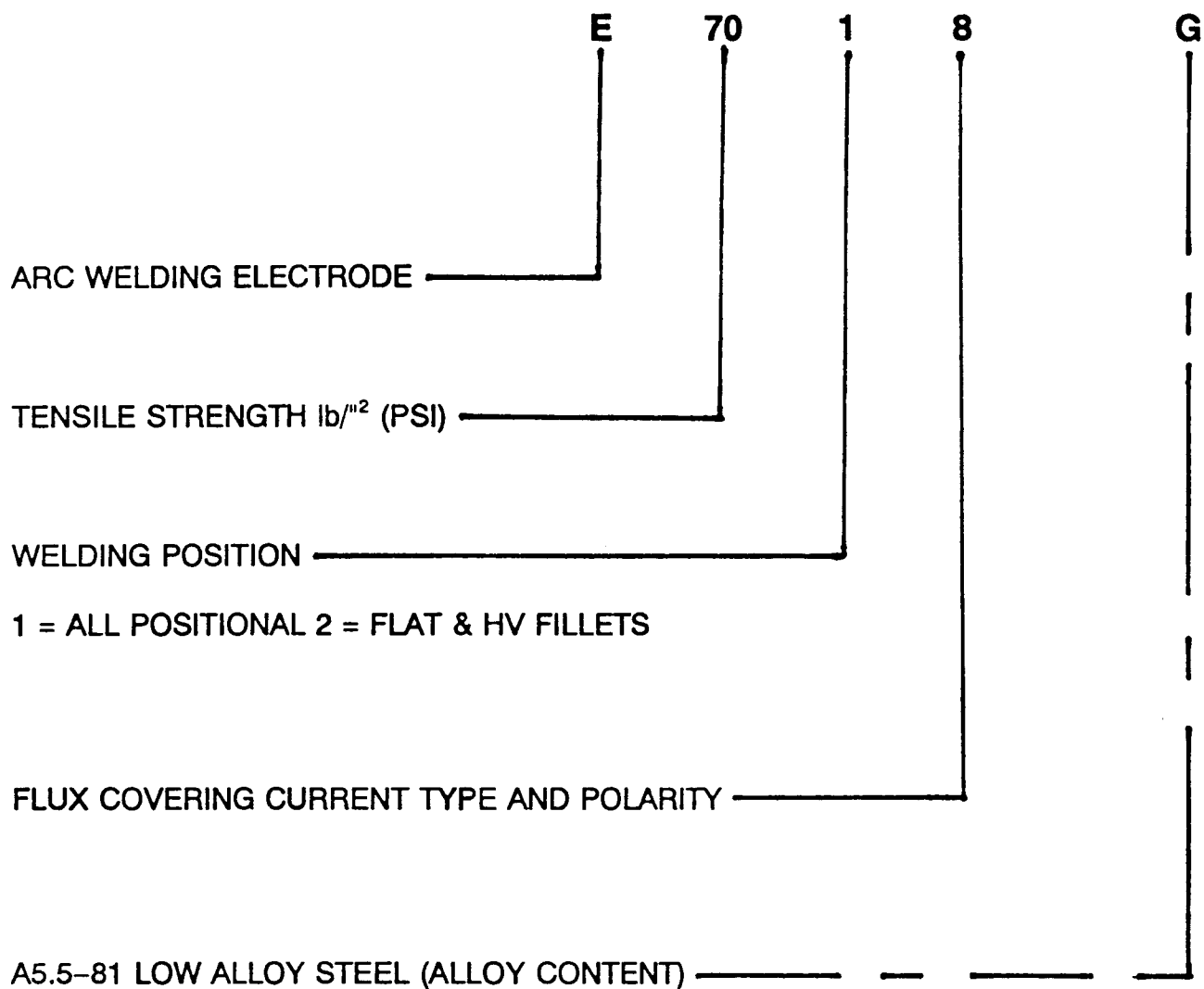
| Code | Direct current                          | Alternating current             |
|------|-----------------------------------------|---------------------------------|
|      | Recommended electrode polarity          | Minimum open-circuit voltage, V |
|      | Polarity as recommended by manufacturer | Not suitable for use on AC      |
| 0    |                                         |                                 |
| 1    | + or -                                  | 50                              |
| 2    | -                                       | 50                              |
| 3    | +                                       | 50                              |
| 4    | + or -                                  | 70                              |
| 5    | -                                       | 70                              |
| 6    | +                                       | 70                              |
| 7    | + or -                                  | 80                              |
| 8    | -                                       | 80                              |
| 9    | +                                       | 80                              |

## BRITISH STANDARD 639 1986

### MANUAL METAL ARC WELDING CONSUMABLES FOR C.C/Mn STEELS



AMERICAN WELDING SOCIETY A5. 1-81  
MANUAL METAL ARC WELDING  
CONSUMABLES FOR  
C. C/Mn STEELS



## QUESTIONS:

### THE BRITISH STANDARD CLASSIFICATION OF MMA ELECTRODES

Q1. Explain the following factors:

E 51 33 B 160 2 0 (H)

covering

Q2. What is the compulsory part?

Q3. State the meaning of the following:

- a) B = basic
- b) R =
- c) AR =
- d) O =
- e) C =
- f) RR =

Q4. When an electrode specification terminates with an (H), what is usually required in order to give the specified results?

Q5. What is the meaning of:

"S" ..... "T" ..... "C" .....

# SENIOR WELDING INSPECTOR

## CONSUMABLES

- Q1. What would be the manganese content of an S2 wire—specified to BS 4165?
- Q2. What is the significance of the prefix letter 'S' in the following wire specification: S2?
- Q3. If your wire/flux specification indicates a basicity number of 2.8, would you expect it to be an acid or basic type of flux?
- Q4. How are the wires classified in respect to composition using AWS A5.17.80?
- Q5. Basic electrodes are to be used for a fabrication and hydrogen control to 1.5ml/100g of weld metal as-deposited is called for
- a) Generally comment
  - b) Draw up an inspection schedule
  - c) Draw up a quality control schedule
  - d) Draw up a workshop method of ensuring that the electrodes are fully hydrogen controlled.
- Q6. An electrode is specified as E51 32B 160 20H  
Write out a description of the requirements of this electrode.
- Q7. What is the effect of increasing the percentage of 'fines' in a submerged arc flux?
- Q8. After hydrogen control treatment some MMA electrodes are suffering flux flaking. Review your course of action.
- Q9. Some rolls of MIG/MAG wire consumable shows incomplete copper cover. Comment.
- Q10. A very high quality TIG weld is to be made. Draw up a check list.

## **THE FOUR ESSENTIAL FACTORS FOR ESTABLISHING A WELD**

Welding is usually regarded as a joining process in which the work pieces are in atomic contact often with a filler metal of broadly similar properties.

Hence soldering and brazing are excluded but both solid-state and fusion welding are included.

Solid state processes include:

- Forge welding
- Friction welding

Fusion welding processes include:

- Oxy-acetylene
- Manual metal arc (MMA)
- Metal inert/active gas (MIG/MAG)
- Submerged arc welding (SAW)
- Electro-slag welding (ESW)

### **Fusion welding factors**

#### **1. Fusion (melting)**

The metal must be melted which requires a high intensity heat source.

2. The process must remove any oxide and other contamination from the joint faces.
3. Contamination by the atmosphere must be avoided.
4. The welded joint must possess adequate properties.

## QUESTIONS:

### FOUR FACTORS IN WELDING

- Q1. State the four (4) factors which must be satisfied for good welds.
- Q2. What are the mechanical tests which are usually used to ensure compliance with adequate mechanical properties.
- Q3. Name three (3) methods of protecting the molten metal from contamination.
- Q4. Describe the metal cleaning requirements required when making high class stainless steel welds.
- Q5. Name two methods of protecting the arc from contamination.

# SENIOR WELDING INSPECTOR

## 4 FACTORS

- Q1. State the method of atmospheric protection for submerged arc welding.
- Q2. What is a transition joint?
- Q3. Give one factor which makes transition joints between 3mm and 50mm difficult (assume MMA welding)
- Q4. A transition joint is to be made between stainless steel and carbon steel. State two (2) possible problems.
- Q5. In a similar joint to question 4, where would you expect the corrosion (if any) to occur.
- Q6. How can the high chrome plus high carbon of stainless steel and carbon steel transition joints be prevented.
- Q7. State the welding process which is often used to avoid metallurgical problems that will achieve high quality transition joints.
- Q8. What is meant by the term 'pick up'.
- Q9. What is meant by the term 'dilution'.
- Q10. Long question: Prepare a general checklist for the various items to be considered when marking transition joints between carbon and stainless steel.

## **EQUIPMENT**

Welding inspection necessarily involves checking that the correct welding/cutting process is being used, that the equipment is in workable condition and that the welding parameters of amperes and volts are being adhered to. The following pages outline the constant current process and list the types of defects which are associated with them.

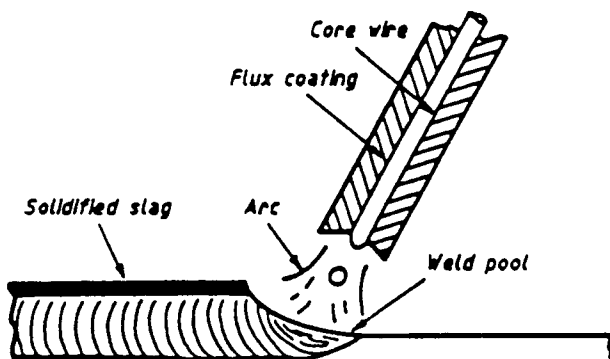
You will notice that the arc processes are divided into two (2) types ('drooping' and 'flat'). This refers to their volt-amp output characteristics.

The conventional machine is known as the constant current machine (drooping characteristic) and has for many years been used for manual metal arc and tungsten inert gas welding. By using drooping an alteration in arc length gives a very small change in current.

## A 'DROOPING ARC' PROCESS (CONSTANT CURRENT)

### MANUAL METAL-ARC (MMA)

Shielded metal-arc (US); Stick; Electric arc welding



**Type of Operation**  
Manual.

#### Mode of Operation

Arc melts parent plate and electrode to form a weld pool which is protected by flux cover.

Operator adjusts electrode feed rate, *i.e.* hand movement, to keep arc length constant. Slag must be removed after depositing each bead. Normally a small degree of penetration, requiring plate edge preparation. Butt welds in thick plate or large fillets are deposited in a number of passes. The process can also be used to deposit metal to form a surface with alternative properties.

Typical defects associated with this process:

Overlap.

- Porosity.
- Slag inclusions.
- Excessive spatter.

Stray flash.

Incomplete penetration.

Excess penetration.

- Undercut.

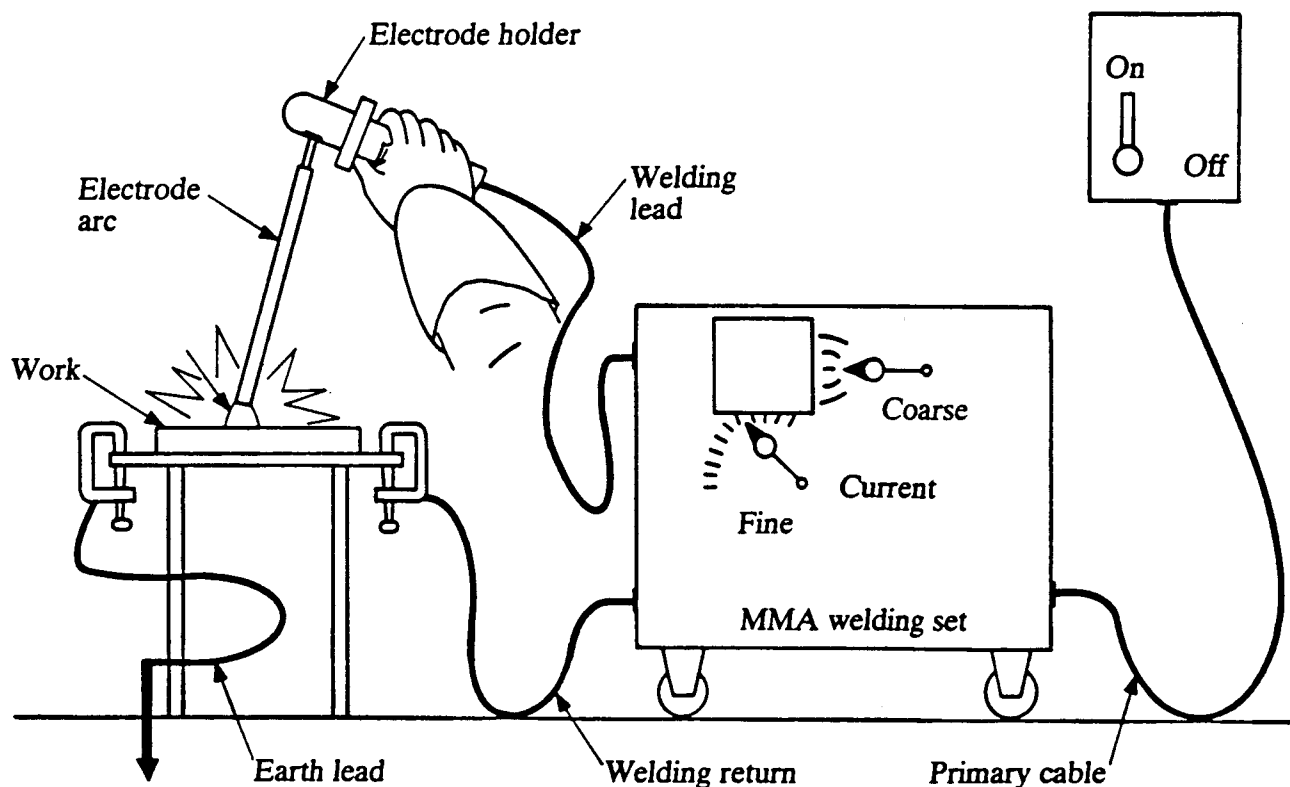
Crater cracks.

Lack of fusion.

## WELDING EQUIPMENT

### MANUAL METAL ARC

#### Welding sets



Manual metal arc sets are manufactured in a range of sizes, usually distinguished by current: note the duty cycle at which the current is quoted when comparing sets. Engine powered generators allow operation away from mains supplies.

Electrical input is single-phase at 240 volts for small sets, and 415 volts (2 live phases of a three-phase supply) for larger ones.

Output is AC or DC. AC only sets need an open circuit voltage of 80V to run all electrodes; 50V is safer and allows more current to be drawn, but is limited to general purpose rutile electrodes only.

A control on the set adjusts current; the current is shown either on a simple scale, or for accurate work on a meter.

# MANUAL METAL ARC WELDING

## INTRODUCTION

In manual metal arc welding the heat source is an electric arc which is formed between a consumable electrode and the parent plate. The arc is formed by momentarily touching the tip of the electrode onto the plate and then lifting the electrode to give a gap of 3.0mm ( $\frac{1}{8}$ " ) – 6.0mm ( $\frac{1}{4}$ " ) between the tip and the plate. When the electrode touches the plate, current commences to flow and as it is withdrawn the current continues to flow in the form of a small spark across the gap, which will cause the air in the gap to become ionized, or made conductive. As a result of this the current continues to flow even when the gap is quite large. The heat generated is sufficient to melt the parent plate and also melt the end of the electrode; the molten metal so formed is transferred as small globules across the arc into the molten pool.

## EQUIPMENT

### 1. Power Source

The welding machine consists of a power source with welding lead and an electrode holder.

The function of the power source is to provide the voltage necessary to maintain an arc between the electrode and the workpiece and the end of the electrode. The amount of current provided by the power source can be altered by a control to suit different welding conditions.

Power source may supply direct current (DC) or alternating current (AC) to the electrode. AC transformers and DC generators supply only one type of current, but transformer – rectifiers can be switched between AC or DC output.

### 2. Welding cables

The welding current is conducted from the power source to the work by multi-strand, insulated flexible copper or aluminium cables. A return cable is required to complete the welding circuit between the work and power source. The size of the cable must be sufficient for the maximum output of the welding power source.

The earth lead is a third cable and acts as a safety device in the event of an electrical fault.

### **3. Electrode holder**

The holder should be relatively light, fully insulated and rated for at least maximum power source output.

### **4. Return clamp**

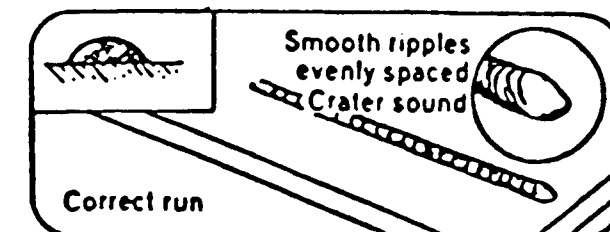
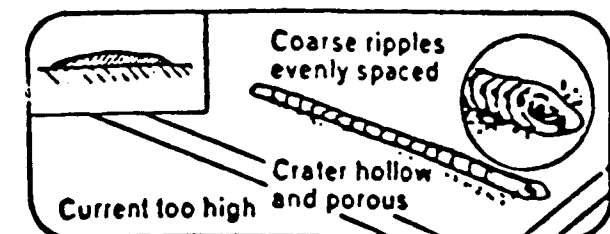
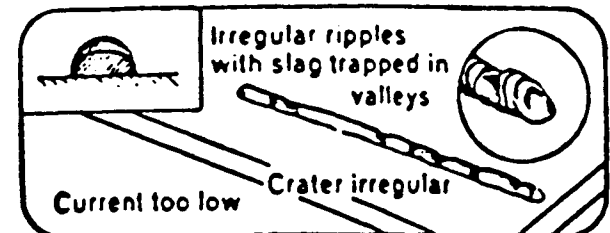
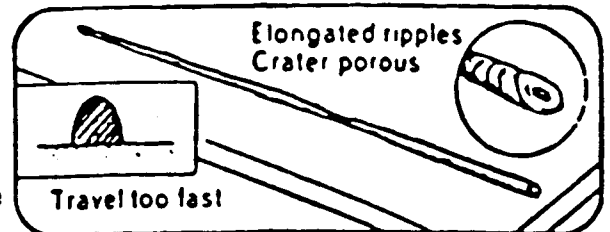
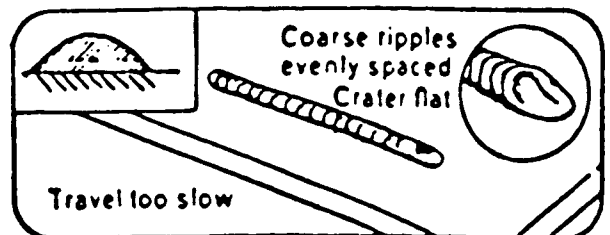
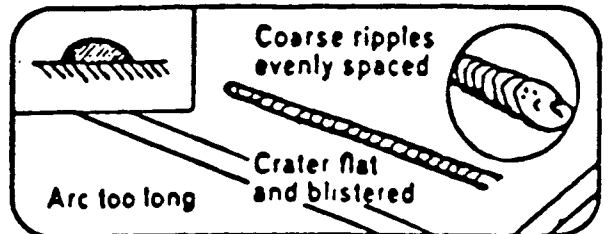
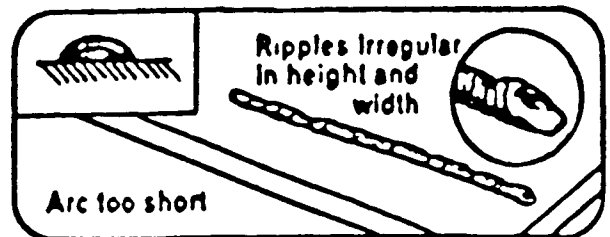
This is fastened to the work or bench on which the work is placed and completes the welding circuit. The surface clamped should be clean enough to allow good metal to metal contact.

### **5. Welding shield or helmet**

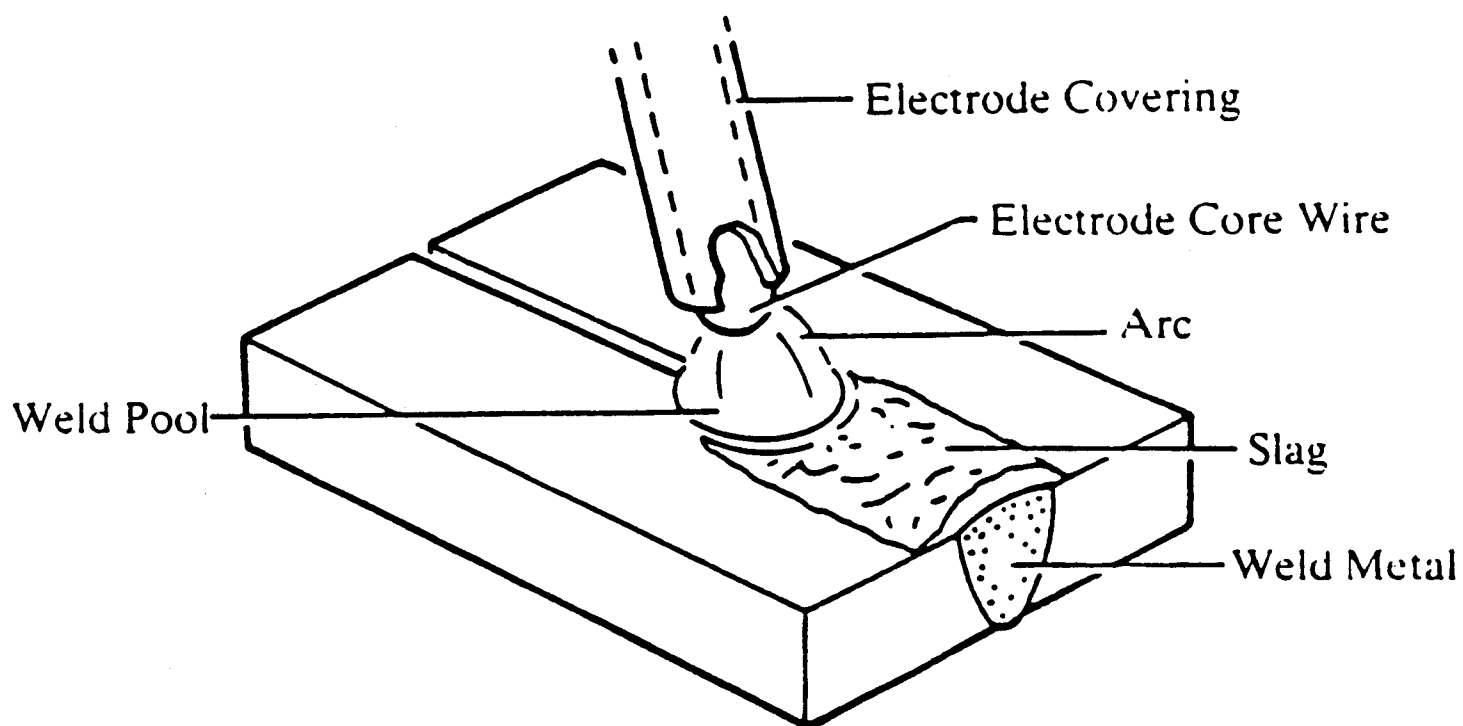
A welding shield or helmet is necessary for protection from arc ray and heat, and the spatter from the molten metal. The arc is viewed through a filter which reduces the intensity of the radiation, but allows a safe amount of light to pass for viewing the weld pool and end of the electrode.

## EFFECT OF VARIATION IN PROCEDURE

1. Too short an arc length will cause irregular piling of the weld metal.
2. Too long an arc length will cause the deposit to be coarse rippled and flatter than normal.
3. A slow rate of travel gives a wider thicker deposit, shorter than normal length; too slow a rate of travel may allow the slag to flood the weld pool causing difficulty in controlling deposition.
4. A fast rate of travel gives a narrower, thinner deposit, longer than normal length; too fast a rate of travel may prevent adequate interfusion with the parent metal.
5. A low welding current tends to cause the weld metal to pile up without adequate penetration into the parent metal; too low a welding current makes the slag difficult to control.
6. A high welding current gives a deposit that is flatter and wider than normal with excessive penetration into the parent metal; too high a welding current causes considerable spatter.
7. With correct arc length, correct rate of travel, correct welding conditions and technique, the run deposited metal will be regular in thickness and width, with a neat finely rippled surface, free from porosity or any slag entrapment.



The shielded arc. Manual arc weld on steel base plate with a covered electrode.



## QUESTIONS:

### MANUAL METAL ARC

- Q1. State the main three (3) welding parameters of the process.
- a) Amperes
  - b)
  - c)
- Q2. Explain two types of electrical supply and an advantage of each type.
- Q3. What type of power source characteristics is considered essential for MMA?
- a) Constant current ?
  - b) Constant voltage ?
- Q4. Give six functions of an electrode coating.
- i) Provides a gas shield
  - ii)
  - iii)
  - iv)
  - v)
  - vi)
- Q5. What is the usual composition of the core wire of an MMA electrode?

# WELDING PROCEDURE SHEET MANUAL METAL ARC

|                                                                                                                                                                                      |          |               |                        |               |                                                                                                   |                    |               |                                                                                                                                                                                                                                                                                                                                                     |  |  |  |  |                                      |               |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|---------------|------------------------|---------------|---------------------------------------------------------------------------------------------------|--------------------|---------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--|--|--|--|--------------------------------------|---------------|
| DATE<br>0-00-00                                                                                                                                                                      |          |               | REFERENCE NO.<br>SWI 1 |               |                                                                                                   | PROCEDURE NO.<br>1 |               |                                                                                                                                                                                                                                                                                                                                                     |  |  |  |  |                                      |               |
| <b>PARENT MATERIAL DETAILS</b><br><br>SPECIFICATION                      API 5L<br><br>COMPOSITION                      AS SPECIFIED<br><br>THICKNESS                         12.5mm |          |               |                        |               | <b>SKETCH</b><br>                                                                                 |                    |               |                                                                                                                                                                                                                                                                                                                                                     |  |  |  |  |                                      |               |
|                                                                                                                                                                                      |          |               |                        |               |                                                                                                   |                    |               | <b>CONSUMABLE DETAILS</b><br><br>TRADE NAMES                      FLEETWELD 5P<br><br>SPECIFICATIONS                    BS 639 1986 E5143C<br><br>DIAMETERS                         4.0mm & 5.0mm<br><br>LENGTHS                            450mm<br><br>DRYING TEMP. AND TIME        150°C - 2 hrs<br><br>STORAGE TEMP.                    AMBIENT |  |  |  |  |                                      |               |
|                                                                                                                                                                                      |          |               |                        |               |                                                                                                   |                    |               |                                                                                                                                                                                                                                                                                                                                                     |  |  |  |  | <b>EDGE PREPARATION</b><br>FLAME CUT |               |
|                                                                                                                                                                                      |          |               |                        |               |                                                                                                   |                    |               |                                                                                                                                                                                                                                                                                                                                                     |  |  |  |  | INCLUDED ANGLE<br>80°                | RADIUS<br>N/A |
|                                                                                                                                                                                      |          |               |                        |               | ROOT FACE<br>2.0mm max                                                                            | LAND<br>N/A        |               |                                                                                                                                                                                                                                                                                                                                                     |  |  |  |  |                                      |               |
|                                                                                                                                                                                      |          |               |                        |               | ROOT GAP<br>2.5mm max                                                                             | BACKING<br>N/A     |               |                                                                                                                                                                                                                                                                                                                                                     |  |  |  |  |                                      |               |
|                                                                                                                                                                                      |          |               |                        |               | <b>ROOT RUN PROCESS</b> S.M A W                                                                   |                    |               |                                                                                                                                                                                                                                                                                                                                                     |  |  |  |  |                                      |               |
| <b>WELDING CONDITIONS</b><br><br>PREHEAT TEMPERATURE        NOT REQUIRED<br>MINIMUM OPEN CIRCUIT VOLTAGE    50 VOLTS                                                                 |          |               |                        |               | WELDING POSITION PIPE AXIS VERT<br>HORIZONTAL DOWN                                                |                    |               |                                                                                                                                                                                                                                                                                                                                                     |  |  |  |  |                                      |               |
|                                                                                                                                                                                      |          |               |                        |               | INTERPASS TEMPERATURE 200°C<br>INTER RUN CLEANING OR<br>GOUGING                      CHIP & BRUSH |                    |               |                                                                                                                                                                                                                                                                                                                                                     |  |  |  |  |                                      |               |
| RUN NO                                                                                                                                                                               | 1        | 2             | 3                      | 4             | 5                                                                                                 | 6                  | 7             |                                                                                                                                                                                                                                                                                                                                                     |  |  |  |  |                                      |               |
| ELECTRODE DIA                                                                                                                                                                        | 4.0      | 5.0           | 5.0                    | 5.0           | 5.0                                                                                               | 5.0                | 4.0           |                                                                                                                                                                                                                                                                                                                                                     |  |  |  |  |                                      |               |
| ELECTRODE LENGTH                                                                                                                                                                     | 450      | 450           | 450                    | 450           | 450                                                                                               | 450                | 450           |                                                                                                                                                                                                                                                                                                                                                     |  |  |  |  |                                      |               |
| AC DC +/-                                                                                                                                                                            | DC-      | DC+           | DC+                    | DC+           | DC+                                                                                               | DC+                | DC+           |                                                                                                                                                                                                                                                                                                                                                     |  |  |  |  |                                      |               |
| CURRENT                                                                                                                                                                              | 150/210  | 180/240       | 190/250                | 190/250       | 190/250                                                                                           | 190/250            | 190/250       |                                                                                                                                                                                                                                                                                                                                                     |  |  |  |  |                                      |               |
| ARC VOLTAGE                                                                                                                                                                          | 20-22    | 20-22         | 20-22                  | 20-22         | 20-22                                                                                             | 20-22              | 20-22         |                                                                                                                                                                                                                                                                                                                                                     |  |  |  |  |                                      |               |
| WEAVE WIDTH                                                                                                                                                                          | 2-3mm    | 4-5mm         | 4-5mm                  | 4-5mm         | 4-5mm                                                                                             | 4-5mm              | 2-3mm         |                                                                                                                                                                                                                                                                                                                                                     |  |  |  |  |                                      |               |
| RUN OUT LENGTH                                                                                                                                                                       | 99/138   | 118/158       | 125/165                | 125/165       | 125/165                                                                                           | 125/165            | 125/165       |                                                                                                                                                                                                                                                                                                                                                     |  |  |  |  |                                      |               |
| BURN OFF TIME    secs                                                                                                                                                                | 90       | 90            | 98                     | 98            | 98                                                                                                | 98                 | 58            |                                                                                                                                                                                                                                                                                                                                                     |  |  |  |  |                                      |               |
| ENERGY INPUT                                                                                                                                                                         | 2.0KJ/mm | as run<br>one | as run<br>one          | as run<br>one | as run<br>one                                                                                     | as run<br>one      | as run<br>one |                                                                                                                                                                                                                                                                                                                                                     |  |  |  |  |                                      |               |

|                             |                     |
|-----------------------------|---------------------|
| POST WELD HEAT TREATMENT    | NOT REQUIRED        |
| POST WELD INSPECTION METHOD | VISUAL, RADIOGRAPHY |
| ADDITIONAL INFORMATION      |                     |

Form PW 3/1

COMPILED BY.....

# SENIOR WELDING INSPECTOR

## MANUAL METAL ARC

- Q1. Explain why DC–ve is used on open root joints and why it should not be used on fillet welded joints.
- Q2. What polarity gives highest deposition.
- Q3. State six (6) causes of lack of penetration.
- Q4. State four (4) causes of undercut
- Q5. State four (4) causes of porosity
- Q6. State the effects of the following:
- Excessive current
  - Excessive voltage
  - Excessive travel speed
- Q7. How can the weld metal composition be controlled in manual metal arc?
- Q8. State two possible causes of stray arcing (arc strikes).
- Q9. State the types of power sources required for
- a) DC welding
  - b) AC welding
- and why each type is used.
- Q10. Long question: Prepare a checklist for open–site MMA welding, using the stove–pipe technique.

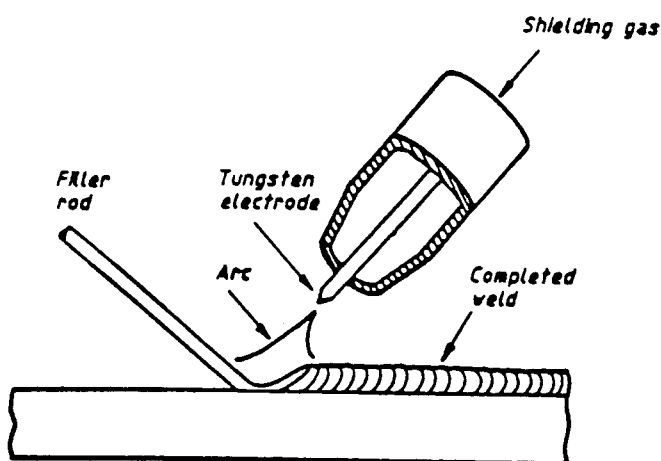
## A 'DROOPING' ARC PROCESS (CONSTANT CURRENT)

### TUNGSTEN INERT GAS (TIG)

Tungsten arc gas shielded; Argon arc;  
Gas tungsten arc welding; GTAW (USA)

Typical defects associated with this process:

- Tungsten inclusions.
- Lack of fusion.
- Incomplete penetration.
- Undercut.
- Porosity.
- Burnthrough.
- Excess penetration.
- Oxide inclusions.
- Unequal leg length.



#### Type of Operation

Usually manual, but can be mechanised.

#### Mode of Operation

An arc is maintained between the end of a tungsten electrode and the work. The electrode is not consumed and the current is controlled by the power source setting. The operator must control the arc length and also add filler metal if needed to obtain the correct weld: consequently, a high degree of skill is needed for best results.

The arc is unstable at low currents. Special provision is made for starting (h.f. or surge injection) and for welding thin materials (pulse TIG).

In all cases the electrode and weld pool are shielded by a stream of inert gas. Filler rod is fed into the weld pool in some cases.

## TIG WELDING SETS

Sets are manufactured in a range of sizes, identified by current: also important is whether the output is DC only, DC/AC or AC only. AC is needed for most work on aluminium.

Electrical input may be single-phase at 240 or 415v, or three-phase at 415v. On the normal d.c. or a.c. output an 'h.f. unit' superimposes a high voltage high frequency supply to cause a spark from electrode to parent metal when the welder wants to start the arc: alternatively, an electronic control switches the current on just as the welder lifts the electrode off the work ('touch start'). The output has a drooping characteristic, so by switching off the h.f. unit it can be used for manual metal arc. Alternatively, an add-on h.f. unit can convert a manual metal arc set to TIG.

The welder often uses a foot switch wired to the set to switch on and off, and to give a fine control of current.

A 'slow-start' and 'current delay' controls allow current to rise and fall slowly at the beginning and end of a weld, for example welding round a pipe.

As for gas-shielded metal-arc sets a cylinder holder and/or a water-cooling unit for use with heavier guns, may be built in.

### Accessories

Welding return cable (torch has its own built-in lead to stand up to high frequency supply).

Connectors to set.

Clamps or clips.

Torch and connecting hose assembly, to suit current.

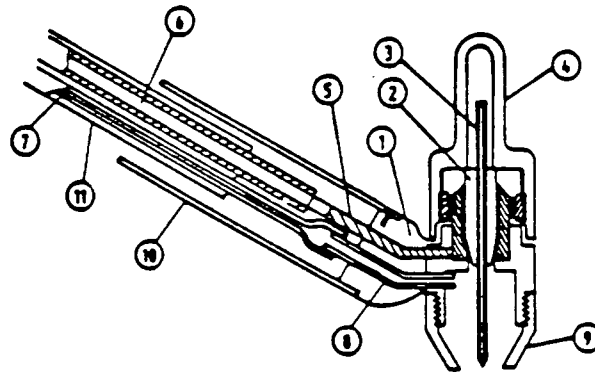
Gas hose.

Gas regulator.

Cylinder stand.

### Typical air cooled TIG torch

1. Torch body, plastic with metal inserts
2. Collect, interchangeable to suit electrode diameter
3. Electrode
4. Insulating cap
5. Current connection
6. Welding cable
7. Gas hose
8. Gas pipe
9. Nozzle – ceramic
10. Handle
11. Outer flexible sleeve



### Spares

Electrodes –

Collets – various sizes to clamp electrodes in torch

Electrode rear cover – various lengths to accommodate a long electrode, or short to work where space is restricted.

Gas-shielding nozzle – ceramic.

Silicone rubber ring seals joint between nozzle and torch body.

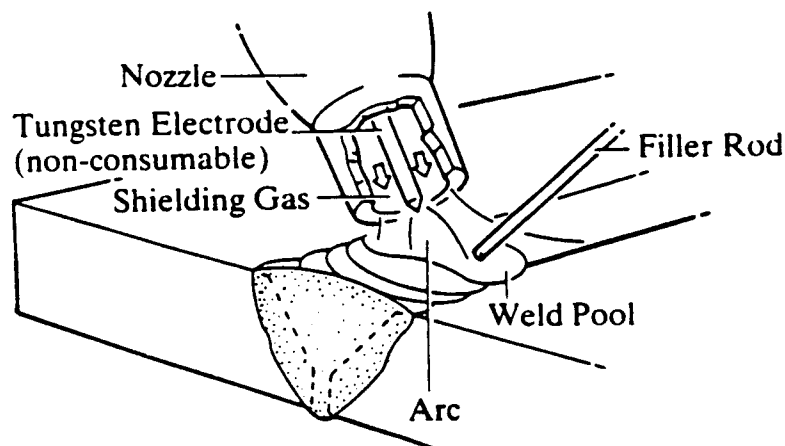
In DC welding, the electrode usually has negative polarity which reduces the risk of overheating which may otherwise occur with electrode positive. The ionised gas or plasma stream can attain a temperature of several thousand degrees centigrade. Consequently, within the normal range of welding currents (5–300A) rapid cooling can be effected.

The gas supplied to the arc has two functions: it generates the arc plasma, and it protects the electrode, weld pool and weld bead from undesirable oxidation.

## DC TIG

The TIG torch allows the electrode to extend beyond the shielding gas nozzle, as shown.

The arc is ignited to high voltage, high frequency (HF) pulses, or by short circuiting the electrode to the workpiece and withdrawing at a present low current. In DC welding, the arc is in the form of a cone, the size of which is determined by current, the electrode diameter and the vertex angle.



## Electrode

Selection of electrode composition and size is not completely independent and must be considered in relation to the operating mode and the current level. Electrodes for DC welding are pure tungsten or tungsten with 1 or 2% thoria, the thoria being added to improve electron emission which facilitates arc ignition. In AC welding, where the electrode must operate at a higher temperature, a pure tungsten or tungsten–zirconia electrode is preferred, as the rate of tungsten loss is somewhat less than with thoriated electrodes and the zirconia aids retention of the 'balled' tip.

Table 1. Recommended electrode diameter and vertex angle for TIG welding at various current levels

| Welding current<br>A | DC electrode negative        |                             | AC                             |
|----------------------|------------------------------|-----------------------------|--------------------------------|
|                      | Electrode*<br>diameter<br>mm | Vertex<br>angle,<br>degrees | Electrode ><br>diameter,<br>mm |
| <20                  | 1.0                          | 30                          | 1.0 – 1.6                      |
| 20 to 100            | 1.6                          | 30 – 60                     | 1.6 – 2.4                      |
| 100 to 200           | 2.4                          | 60 – 90                     | 2.4 – 4.0                      |
| 200 – 300≈           | 3.2                          | 90 – 120                    | 4.0 – 4.8                      |
| 300 to 400≈          | 3.2                          | 120                         | 4.8 – 6.4                      |

\* Thoriated tungsten

τ Zirconiated tungsten, balled tip, electrode diameter depends on degree of balance on AC waveform.

≈ Use current slope-in to minimise thermal shock which may cause splitting of the electrode.

In DC welding, a small diameter, finely pointed approximately 30° electrode must be used to stabilise low current arcs at less than 20A. As the current is increased, it is equally important to readjust the electrode diameter and vertex angle. Too fine an electrode tip causes excessive broadening of the plasma stream, due to the high current density, which results in a marked decrease in the depth to width ratio of the weld pool. More extreme current levels will result in excessively high erosion rates and eventually in melting of the electrode tip. Recommended electrode diameters and vertex angles in argon shielding gases for the normal range of currents are given in Table 1.

## Shielding gas

The shielding gas composition is selected according to the material being welded, and the normal range of commercially available gases is given in the Table below. In selecting a shielding gas it should be noted that:

1. The most common shielding gas is argon. This can be used for welding a wide range of material including mild steel, stainless steel, and the reactive aluminium, titanium and magnesium..
2. Argon–hydrogen mixtures, typically 2% and 5% H<sub>2</sub>, can be used for welding austenitic stainless steel and some nickel alloys. The advantages of adding hydrogen are that the shielding gas is slightly reducing, producing cleaner welds, and the arc itself is more constricted, thus enabling higher speeds to be achieved and/or producing an improved weld bead penetration profile, i.e. greater depth to width ratio. It should be noted that the use of a hydrogen addition introduces the risk of hydrogen cracking (carbon and alloy steels) and weld metal porosity (ferritic steels, aluminium and copper), particularly in multipass welds.
3. Helium, and helium–argon mixtures, typically 75/25 helium/argon, have particular advantages with regard to higher heat input; the greater heat input is caused by the higher ionisation potential of helium, which is approximately 25eV compared with 16eV for argon.
4. As nitrogen is a diatomic gas, on re–association at the workpiece surface, it is capable of transferring more energy than monatomic argon or helium. Hence its addition to argon can be particularly beneficial when welding materials such as copper, which have high thermal conductivity; the advantages of nitrogen additions cannot be exploited when welding ferritic and stainless steels because nitrogen pick–up in the weld pool could cause a significant reduction in toughness and corrosion resistance.

Recommended shielding gases for TIG welding

| Metal                  | Shielding gas mixtures |                        |        |              |          |                |
|------------------------|------------------------|------------------------|--------|--------------|----------|----------------|
|                        | Argon                  | Argon + H <sub>2</sub> | Helium | Helium-argon | Nitrogen | Argon-nitrogen |
| Mild steel             | ●                      |                        |        |              |          |                |
| Carbon steel           | ●                      |                        |        | ○            |          |                |
| Low alloy steel        | ●                      |                        |        | ●            |          |                |
| Stainless steel        | ●                      | ●                      | ○      | ○            |          |                |
| Aluminium              | ●                      |                        | ●      | ●            |          |                |
| Copper                 | ●                      |                        | ●      | ●            | ○        | ○              |
| Nickel alloys          | ○                      | ●                      |        | ○            |          |                |
| Titanium and magnesium | ●                      |                        | ○      |              |          |                |

● most common gas

○ also used

The effectiveness of a gas shield is determined at least in part by the gas density. As the density of helium is approximately one tenth that of argon, difficulties can be experienced in protecting the weld pool, particularly when welding under draughty conditions or at high currents which may induce turbulence in the gas shielding stream.

However, effective shielding can be maintained by increasing the gas flow, typically by a factor of two. Shielding of the weld pool area can also be improved by use of a gas lens, which is inserted into the torch nozzle to ensure laminar flow. Adoption of this technique is strongly recommended when welding in positions other than the flat and for welding curved surfaces.

## **AC TIG**

TIG welding is also practised with AC, the electrode polarity oscillating at 50Hz. The technique is used in welding aluminium and magnesium alloys, where the periods of electrode positive ensure efficient cathodic cleaning of the tenacious oxide film on the surface of the material. Compared with DC welding, the disadvantages of the technique lie in the low penetration capacity of the arc and, as the arc extinguishes at each current reversal, in the necessity for a high open circuit voltage, typically 100V and above, or continuously applied HF, to stabilise the arc. Low penetration results in particular from the blunt or "balled" electrode which is caused by the high degree of electrode heating during the positive half-cycle. Where deep penetration is required, use of DC with helium as the shielding gas, which does not suffer from these disadvantages and is somewhat tolerant to surface oxide, may be an alternative. Use of helium, however, is not particularly attractive because of its high cost and, in the absence of the cleaning action of the arc, the weld pool/parent metal boundaries can be somewhat indistinct, thus making it difficult to monitor and control the behaviour of the weld pool.

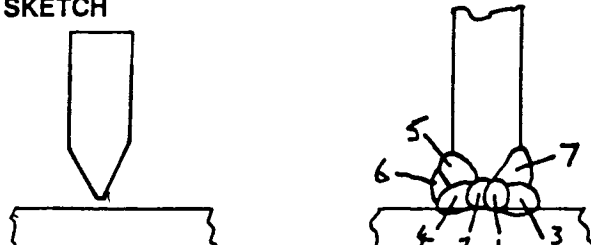
## **QUESTIONS:**

### **TUNGSTEN INERT GAS**

- Q1. State the welding variables for TIG.
- Q2. What is the type of current used for steels, and what is the electrode polarity ?
- Q3. What is the purpose of high frequency ?
- a) For direct current
  - b) For alternating current
- Q4. Name the two inert gases mainly used in TIG and give an advantage for each gas.
- Q5. Give an advantage and a disadvantage of the process.

**WELDING PROCEDURE SHEET****TIG****JOB TITLE**

TEE BUTT FOR DRAWING REF A154

|                                                                                                |       |                     |        |                                                                                                     |        |        |                                                                                                                                                   |  |  |
|------------------------------------------------------------------------------------------------|-------|---------------------|--------|-----------------------------------------------------------------------------------------------------|--------|--------|---------------------------------------------------------------------------------------------------------------------------------------------------|--|--|
| DATE. 00.00.00                                                                                 |       | REFERENCE NO. SWI 3 |        | PROCEDURE NO. 2                                                                                     |        |        |                                                                                                                                                   |  |  |
| <b>PARENT MATERIAL DETAILS</b><br>SPECIFICATION<br>COMPOSITION AS SPECIFIED<br>THICKNESS 8.0mm |       |                     |        | <b>SKETCH</b><br> |        |        |                                                                                                                                                   |  |  |
|                                                                                                |       |                     |        |                                                                                                     |        |        | <b>CONSUMABLE DETAILS</b><br>TRADE NAME ESAB<br>SPECIFICATION BS 2901 Pt.1<br>DIAMETER 2.4/3.2mm                                                  |  |  |
|                                                                                                |       |                     |        |                                                                                                     |        |        | EDGE PREPARATION PLASMA CUT & GROUND<br>INCL. ANGLE $40^{\circ} +.5^{\circ} - 0^{\circ}$ RADIUS N/A<br>ROOT GAP 3.0mm LAND N/A<br>ROOT FACE 3.0mm |  |  |
|                                                                                                |       |                     |        |                                                                                                     |        |        | SHIELDING GAS TYPE ARGON BACKING N/A                                                                                                              |  |  |
| <b>WELDING EQUIPMENT DETAILS</b>                                                               |       |                     |        |                                                                                                     |        |        |                                                                                                                                                   |  |  |
| TUNGSTEN TYPE ZIRCONIATED                                                                      |       | TUNGSTEN DIA. 3.2mm |        | TUNGSTEN TIP GEOMETRY $60^{\circ}$ VERTEX                                                           |        |        |                                                                                                                                                   |  |  |
| GAS NOZZLE TYPE CERAMIC                                                                        |       | ORIFICE DIA. 12 mm  |        | GAS LENS                                                                                            |        | YES NO |                                                                                                                                                   |  |  |
| WELDING CONDITIONS SITE                                                                        |       | MANUAL YES          |        | MECHANISED NO                                                                                       |        |        |                                                                                                                                                   |  |  |
| WELDING POSITION ALL                                                                           |       | PREHEAT TEMP. N/A   |        | INTERPASS TEMP. $150^{\circ}\text{C}$                                                               |        |        |                                                                                                                                                   |  |  |
| GAS FLOW RATES - SHIELDING 15L/MIN                                                             |       |                     |        | BACKING N/A                                                                                         |        |        |                                                                                                                                                   |  |  |
| RUN NUMBER                                                                                     | 1     | 2                   | 3      | 4                                                                                                   | 5      | 6      |                                                                                                                                                   |  |  |
| WIRE DIAMETER                                                                                  | 3.2   | 3.2                 | 3.2    | 2.4                                                                                                 | 3.2    | 2.4    |                                                                                                                                                   |  |  |
| WIRE FEED RATE                                                                                 | - M   | A                   | N      | U                                                                                                   | A      | L -    |                                                                                                                                                   |  |  |
| AC DC +/-                                                                                      | DCEN  | DCEN                | DCEN   | DCEN                                                                                                | DCEN   | DCEN   |                                                                                                                                                   |  |  |
| WAVE FORM                                                                                      | N/A   | N/A                 | N/A    | N/A                                                                                                 | N/A    | N/A    |                                                                                                                                                   |  |  |
| BACKGROUND CURRENT                                                                             | "     | "                   | "      | "                                                                                                   | "      | "      |                                                                                                                                                   |  |  |
| PEAK CURRENT                                                                                   | "     | "                   | "      | "                                                                                                   | "      | "      |                                                                                                                                                   |  |  |
| MEAN CURRENT                                                                                   | 70-90 | 80-100              | 80-100 | 80-100                                                                                              | 80-100 | 80-100 |                                                                                                                                                   |  |  |
| BACKGROUND TIME                                                                                | N/A   | N/A                 | N/A    | N/A                                                                                                 | N/A    | N/A    |                                                                                                                                                   |  |  |
| PEAK TIME                                                                                      | "     | "                   | "      | "                                                                                                   | "      | "      |                                                                                                                                                   |  |  |
| ARC VOLTAGE                                                                                    | 10-12 | 10-12               | 10-12  | 10-12                                                                                               | 10-12  | 10-12  |                                                                                                                                                   |  |  |
| TRAVEL SPEED mm/min                                                                            | 60    | 50                  | 50     | 50                                                                                                  | 70     | 70     |                                                                                                                                                   |  |  |
| BEAD WIDTH                                                                                     | 5.0   | 5.0                 | 5.0    | 5.0                                                                                                 | 5.0    | 5.0    |                                                                                                                                                   |  |  |
| ENERGY INPUT Kj/mm                                                                             | 1.0   | 1.0                 | 1.0    | 1.0                                                                                                 | 1.0    | 1.0    |                                                                                                                                                   |  |  |

POST WELD HEAT TREATMENT

NOT REQUIRED

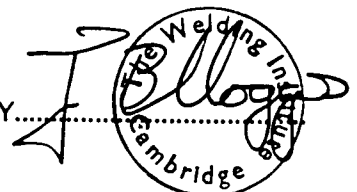
POST WELD INSPECTION METHOD

AS PER STANDARD

ADDITIONAL INFORMATION

BACKGOUING REQUIRED AFTER RUN ONE

COMPILED BY.....



# SENIOR WELDING INSPECTOR

## T.I.G WELDING

- Q1. State typical dimensions of preparation for a TIG weld to be made in 5mm thick carbon steel.
- Q2. How would your choice differ if stainless steel is used.
- Q3. State three (3) advantages of pulsed TIG welding.
- Q4. Why is helium sometimes preferred in gas shielded arc welding and give
  - a) two (2) advantages
  - b) two (2) disadvantages
- Q5. State the principle limitation of the TIG process.
- Q6. State three (3) methods of arc initiation used in TIG welding.
- Q7. What is meant by the term "fusible insert" and give two (2) reasons why manual welding should be avoided.
- Q8. State the typical amps and volts ranges used with DC welding.
- Q9. Why is the level of finish of materials important with TIG welding.
- Q10. State the relevant British Standard for TIG welding consumables, and a summary of its contents.

## **DEFECTS WHICH MAY BE DETECTED BY SURFACE INSPECTION**

Defects which may be detected by visual inspection can be grouped under four headings.

1.       Cracks
  
  
  
  
  
  
  
  
  
  
2.       Surface irregularities
  
  
  
  
  
  
  
  
  
  
3.       Contour defects
  
  
  
  
  
  
  
  
  
  
4.       Root defects

Internal defects such as cavities

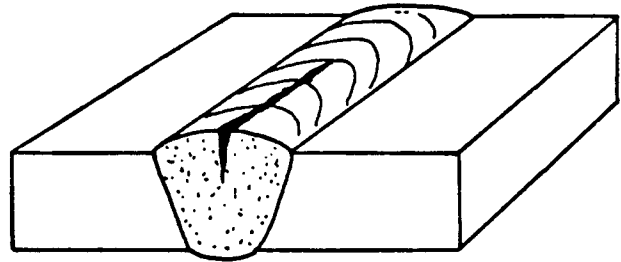
Solid inclusions will be dealt with during macroscopic examination

## Surface Cracks

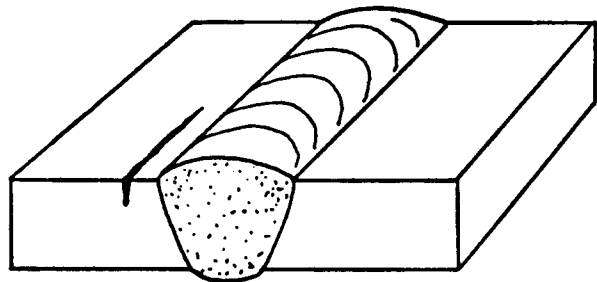
**60 015\* Crack**  
A linear discontinuity produced by fracture.

Cracks may be

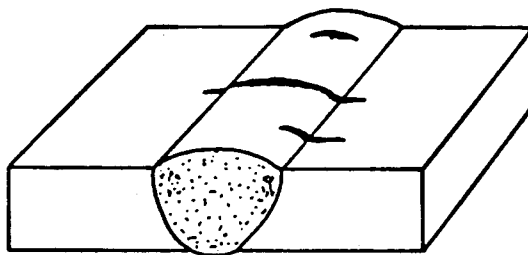
longitudinal, in the weld metal,  
*i.e.* centreline



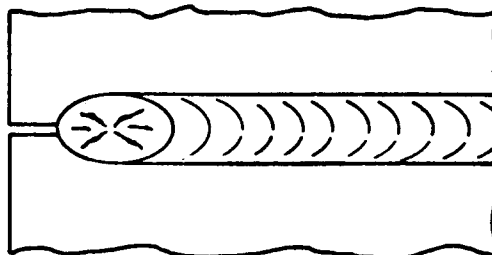
longitudinal, in the parent metal



transverse



crater  
(star cracking)

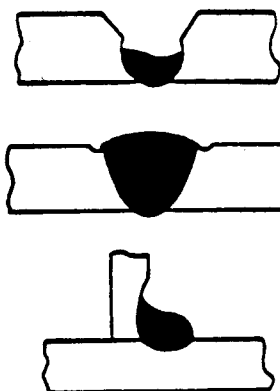


## Surface Irregularities

60 006\*

### Undercut

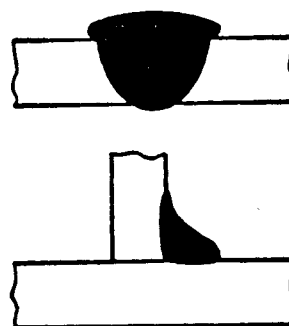
An irregular groove at a toe of a run in the parent metal or in previously deposited weld metal.



60 007\*

### Overlap

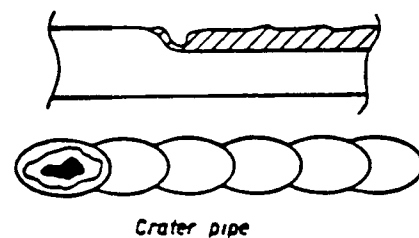
An imperfection at the toe or root of a weld caused by metal flowing on to the surface of the parent metal without fusing to it.



60 038

### Crater pipe

A depression due to shrinkage at the end of a run where the source of heat was removed.



Crater pipe

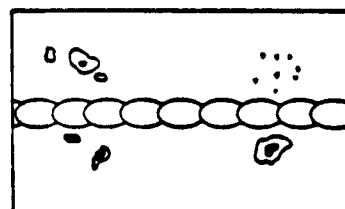
10 031

### Spatter

32 104

### Stray flash

(stray arcing)

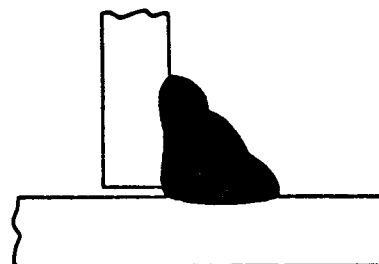
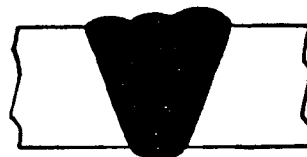


## Contour Defects

- 60 003 Incompletely filled groove**  
 A continuous or intermittent channel in the surface of a weld, running along its length, due to insufficient weld metal. The channel may be along the centre or along one or both edges of the weld.



- 00 000\* Bulbous contour**  
 (not BS 499 term)



- 00 000\* Unequal legs**  
 (not BS 499 term)

Variation of leg length on a fillet weld.

N.B. Unequal leg lengths may be specified as part of the design — in which case they are not defects.



## Root Defects

- 60 022\*** **Incomplete root penetration**  
Failure of weld metal to extend into the root of a joint.



- 60 020** **Lack of root fusion**  
Lack of union at the root of a joint.



- 60 001\*** **Excess penetration bead**  
Excess weld metal protruding through the root of a fusion weld made from one side only.



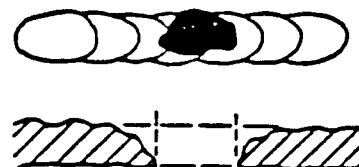
- 60 002\*** **Root concavity**  
(suck-back; underwashing)  
  
A shallow groove which may occur in the root of a butt weld.



- 60 004\*** **Shrinkage groove**  
A shallow groove caused by contraction in the metal along each side of a penetration bead.



- 60 039** **Burnthrough**  
(melt through)  
A localised collapse of the molten pool due to excessive penetration, resulting in a hole in the weld run.



## QUESTIONS

### REVIEW OF DEFECTS

Q1      Name two (2) crack/planar defects found within the weld metal.

Q2      Give two (2) main causes of excess penetration

Q3      Sketch   a)   Incomplete filled groove  
                     b)   Lack of sidewall fusion at the weld toe

Q4      Give three (3) main causes of undercut

Q5      Give three possible causes of lack of side wall fusion

# **SENIOR WELDING INSPECTOR**

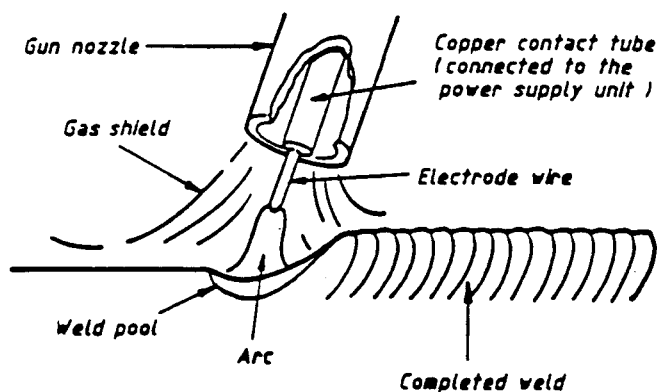
## **DEFECTS**

- Q1. State three (3) causes of centreline cracking.
- Q2. State four (4) types of planar defects.
- Q3. Give the main causes of porosity found in weldments.
- Q4. Define wormhole porosity and three (3) possible causes.
- Q5. For what reasons is undercut found in horizontal vertical multipass welds.
- Q6. Give the main causes of lack of fusion at stop/starts on root passes.
- Q7. State three (3) methods of avoiding crater pipes.
- Q8. Give six (6) reasons for penetration.
- Q9. Give five (5) reasons why a weld cap may be rejected to a code.
- Q10. State the difference between incomplete toe fusion and incomplete filled groove.

With a 'flat' volts/amps characteristic an attempted alteration in arc length (volts) will have little effect, hence arc length (volts) remains constant but a significant change in current will result. This is often referred to as the "self-adjusting arc".

## A 'FLAT' ARC PROCESS (CONSTANT) VOLTAGE

### METAL INERT GAS (MIG)



#### Type of Operation

Manual, mechanised or automatic.

#### Mode of Operation

An arc is maintained between the end of the bare wire electrode and the work. The wire is fed at a constant speed, selected to give the required current, and the arc length is controlled by the power source. The operator is not therefore concerned with controlling the arc length and can concentrate on depositing the weld metal in the correct manner.

The process can be operated at high currents (250-500A) when metal transfer is in the form of a 'spray', but, except for aluminium, this technique is confined to welding in the flat and horizontal positions. For vertical and overhead welding special low-current techniques must be used, *i.e.* 'dip' transfer or pulsed arc. The arc and weld pool are shielded by a stream of gas.

The electrode can be solid or flux cored.

Metal Active Gas (MAG); CO<sub>2</sub>; Metal-arc gas shielded; GMAW (US)

Typical defects associated with this process:

Incomplete penetration.

Excessive penetration.

• Undercut.

Excessive spatter.

Cracking.

• Porosity.

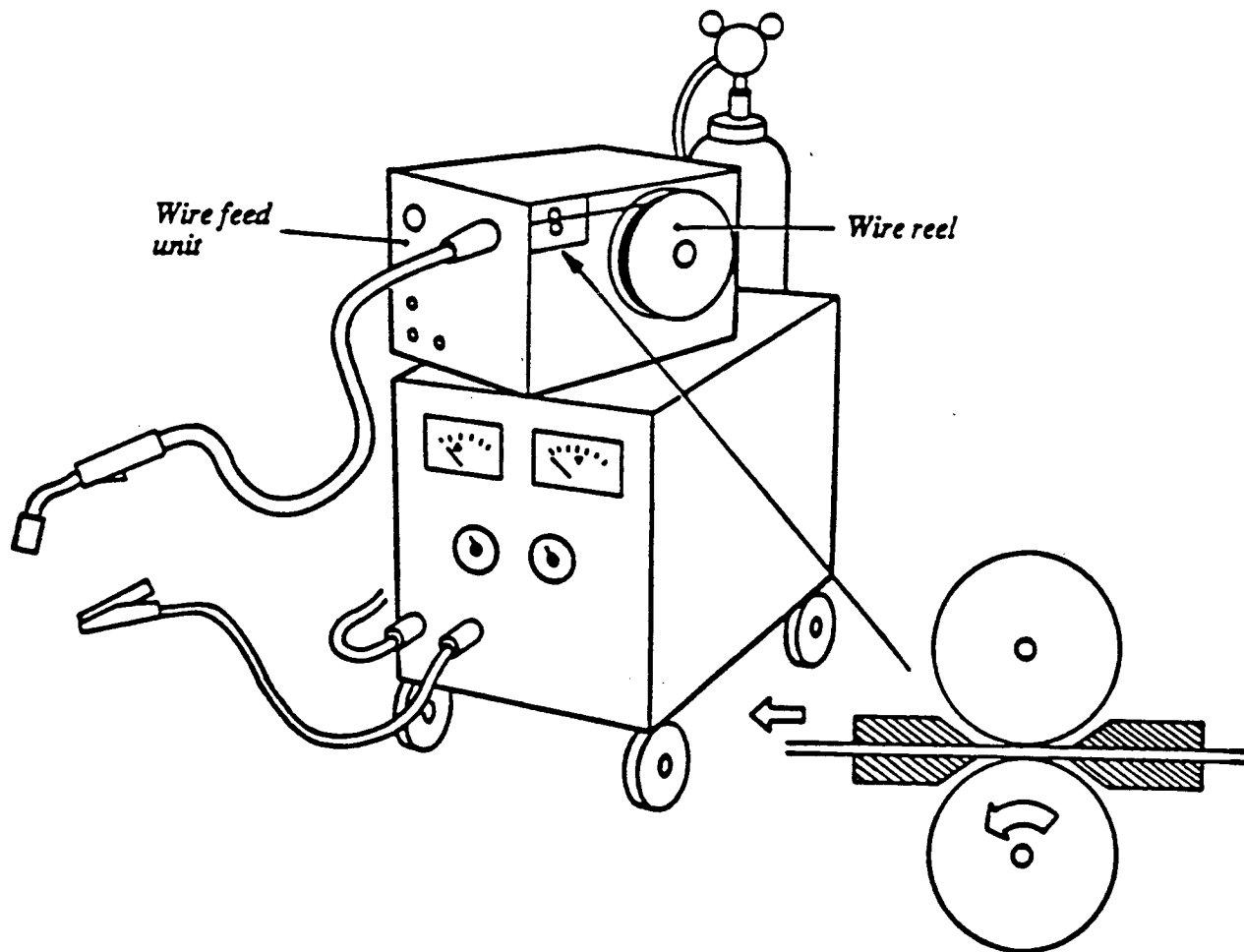
• Lack of fusion.

Stray flash.

In mechanised MIG and submerged arc welding the process may also be operated using constant current or drooping arc characteristics.

# GAS SHIELDED METAL ARC WELDING

## Welding sets



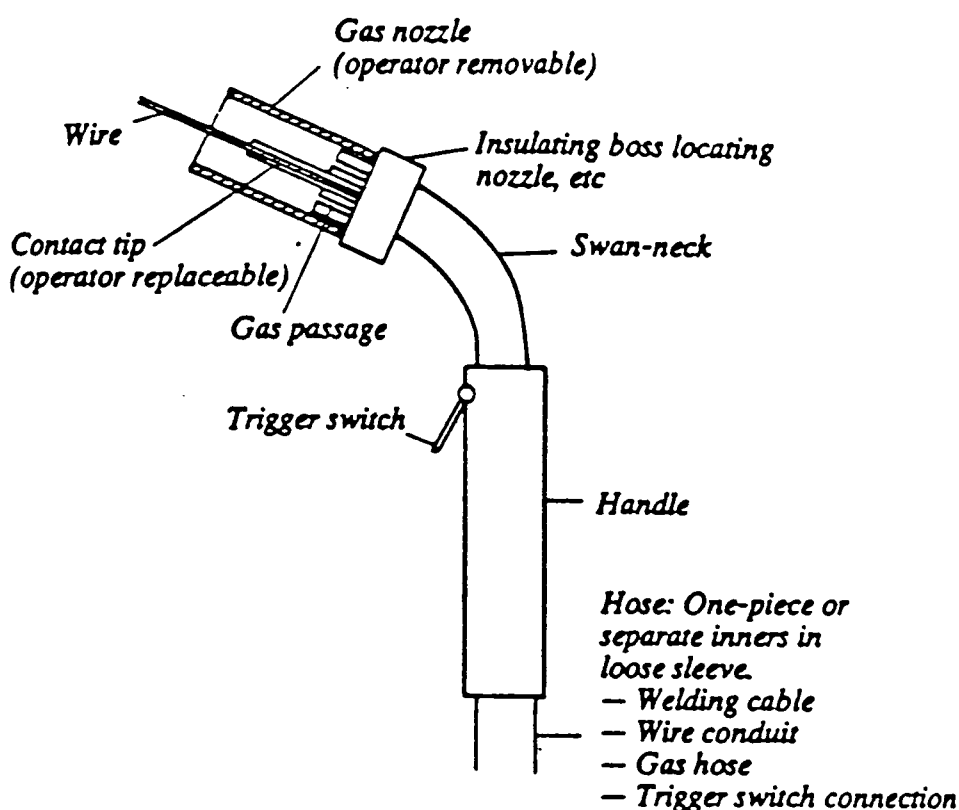
Sets are manufactured in a range of sizes, identified by current, similar to metal arc welding. Currents below 200A can only give 'dip transfer' operation, suitable for welding steel only.

Larger sets may have the wire reel and motor as a separate unit, so it can be placed near the job. Controls on the set adjust output voltage and may allow a choice of inductance: the wire speed control will be on the wire feed unit.

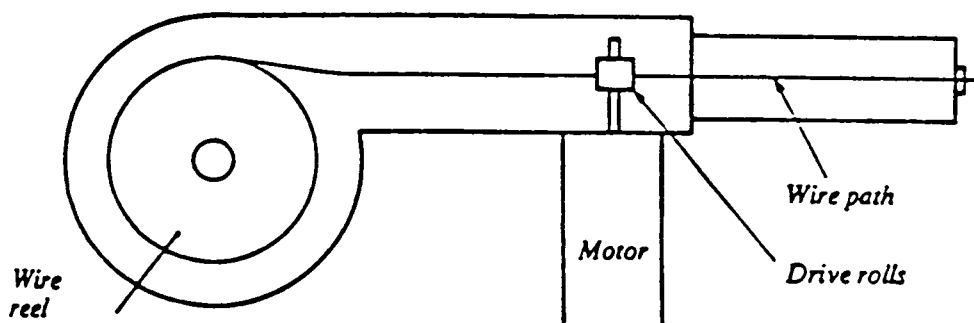
Electrical input is from single-phase 240V mains for small sets, or three-phase 415V for medium size upwards. Output is always DC with a flat output characteristic (semi automatic), drooping output (mechanised).

Sets often have a built-in holder for a gas cylinder.

A set will usually be supplied complete with a suitable gun: also see 'Accessories' below. Heavy duty guns may be water cooled, and the set may have a water tank and cooling radiator built in.



When welding aluminium, the wire is soft, and tends to kink when pushed through a hose – a gun carrying a small reel of wire – 'reel-on-gun' – obviates this.



Sets which supply current in pulses (at 40–200 per second) give improved results on some jobs: as this 'pulse-MIG' would increase the number of controls, an electronic 'synergic' control system varies all the parameters in step to simplify adjustments.

### **Accessories**

|                   |   |                                                       |
|-------------------|---|-------------------------------------------------------|
| Welding cables    | } |                                                       |
| Connectors to set | } | similar to manual metal arc: one set usually included |
| Clamps or clips   | } |                                                       |

Gun and connecting hose assembly to suit current, usually supplied with set; also see 'spares' below.

Gas regulators and hose, connections to suit.

Vaporiser for carbon dioxide gas on industrial sets.

Cylinder stand

### **Spares**

The following parts come into contact with the wire – spares are needed to replace worn parts, or if wire size or type is changed.

|                         |   |                   |
|-------------------------|---|-------------------|
| Inlet and outlet guides | } |                   |
|                         | } | on drive assembly |
| Drive rolls             | } |                   |

Wire conduit liner – spring steel coil, like curtain wire, for steel electrode wire, or plastic tube for aluminium.

Contact tip in gun – needs fairly frequent replacement.

Gas shielding nozzle for gun – various sizes to suit different jobs.

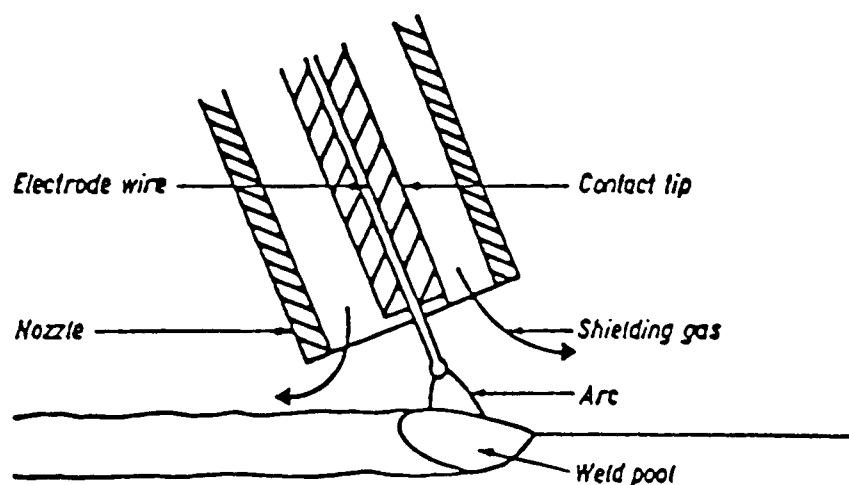
# MIG/MAG WELDING

## PROCESS CHARACTERISTICS

The heat source used to melt the parent metal is obtained from an electric arc which is formed between the end of a consumable electrode wire and the work-piece. The arc melts the end of the electrode wire which is transferred to the molten weld pool. The electrode wire is fed from a spool which is attached to the wire driving system and passes through a set of rolls which are driven by a variable speed electric motor. By varying the speed of the motor we can adjust the level of the welding current: high wire feed speed gives high welding current. The arc length can also be varied by altering the voltage: high voltages give longer arc lengths and vice versa.

In order to prevent the air reacting chemically with the molten metal a shielding gas of either CO<sub>2</sub> or argon/CO<sub>2</sub> mixture is passed over the weld zone from a nozzle attached to the welding gun or torch. This protects the molten droplets passing across the arc and the molten weld pool.

Electrical power for the process is a direct current which is obtained from a transformer-rectifier. The welding gun or torch is connected to the positive pole of the power supply unit and electrical contact to the wire is obtained as close to the arc as possible by means of a copper contact tip or tube.



## **Metal transfer**

The metal at the end of the electrode is melted and transferred to the molten weld pool.

The type of metal transfer are:

1. Spray or globular transfer
2. Short-circuiting or dip transfer

### **Spray transfer/globular transfer**

This type of metal transfer generally occurs at high current high arc voltage ranges, e.g. 250–600A at 28–40V. As the current is increased the rate at which the droplets are transferred across the arc increases and they become smaller in volume. The droplets can be seen on a high-speed cine film but cannot be distinguished with the naked eye. It appears as if there is a spray of metal.

The type of shielding gas greatly affects the current rate at which the spray transfer occurs. The use of CO<sub>2</sub> as a shielding gas requires a much greater current density than argon to produce the same droplet rate.

With the use of high currents giving strong magnetic forces very directional arcs are produced. In argon shielding gases the action of these forces on the droplets is well-balanced and transfer from wire to work is smooth with little or not spatter. However, in a CO<sub>2</sub> shield the forces tend to be out-of-balance giving rise to an arcing condition that is less smooth and spatter levels are heavier. Metal transfer under these conditions is normally called globular or free-flight.

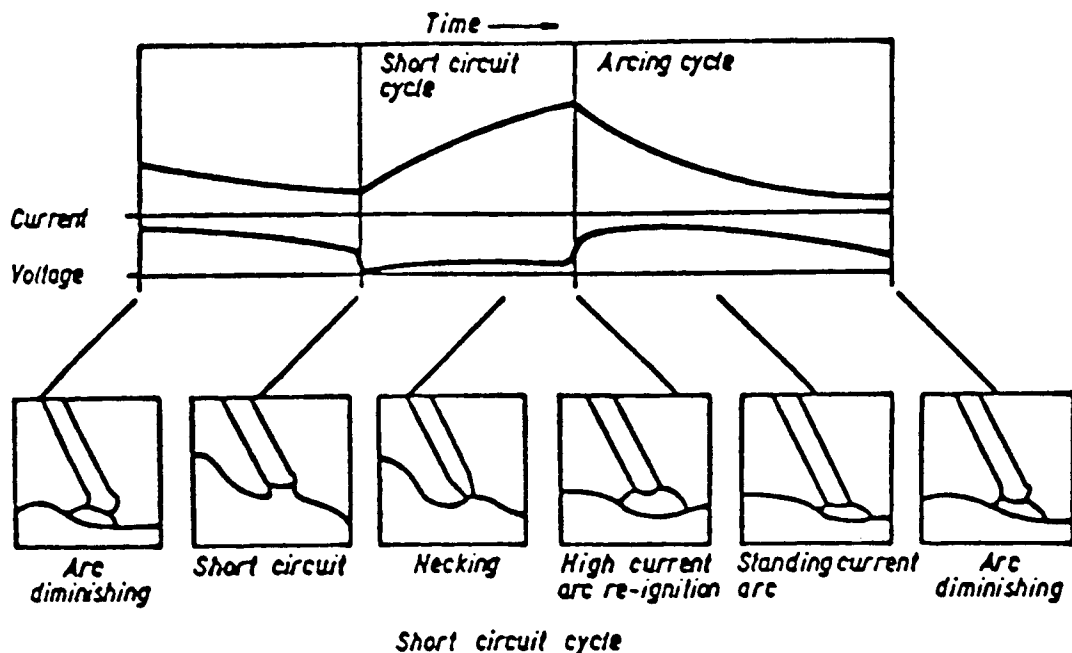
The welding conditions which give spray or globular transfer are normally associated with high deposition rates on medium and thick sections and can only be used when welding in the flat position.

## Short-circuiting arc or dip-transfer

At lower arc voltages and currents, generally within the 16–26V, 60–180A ranges, metal transfer takes place during short circuits between the electrode and the weld pool. These follow a consistent sequence of alternate arcing and short-circuiting causing the end of the electrode wire to dip into the weld. As the wire touches the weld pool there is a rise of current, the resistance of the wire causes heating and the end of the electrode melts. The wire necks due to a magnetic pinch effect and the molten metal flows into the pool. During this short-circuit period the current delivered by the power source is much higher than during arcing, typically 1000–1500A. This creates high forces which have an explosive effect on the weld pool and spatter is considerable. To reduce this effect an inductance is connected in series with the power supply and the arc to reduce the rate of rise of current during the short-circuit period.

The short-circuit is cleared more slowly and gently, and the spatter is reduced to an acceptable level. Ideally an almost irregular dip/arc cycle takes place about 50–200 times a second. Too little inductance gives rise to unstable arcing conditions, excessive spatter and lack of fusion defects.

The dip transfer mode is used for the welding of thin sheet and medium plate, and for all thicknesses when welding in the vertical or overhead positions.



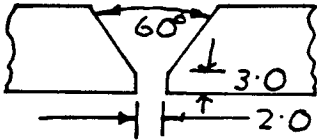
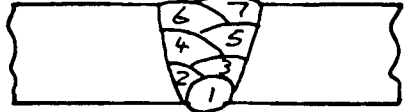
## QUESTIONS

### MIG MAG AND CO<sub>2</sub> WELDING (METAL INERT GAS WELDING)

- Q1 State the main welding parameters and variables of the process.
- a)
  - b)
  - c)
  - d)
  - e) Tilt angle
  - f)
  - g)
- Q2 What polarity is normally used for welding applications ?
- Q3 State the modes of transfer
- a)
  - b)
  - c) Spray transfer
  - d)
- Q4 State three (3) items of importance when inspecting a wire to be used for MIG welding.
- Q5 Which defect can be quite common when using the short circuiting mode of transfer?
- a) Lack of penetration
  - b) Undercut
  - c) Lack of fusion
  - d) Porosity

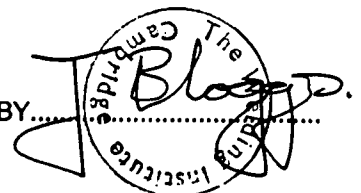
**WELDING PROCEDURE SHEET**  
**JOB TITLE**

**MIG**

|                                                                                                                                                            |                      |                                                                                                                                                                                                                                                                                                                                                                 |         |                                                                                                                         |  |                    |            |                      |                 |          |  |                                |                |         |  |
|------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------|-------------------------------------------------------------------------------------------------------------------------|--|--------------------|------------|----------------------|-----------------|----------|--|--------------------------------|----------------|---------|--|
| DATE<br>00-00-00                                                                                                                                           | REFERENCE<br>NO. SW3 | PROCEDURE NO.<br>3                                                                                                                                                                                                                                                                                                                                              |         |                                                                                                                         |  |                    |            |                      |                 |          |  |                                |                |         |  |
| <b>PARENT MATERIAL DETAILS</b><br><br>SPECIFICATION 316L S92<br>STAINLESS STEEL<br>COMPOSITION 0.1C 13Ni 20Cr<br>3Mo<br>THICKNESS 25mm                     |                      | <b>SKETCH OF PREPARATION</b><br><br>                                                                                                                                                                                                                                           |         | <b>SKETCH OF RUN SEQUENCE</b><br><br> |  |                    |            |                      |                 |          |  |                                |                |         |  |
| <b>CONSUMABLE DETAILS</b><br><br>TRADE NAME W R EXCEL WIRE<br>316L<br>SPECIFICATIONS BS2901 Pt.3<br>DIAMETERS 1.2mm<br>SHIELDING GAS ARGON                 |                      | <b>EDGE PREPARATION</b> SINGLE VEE BUTT<br><br><table border="1"> <tr> <td>INCLUDED ANGLE 60°</td> <td>RADIUS N/A</td> </tr> <tr> <td>ROOT RUN PROCESS MIG</td> <td>ROOT FACE 3.0mm</td> </tr> <tr> <td>LAND N/A</td> <td></td> </tr> <tr> <td>WELDING POSITION ALL POSITIONS</td> <td>ROOT GAP 2.0mm</td> </tr> <tr> <td>BACKING</td> <td></td> </tr> </table> |         |                                                                                                                         |  | INCLUDED ANGLE 60° | RADIUS N/A | ROOT RUN PROCESS MIG | ROOT FACE 3.0mm | LAND N/A |  | WELDING POSITION ALL POSITIONS | ROOT GAP 2.0mm | BACKING |  |
| INCLUDED ANGLE 60°                                                                                                                                         | RADIUS N/A           |                                                                                                                                                                                                                                                                                                                                                                 |         |                                                                                                                         |  |                    |            |                      |                 |          |  |                                |                |         |  |
| ROOT RUN PROCESS MIG                                                                                                                                       | ROOT FACE 3.0mm      |                                                                                                                                                                                                                                                                                                                                                                 |         |                                                                                                                         |  |                    |            |                      |                 |          |  |                                |                |         |  |
| LAND N/A                                                                                                                                                   |                      |                                                                                                                                                                                                                                                                                                                                                                 |         |                                                                                                                         |  |                    |            |                      |                 |          |  |                                |                |         |  |
| WELDING POSITION ALL POSITIONS                                                                                                                             | ROOT GAP 2.0mm       |                                                                                                                                                                                                                                                                                                                                                                 |         |                                                                                                                         |  |                    |            |                      |                 |          |  |                                |                |         |  |
| BACKING                                                                                                                                                    |                      |                                                                                                                                                                                                                                                                                                                                                                 |         |                                                                                                                         |  |                    |            |                      |                 |          |  |                                |                |         |  |
| <b>WELDING CONDITIONS</b>                                                                                                                                  |                      |                                                                                                                                                                                                                                                                                                                                                                 |         |                                                                                                                         |  |                    |            |                      |                 |          |  |                                |                |         |  |
| MANUAL YES MECHANISED NO<br>PREHEAT TEMPERATURE NOT REQUIRED INTERPASS TEMPERATURE 100°C<br>GAS FLOW RATE 15L/MIN INTER RUN CLEANING OR GOUGING WIRE BRUSH |                      |                                                                                                                                                                                                                                                                                                                                                                 |         |                                                                                                                         |  |                    |            |                      |                 |          |  |                                |                |         |  |
| RUN NO.                                                                                                                                                    | 1                    | 2                                                                                                                                                                                                                                                                                                                                                               | 3       | 4                                                                                                                       |  |                    |            |                      |                 |          |  |                                |                |         |  |
| MEAN CURRENT                                                                                                                                               | 150                  | 175                                                                                                                                                                                                                                                                                                                                                             | 175     | 175                                                                                                                     |  |                    |            |                      |                 |          |  |                                |                |         |  |
| WIRE DIA.                                                                                                                                                  | 1.2                  | 1.2                                                                                                                                                                                                                                                                                                                                                             | 1.2     | 1.2                                                                                                                     |  |                    |            |                      |                 |          |  |                                |                |         |  |
| WIRE FEED SPEED                                                                                                                                            | -                    | -                                                                                                                                                                                                                                                                                                                                                               | -       | -                                                                                                                       |  |                    |            |                      |                 |          |  |                                |                |         |  |
| AC DC +/-                                                                                                                                                  | DC                   | DC                                                                                                                                                                                                                                                                                                                                                              | DC      | DC                                                                                                                      |  |                    |            |                      |                 |          |  |                                |                |         |  |
| WAVE FORM                                                                                                                                                  | -                    | -                                                                                                                                                                                                                                                                                                                                                               | -       | -                                                                                                                       |  |                    |            |                      |                 |          |  |                                |                |         |  |
| BACKGROUND CURRENT                                                                                                                                         | -                    | -                                                                                                                                                                                                                                                                                                                                                               | -       | -                                                                                                                       |  |                    |            |                      |                 |          |  |                                |                |         |  |
| PEAK CURRENT                                                                                                                                               | 120-180              | 150-200                                                                                                                                                                                                                                                                                                                                                         | 150-200 | 150-200                                                                                                                 |  |                    |            |                      |                 |          |  |                                |                |         |  |
| PULSE FREQUENCY                                                                                                                                            | -                    | -                                                                                                                                                                                                                                                                                                                                                               | -       | -                                                                                                                       |  |                    |            |                      |                 |          |  |                                |                |         |  |
| VOLTAGE                                                                                                                                                    | 23 / 21              | 24 / 22                                                                                                                                                                                                                                                                                                                                                         | 28 / 30 | 28 / 30                                                                                                                 |  |                    |            |                      |                 |          |  |                                |                |         |  |
| ELECTRODE EXTENSION (mm)                                                                                                                                   | 25                   | 25                                                                                                                                                                                                                                                                                                                                                              | 25      | 25                                                                                                                      |  |                    |            |                      |                 |          |  |                                |                |         |  |
| BEAD WIDTH                                                                                                                                                 | -                    | -                                                                                                                                                                                                                                                                                                                                                               | -       | -                                                                                                                       |  |                    |            |                      |                 |          |  |                                |                |         |  |
| TRAVEL SPEED                                                                                                                                               | -                    | -                                                                                                                                                                                                                                                                                                                                                               | -       | -                                                                                                                       |  |                    |            |                      |                 |          |  |                                |                |         |  |
| ENERGY INPUT                                                                                                                                               | -                    | -                                                                                                                                                                                                                                                                                                                                                               | -       | -                                                                                                                       |  |                    |            |                      |                 |          |  |                                |                |         |  |

POST WELD HEAT TREATMENT  
POST WELD INSPECTION METHOD  
ADDITIONAL INFORMATION

NOT REQUIRED  
TO BS 4871



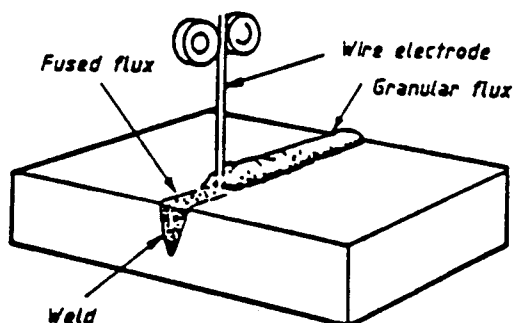
# **SENIOR WELDING INSPECTOR**

## **MIG MAG WELDING**

- Q1. Why is inductance added to the circuit during dip transfer?
- Q2. Why is CO<sub>2</sub> added to argon when welding steels?
- Q3. State the principal causes of lack of fusion defects.
- Q4. State why centreline defects may be found when using spray transfer.
- Q5. Name six (6) items of equipment which require routine maintenance.
- Q6. State four (4) typical wire sizes and their typical applications.
- Q7. State a typical gas flow rate.
- Q8. Name the four (4) types of transfer and for each give
  - a) typical amps and volts
  - b) welding positions
- Q9. Give five (5) advantages of cored wires.
- Q10. Compare the use of a C.V. output power source against a C.C.

# A 'FLAT' ARC PROCESS (CONSTANT) VOLTAGE

## SUBMERGED-ARC (SA)



### Type of Operation

Mechanised, automatic or semi-automatic.

### Mode of Operation

An arc is maintained between the end of a bare wire electrode and the work. As the electrode is melted, it is fed into the arc by a set of rolls, driven by a governed motor. Wire feed speed is automatically controlled to equal the rate at which the electrode is melted, thus arc length is constant. The arc operates under a layer of granular flux (hence 'submerged' arc). Some of the flux melts to provide a protective blanket over the weld pool; the remainder of the flux is unaffected and can be recovered and re-used provided it is dry and not contaminated.

A semi-automatic version is available in which the operator has control of a welding gun which carries a small quantity of flux in a hopper.

Typical defects associated with this process:

Porosity.

Cracking.

- Slag inclusions.

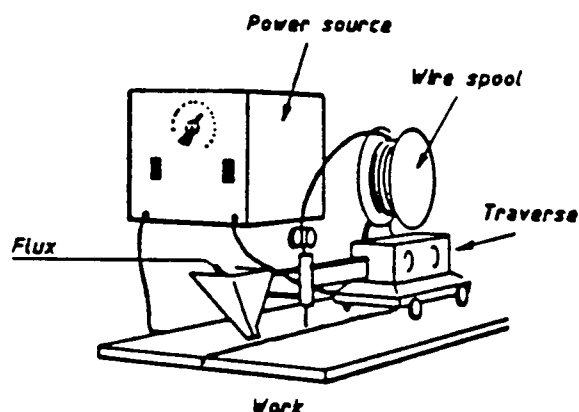
- Incomplete penetration.

Excessive penetration.

Weld profile defects.

- Undercut.

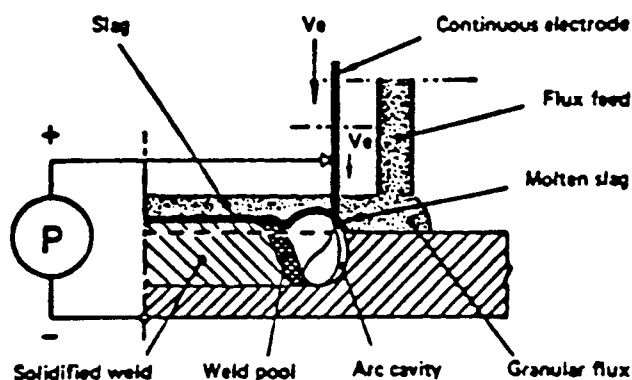
Lack of fusion.



## SUBMERGED ARC WELDING:

### PROCESS AND EQUIPMENT FUNDAMENTALS

The principle of the submerged-arc process is shown schematically below. A power source P, is connected across the contact nozzle on the welding head and the workpiece. The power source can be a transformer for AC welding or a rectifier (or motor generator) for DC welding. The filler materials are an uncoated continuous electrode and a granular welding flux fed down to the joint by way of a hose from the flux hopper. To prevent the electrode overheating at high currents the welding current is transferred to the electrode at a point very close to the electric arc. The arc is burning in a cavity filled with gas ( $\text{CO}_2$ , CO, etc) and metal fumes. In front the cavity is walled in by unfused parent material, and behind the arc by solidifying weld metal. The covering over the cavity consists of molten slag. The diagram below also shows the solidified weld and the thin covering of solid slag which has to be detached after the completion of each run.



Since the arc is completely submerged by the flux there is none of the irritating arc radiation which is so characteristic of the open arc processes; welding screens are therefore unnecessary.

The welding flux is never completely consumed and the surplus quantity left can be collected either by hand or automatically and returned to the flux hopper to be used again.

Although semi-automatic submerged-arc welding equipment exists and is convenient for certain applications, most of the submerged-arc welding carried out today makes use of fully mechanised welding equipment. Indeed, one of the main virtues of the submerged-arc process is the ease with which it can be incorporated into fully mechanised welding systems to give high deposition rates and consistent weld quality. Weld metal recovery approaches 100% since losses through spatter are extremely small. Heat losses from the arc are also quite low owing to the insulating effect of the flux bed, and for this reason the thermal efficiency of the submerged-arc process can be as high as 60% compared with about 25% for manual metal-arc (MMA) welding.

Flux consumption is approximately equal to the wire consumption, the actual ratio – weight of wire consumed: weight of flux consumed – being dependent on the flux type and the welding parameters used.

Welding parameters are maintained at their set values by the arc control unit. A feed-back system is usually used to maintain a stable arc length so that a change in the arc length – corresponding to a change in arc voltage – will produce an increase or decrease in the wire feed speed until the original arc length is regained.

### **Joint preparation**

Joint preparation depends on plate thickness, and type of joint, e.g. circumferential or longitudinal, and to some extent, on the standards to which the structure is being made.

Plates of up to 14mm thick can be butt welded without preparation with a gap not exceeding 1mm or 10% of the plate thickness, whichever is the greater. Thicker plates need preparation if full penetration is to be obtained. Variable fitup cannot be tolerated.

A welder using stick electrodes can adjust his technique to cope with varying joint gaps and root faces or varying dimensions. Not so an automatic welding head. If conditions are set up for a root gap of 0.5mm and this increases to 2 or 3mm, burnthrough will occur unless an efficient backing strip is used. In such circumstances a hand-welded root run using MIG or MMA electrodes is advisable. All plate edges must be absolutely clean and free from rust, oil, millscale, paint etc. If impurities are present and are melted into the weld, porosity and cracking can easily occur.

Time spent in minimising such defects by careful joint preparation and thorough inspection prior to welding is time well spent since cutting out weld defects and then rewelding is very expensive and time-consuming

## **Welding procedure**

In general the more severe the requirements regarding low temperature notch toughness the lower the maximum welding current that can be used to minimise heat input, which means that a multipass technique is called for. When welding stainless steels the heat input should be kept low for other reasons: stainless steel has poor thermal conductivity and a high coefficient of expansion compared with mild steel. These two effects lead to overheating and excessive distortion if large diameter wires and high currents are used. Multirun welds using small diameter wires are therefore recommended for stainless steels and high nickel alloys such as Inconel.

## **Selection of welding conditions**

Selection of the correct welding conditions for the plate thickness and joint preparation to be welded is very important if satisfactory joints free from defects such as cracking, porosity, and undercut are to be obtained. The process variables which have to be considered are:

- a. electrode polarity
- b. welding current
- c. electrode diameter
- d. arc voltage
- e. welding speed
- f. electrode extension
- g. electrode angle
- h. flux depth

These are the variables which determine bead size, bead shape, depth of penetration, and, in some circumstances, metallurgical effects such as incidence of cracking, porosity and weld metal composition.

### **a. electrode polarity**

The deepest penetration is usually obtained with DC reverse polarity (electrode +ve) which also gives the best surface appearance, bead shape, and resistance to porosity.

Direct current straight polarity (electrode -ve) gives faster burnoff (about 35%) and decreased penetration since the maximum heat is developed at the tip of the electrode instead of at the surface of the plate. For this reason DC -ve polarity is often used when welding steels of limited weldability and when surfacing since, in both instances, penetration into the parent material must be kept as low as possible. The flux/wire consumption ratio is less with electrode -ve polarity than with electrode +ve so that alloying from the flux is reduced.

In changing from electrode +ve to -ve polarity some increase in arc voltage may be necessary to obtain a comparable bead shape. Alternating current gives a result about half way between DC electrode +ve and -ve polarity. It is particularly useful when arc blow is a problem and is often used in tandem arc systems, where a DC +ve electrode is used as the leading electrode and an AC electrode as the trail.

#### b. welding current

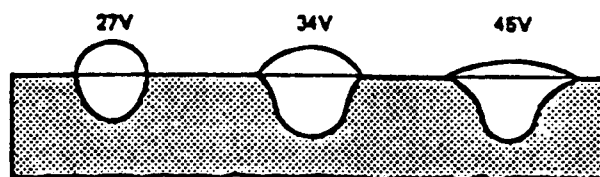
Increasing the wire feed speed increases the welding current so that the deposition rate increases as the welding current increases. The current density determines the depth of penetration: the higher the current density the greater the penetration. For a given flux, arc stability will be lost below a minimum threshold current density so that if the current for a given electrode diameter is too low arc stability is lost and a rugged irregular bead is obtained. Too high a current density also leads to instability because the electrode overheats. Undercutting may also occur.

#### c. electrode diameter

For given current, changing the electrode diameter will change the current density, which means in practice that a larger diameter will reduce penetration and the likelihood of burnthrough, but at the same time arc striking is more difficult and arc stability is reduced.

#### d. arc voltage

The effect of arc voltage is often misunderstood because it affects dilution rather than penetration. Bead-on-plate welds and square edge close butt welds (no gap) have increased width and dilution as arc voltage increases, but **depth** of penetration remains the same.



*Effect of arc voltage on bead shape*

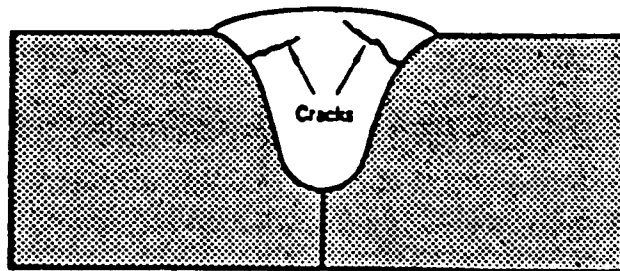
If the joint is 'open', as for example in a butt joint with rather small angled V preparation, increasing the arc voltage can decrease the penetration.

Increasing the arc voltage lengthens the arc so that weld bead width is increased, reinforcement is decreased, flux consumption is increased, and the probability of arc blow is also increased. When alloying fluxes are used arc length and hence arc voltage is very important, since at high arc voltages more flux is melted so that more alloying elements enter the weld metal. Thus arc voltage can affect weld metal composition

**e. welding speed**

Bead size is inversely proportional to welding speed. Faster speeds reduce penetration and bead width, increase the likelihood of porosity and, if taken to the extreme, produce undercutting and irregular beads. At high welding speeds the arc voltage should be kept fairly low otherwise arc blow is likely to occur.

If the welding speed is too slow burn-through can occur. A combination of high arc voltage and slow welding speed can produce a mushroom-shaped weld bead with solidification cracks at the bead sides.



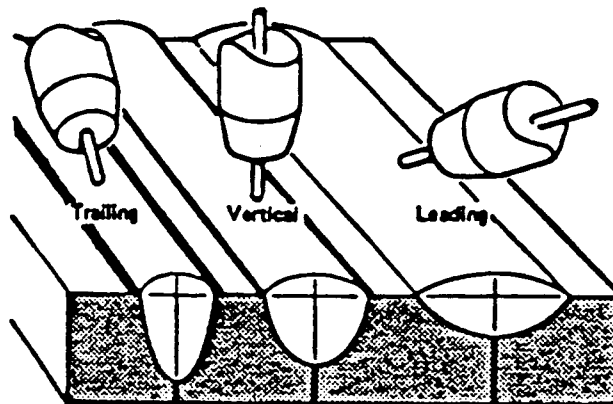
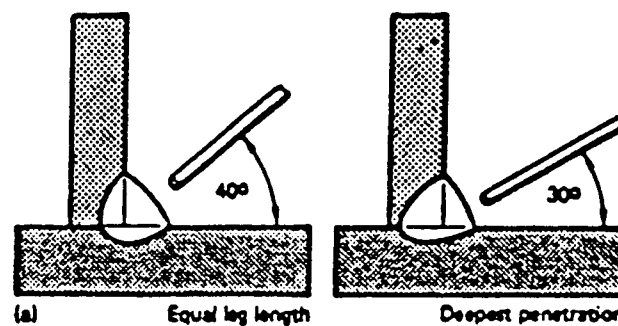
**f. electrode extension (stickout)**

Electrode extension is an important variable since it governs the amount of resistance heating which occurs in the electrode. If the extension is short the heating effect is small and penetration is deep. Increasing the extension increases the temperatures of the electrode but decreases the penetration. Deposition rate is increased. Increased extension is therefore useful in cladding and surfacing applications but steps have to be taken to guide the electrode otherwise it wanders.

For normal welding the electrode extension should be 25–30mm for mild steel and rather less, say 20–25mm, for stainless. This is because the electrical sensitivity of stainless wire is appreciably greater than that of mild steel wire.

### g. electrode angle

Since the angle between the electrode and the plate determines the point of application and direction of the arc force it has a profound effect on both penetration and undercut. The figures show the effect on horizontal/vertical fillet welds, and compare the effect obtained with a vertical arc with those obtained with leading and trailing arcs. The effect on undercutting can be particularly marked.



|                       |        |          |         |
|-----------------------|--------|----------|---------|
| Penetration:          | Deep   | Moderate | Shallow |
| Reinforcement:        | Max.   | Moderate | Min.    |
| Tendency to undercut: | Severe | Moderate | Min.    |

(b)

Effect of electrode angle: (a) H V fillet welds, (b) butt welds

#### **h. flux depth**

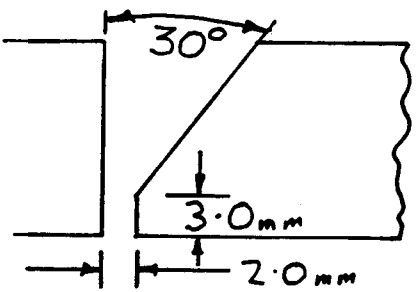
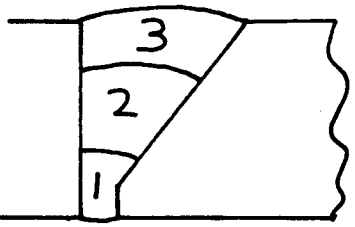
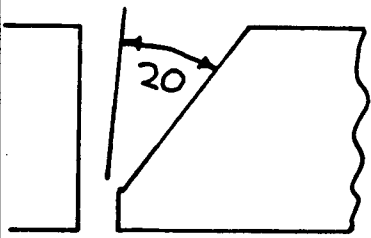
The flux burden or the depth of the flux is often ignored and the powder is simply heaped around the wire until the arc is completely covered. If optimum results are to be obtained the flux depth should be just sufficient to cover the arc, although at the point where the electrode enters the flux bed light reflected from the arc should just be visible. Too shallow a flux bed gives flash-through and can cause porosity because of inadequate metallurgical protection of the molten metal. Too deep a flux bed gives a worse bead appearance and can lead to spillage on circumferential welds. On deep preparations in thick plate it is particularly important to avoid excessive flux depth otherwise the weld bead shape and slag removal can be unsatisfactory.

#### **Strip cladding**

Although most applications of the submerged arc process make use of single – or multiwire systems using round wires, electrodes in the form a strip are often used for cladding purposes. Strips are usually 0.5mm thick, the commonest strip width being 60mm, but wider strips, e.g. 100mm can be used without any loss of quality. The big advantage of strip cladding is that penetration is low, particularly with DC electrode –ve polarity, and deposition rate is relatively high. Modern fluxes designed for strip cladding have greater current tolerance than earlier types and use of currents of up to 1200A with austenitic stainless steel strips gives deposition rates of up to 22mg/hr with DC electrode +ve polarity. Inconel can also be deposited and, provided the flux is low silica type and the Inconel strip used contains 2–3%Nb, good quality crack-free deposits can be obtained. Monel, aluminium bronze, nickel, and 13%Cr strips have also been successfully used as strip cladding electrodes. Good electrical contact between the strip and feed nozzle is essential.

# WELDING PROCEDURE SHEET SUBMERGED ARC

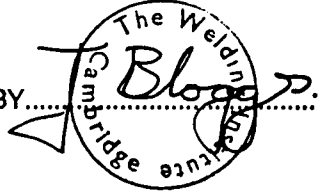
**JOB TITLE** BUTT WELD FOR DRAWING REF A153

|                                                                                                                    |          |                                                                                                                                   |                       |                                                                                                                       |  |
|--------------------------------------------------------------------------------------------------------------------|----------|-----------------------------------------------------------------------------------------------------------------------------------|-----------------------|-----------------------------------------------------------------------------------------------------------------------|--|
| DATE 00-00-00                                                                                                      |          | REFERENCE NO. SW14                                                                                                                |                       | PROCEDURE NO. 4                                                                                                       |  |
| <b>PARENT MATERIAL DETAILS</b><br>SPECIFICATION BS4360 GRADE 500<br>COMPOSITION<br>THICKNESS 15.0mm                |          | <b>CONSUMABLE DETAILS</b><br>TRADE NAMES ESAB WIRE FLUX 10.40<br>AUT ROD 12.10<br>SPECIFICATION BS 4165 S M 12 K<br>DIAMETER 3.25 |                       |                                                                                                                       |  |
| <b>SKETCH OF PREPARATION</b><br> |          | <b>SKETCH OF RUN SEQUENCE</b><br>                |                       | <b>ELECTRODE CONFIGURATION</b><br> |  |
| FLUX DRYING TEMP + TIME 150°C 1 hr                                                                                 |          |                                                                                                                                   | STORAGE TEMP. 60°C    |                                                                                                                       |  |
| ROOT RUN PROCESS SUBMERGED ARC                                                                                     |          |                                                                                                                                   | WELDING POSITION FLAT |                                                                                                                       |  |
| PREHEAT TEMP. 100°C                                                                                                |          |                                                                                                                                   | INTERPASS TEMP. 200°C |                                                                                                                       |  |
| <b>WELDING CONDITIONS</b>                                                                                          |          |                                                                                                                                   |                       |                                                                                                                       |  |
| RUN NO.                                                                                                            | 1        | 2                                                                                                                                 | 3                     |                                                                                                                       |  |
| ELECTRODE NO.                                                                                                      | 12.10    | 12.10                                                                                                                             | 12.10                 |                                                                                                                       |  |
| WIRE DIAMETER                                                                                                      | 3.25     | 3.25                                                                                                                              | 3.25                  |                                                                                                                       |  |
| ELECTRODE EXTENSION                                                                                                | 30mm     | 25mm                                                                                                                              | 25mm                  |                                                                                                                       |  |
| AC DC +/-                                                                                                          | DC+      | DC+                                                                                                                               | DC+                   |                                                                                                                       |  |
| CURRENT                                                                                                            | 250      | 250                                                                                                                               | 300                   |                                                                                                                       |  |
| VOLTAGE                                                                                                            | 22       | 22                                                                                                                                | 23                    |                                                                                                                       |  |
| TRAVEL SPEED mm/min                                                                                                | 330      | 350                                                                                                                               | 414                   |                                                                                                                       |  |
| ENERGY INPUT Kj/mm                                                                                                 | 1.0Kj/mm | 1.0                                                                                                                               | 1.0                   |                                                                                                                       |  |

INTER RUN CLEANING OR GOUGING  
 POST WELD HEAT TREATMENT  
 POST WELD INSPECTION METHOD  
 ADDITIONAL INFORMATION

CHIP & BRUSH  
 NOT REQUIRED  
 AS PER STANDARD

Form PW 3/2

COMPILED BY.....  


## QUESTIONS:

### SUBMERGED ARC WELDING (SAW)

- Q1      What are the welding parameters in SAW?
- Q2      State three (3) items which control weld metal composition in SAW.
- Q3      State three (3) items of a flux which require inspection.
- Q4      State two (2) types of a flux used in SAW and give brief details of recognition.
- Q5      Give an advantage and application for each of the following power types
- a)      DCVe +
  - b)      DCVe –
  - c)      AC

# **SENIOR WELDING INSPECTOR**

## **SUBMERGED ARC WELDING**

- Q1. State typical welding parameters for the process.
- Q2. State the AWS specification for submerged arc consumables.
- Q3. How would arc voltage affect
  - a) penetration
  - b) weld metal composition
- Q4. Describe briefly the basis of wire composition as defined in BS 4165.
- Q5. Submerged arc welding may use a "flat" or drooping amps volt characteristic.
  - a) Explain briefly the principles of each method
  - b) Give the main reason for selection.
- Q6. During circumferential welding how significant is the welding head position in relation to the joint.
- Q7. Define the term "basicity" with reference to submerged arc fluxes.
- Q8. How important is the electrode wire in relation to the centreline of the joint.
- Q9. State the polarity used for surfacing techniques and typical tip to work distances.
- Q10. Long question: During submerged arc welding tee fillet welds in the H.V. position, undercut is a common occurrence, comment.

## **CALIBRATION OF WELDING EQUIPMENT**

Instrumentation fitted to arc welding equipment often becomes inaccurate through neglect, damage, wear, etc. The presence of errors in the readings may remain unknown and their extent unchecked. As a result, the values of the welding parameters indicated may lie well outside the working tolerances. Consequently problems may be experienced in achieving the desired weld quality. A significant level of rejects may be predicted with consequential costs of reworking, repair or even scrapping.

In high quality welding, regular checking of the parameters is therefore essential and should form a mandatory part of Inspection/Quality Assurance.

There are many different types of calibration equipment available, including Ammeters, Voltmeters or equipment specially designed to measure all the welding parameters.

Whatever the type of calibration piece used, they also must be calibrated for accurate measurement (usually to a National Standard).

### **CHECKLIST FOR CALIBRATING ARC WELDING EQUIPMENT**

#### **Welding Current:**

Is the main parameter controlling heat input and penetration.  
Check with Ammeters for inaccuracies.

#### **Arc voltage:**

Which is related to arc length and responsible for the weld bead profile.  
Check with Voltmeter across the electrical circuit for inaccuracies.

#### **Wire Feed Speed:**

The most important parameter in MIG/MAG and submerged arc welding. It determines the welding current being drawn to a) melt the wire and b) fuse the workpiece.

Check with stopwatch of 15 – 30 secs or preferably with tachogenerator for inconsistency and inaccuracies.

**Travel speed**

(Mechanised):

Determines heat in-put penetration.

Pre-set travel speed and check meter against length of distance travelled in one minute.

(Manual)

Run out length

In recent years more attention has been given to Quality Assurance in arc-welding operations and in many cases it is of paramount importance to ensure that the correct welding parameters are being used in order to meet these requirements. Accurate calibration of the equipment therefore is necessary and "certificates of calibration" are required for all equipment,

i.e.      **welding equipment**  
            **measuring equipment**  
            **storage ovens, etc.**

## QUESTIONS

### CALIBRATION OF WELDING EQUIPMENT

- Q1      You have been asked to calibrate the output of a welding power source; indicate the tolerance that would be expected on amperage and voltage readings.
- Q2      How is this tolerance achieved and what standard would you work to?
- Q3      When checking the welding parameters for MIG/MAG and MMA, from what position in the circuit would the most accurate readings be taken?
- Q4      Is wire feed speed considered more accurate than amperage? Give reasons.
- Q5      What is the British Standard for arc welding equipment?

## RESIDUAL STRESS AND DISTORTION

### RESIDUAL STRESSES

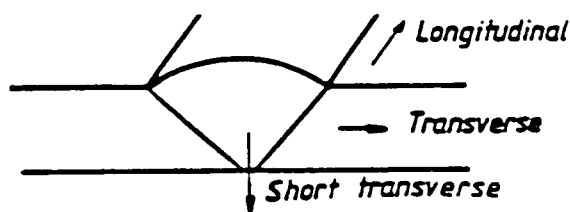
Metals contract during solidification and subsequent cooling, but if this contraction is prevented or inhibited, residual stresses will develop. Most metal products contain residual stresses, often up to the yield point. Pipe products for example are usually very highly stressed.

The tendency to develop residual stresses increases when the heating and cooling are localised. So welding with its very localised heating and the presence of liquid and solid metal in contact can be expected to induce very high levels of residual stresses.

Residual stresses can be difficult to measure with any real accuracy, but a rough guide is that when the weld metal exceeds 2in<sup>3</sup> (14cm) then the total residual stress is about yield point in magnitude.

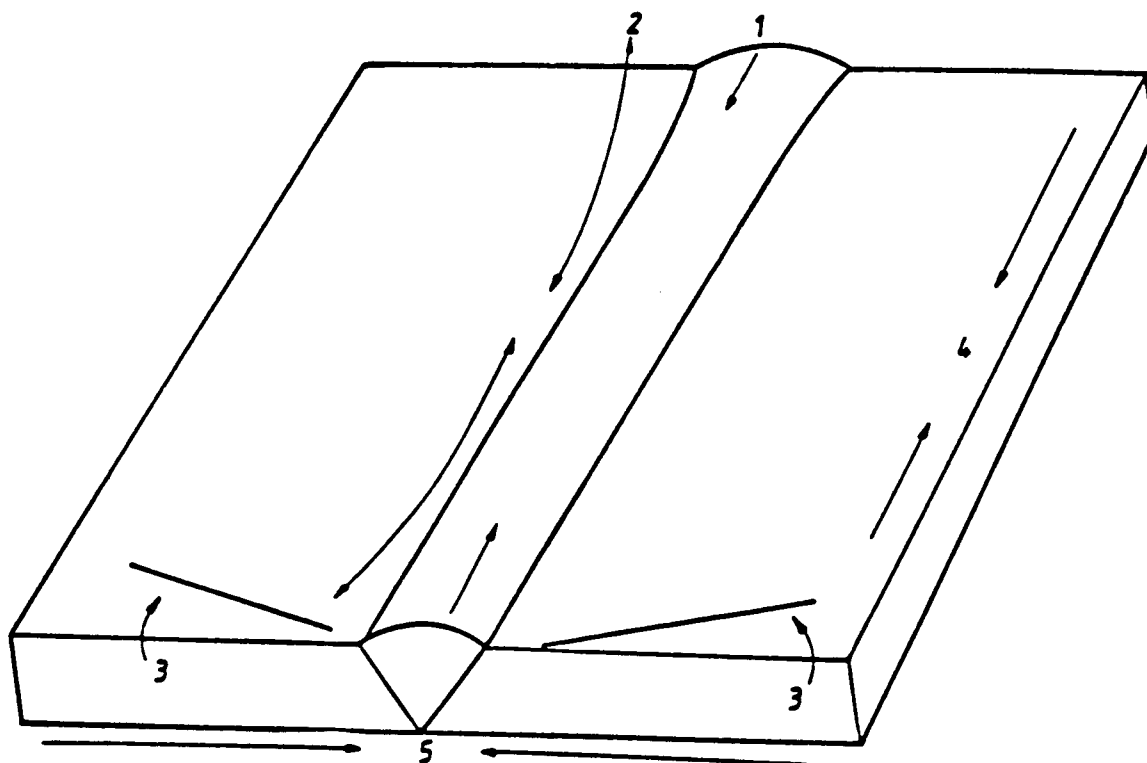
Normal welds develop residual stresses:

- a) along the weld – longitudinal residual stresses
- b) across the weld – transverse residual stresses
- c) through the weld – short transverse residual stresses



## DISTORTION

The action of the residual stresses in welded joints is to cause distortion. Consider a simple weld with a single V preparation.



The following movements can be detected:

1. Contraction in the weld metal and HAZ along the length.
2. Bowing – due to the greater volume of metal at the top of the weld.
3. Peaking due to the V angle.
4. Ripple (in sheet) away from the weld.
5. Contraction in the weld metal and HAZ transverse to the weld.

Control of distortion is achieved in one or more of three ways:

1. Presetting – so that the metal distorts into the required position.
2. Clamping – to prevent distortion, but this increases the level of residual stresses.
3. Welding sequence, i.e. balanced.

## QUESTIONS

### RESIDUAL STRESS AND DISTORTION

- Q1      What causes residual stress in welds?
- Q2      Name the three (3) directions in which residual stresses form in a weld.
- Q3      What kinds of distortion result from each direction of residual stress?
- Q4      State two (2) methods of controlling distortion.
- Q5      How can residual stresses be reduced?

# **SENIOR WELDING INSPECTOR**

## **RESIDUAL STRESS AND DISTORTION**

- Q1. What is the principal reason for the development of residual stresses in metals?
- Q2. What would be the expected level of welding residual stresses in a structural detail of a butt weld between I beam flanges 10in. x 1in. (250 x 25mm) in section?
- Q3. Give a simple account of the development of transverse residual stresses.
- Q4. What is the effect of restraint on residual stresses?
- Q5. Apart from weldments name two other metal products which can be expected to contain high levels of residual stresses.
- Q6. What causes distortion in welded products?
- Q7. Name four (4) directions in which distortion may occur.
- Q8. Explain why the edges of sheet sometimes close up and overlap during welding.
- Q9. When fitting a patch of any size into a plate it is often predished; give a simple explanation of this.
- Q10. During the welding of a pipe 100 $\phi$  X 10, a reduction in the diameter on each side of the weld is observed. A single V preparation was used. Explain why this reduction has occurred and suggest an edge preparation which would minimise the problem. Give an alternative method of avoiding the reduction in diameter.

# WELDABILITY

## Introduction

As a result of the heat input to which the steel is exposed in any form of welding the material undergoes certain changes, some of which are permanent. Amongst these changes are structural transformation during heating and cooling and changes in shape or size due to the thermal stresses. A steel which can be welded without any dangerous consequences resulting from these changes is said to possess **good weldability**. If, on the other hand, the changes due to a normal welding process are in serious danger of causing failure in a welded component, or if actual defects such as cracking occur during welding, the steel is said to possess **limited weldability** and can in most cases be welded, without risk, provided certain precautions are taken or certain pre- or post-welding treatments carried out. The term 'unweldable steels' is unrealistic. Any steel can be welded provided correct metallurgical conditions are chosen. Sometimes, however, these conditions may be impossible to realise in practical production work.

## Weldability of steel

Weldability is a function of many inter-related factors but these may be summarised as :

1. Composition of parent plate
2. Joint design and size
3. Process and technique

## Influence of process

Each process will give a characteristic intensity of power. Processes which offer the higher power intensity offer advantages in fusion welding because the essential melting can be obtained without excessive heat inputs with the consequent thermal expansion of the parent metal.

Successful welding often depends on feeding into the weld pool a filler wire which carries a deoxidant (or ferrite forming elements) hence processes which do not use filler wires are limited in application.

## **Influence of composition**

The composition of the steel and its effect on weldability may be divided into two parts:

### **1. Segregation effects, particularly that of sulphur**

When a steel solidifies, there is a tendency for the iron to solidify fast and for the alloying elements to be accumulated in the centre of the ingot. This configuration is retained even after prolonged and severe rolling and results in high concentrations of sulphur in the central layers of the plate. These layers have little strength and are likely to crack if stressed.

### **2. The tendency of the steel to harden**

The hardening characteristics of steel will be mentioned in the heat treatment session. As the carbon or alloy content of the steel increases, the likelihood of low ductility, hardened microstructures forming also increases and should stresses exist cracking will result.

## **TYPICAL WELDABILITY DEFECTS**

### **1. SOLIDIFICATION CRACKING**

Caused by sulphur from the parent material. During the solidification of the weld metal one is left with thin iron sulphide films between the solidifying grains which possess very little tensile strength – cracking results.

### **2. HYDROGEN CRACKING (under bead cracking/hard zone cracking)**

This phenomenon can occur during the welding of hardenable ferritic steels. Factors involved:

- 1. hardness**
- 2. stress**
- 3. temperature**
- 4. hydrogen level**

### **3. LAMELLAR TEARING**

is a problem involving poor "through thickness" ductility and visually occurs in tee or corner joints in thick ferritic steels where high shrinkage strains act through the plate thickness in combination with parent metal inclusions. A "step-like" crack may occur.

### **4. WELD DECAY IN AUSTENITIC STAINLESS STEELS**

Occurs in the HAZ due to the precipitation of chromium carbides at the grain boundaries resulting in a chromium deficiency in the grains themselves. Because of the loss of chromium, corrosion resistance is lost – "rusting" results.

## QUESTIONS

### WELDABILITY

- Q1 List the four (4) general factors which must be assessed to determine the level of preheat.
- Q2 List three (3) types of cracks found in weldments and their causes.
- Q3 In which type (composition) of steel is weld decay experienced?
- Q4 How can the level of hardness in the heat affected zone (H.A.Z.) be controlled.
- Q5. Describe the full heat treatment requirement required for ensuring that basic electrodes are low in hydrogen.

# SENIOR WELDING INSPECTOR

## LIQUATION CRACKING

Weld metal solidification cracking in its worst form occurs as a longitudinal centreline defect. In less severe cases the crack may be intermittent and if the principal direction of strain is longitudinal to the weld, the cracks may be transverse to the weld. Finishing craters are common points at which to observe solidification cracks.

A related phenomenon due to the presence of grain boundary liquid films can occur in the heat affected zone, i.e. in the parent metal immediately adjacent to the fusion boundary or in previously deposited weld metal. Where such grain boundary melting occurs it is known as liquation and if thermal strain is sufficient, such films can rupture and produce liquation cracks. A pre-requisite for this, is the existence of a segregated micro structure with low melting point material situated at the grain boundaries. For example, in ferritic steels high sulphur levels result in such susceptibility particularly when the welding process involves high heat input such as electro slag. The phenomenon in this case is known as "burning".

Copper from contact tips or return clamps may also cause this particular problem.

## RE-HEAT CRACKING

If, for some metallurgical reason, grain deformation and grain boundary sliding cannot occur, cracking can result. If such cracking occurs with high stresses at high temperatures in short times it is known as stress relief cracking and if it occurs with lower stress and temperatures in long times it is known as creep cracking. Re-heat cracks can occur in either weld metal or heat affected zones and are generally associated with geometrical stress concentrations or small defects, thus it is possible for re-heat cracks to form in the weld metal originating from the root of a partial penetration weld or in the parent metal from the change of shape at the toe of a fillet weld or from small hot cracks in the same region which have resulted from liquation. The problem is at its worst in heavy section structural steels and in steels which have been allowed to give high creep strength such as  $\frac{1}{2}\text{Cr}$   $\frac{1}{2}\text{Mo}$   $\frac{1}{4}\text{V}$ ,  $\frac{1}{2}\text{MoB}$  and  $2\frac{1}{4}\text{CrMo}$ .

To avoid the problem the heat treatment procedure must be carefully controlled and certain other precautions taken. Amongst the precautions which are often worthwhile are the avoidance of unnecessary geometrical stress concentrations such as partial penetration nozzle welds, the use of the lowest hot strength of weld metal consistent with the performance required, the avoidance of materials which suffer from liquation and grinding of the toes of fillet welds prior to heat treatment. The heat treatment itself involves control of the rate of heating, the maximum temperature and the time at temperature according to steel composition and thickness.

# **SENIOR WELDING INSPECTOR**

## **WELDABILITY (Fe STEELS)**

### **SOLIDIFICATION CRACKING**

- Q1. What is the usual cause of centreline cracking?
- Q2. State two (2) elements which cause centreline cracking.
- Q3. Briefly describe the cause of solidification cracking.
- Q4. Why does solidification cracking usually occur in the centre of weld metal?
- Q5. State four (4) methods of minimising solidification cracking.

### **SOLIDIFICATION PIPE**

- Q1. Give three (3) reasons why pipe may form in the weld metal.
- Q2. Give three (3) reasons which contribute to premature freezing of the weld pool surface.
- Q3. Explain why the depth to width ratio of the bead is important.
- Q4. Explain why narrow necked weld beads contribute to the formation of weld metal pipe.
- Q5. When products which have been welded without problems start to show centreline pipe, what would be the most likely variables to have gone off target?

### **WELD METAL CRACKING**

- Q1. In which steels can it be expected that hydrogen induced cracking is found in the weld metal if present at all.
- Q2. Explain why the quality of the parent plate may affect the incidence of weld metal cracking.
- Q3. Explain why the position of the joint within a structure may affect the incidence of weld metal cracking.
- Q4. With reference to typical head shapes explain why weld metal/heat affected zone/parent metal cracking may be linked in submerged arc weldments.
- Q5. State four (4) mechanisms of cracking which may be found in the weld metal of ferritic steel weldments.

## Weldability (Fe steels) Continued/2

### HYDROGEN INDUCED CRACKING

- Q1. State the four (4) factors which give rise to hydrogen cracking.
- Q2. Why are hydrogen cracks in the weld metal positioned across the width of the weld?
- Q3. What are the factors which give rise to hydrogen cracking in alloyed steels?
- Q4. How do residual stresses influence the position and orientation of hydrogen cracks?
- Q5. State three (3) items which may contribute to excessive hardness in a weldment.

### REHEAT CRACKING

- Q1. What is the normal method of avoiding reheat cracking in weldments?
- Q2. State an alternative method of avoiding reheat cracking and note a possible consequence.
- Q3. Why is grain size critical in the formation of reheat cracks?
- Q4. Where do reheat cracks normally form in weldments?
- Q5. What kinds of steel are subject to reheat cracking?

# SENIOR WELDING INSPECTOR

## WELDABILITY (STAINLESS STEELS)

- Q1. State the main weldability problem of the Fe11%Cr steels.
- Q2. Why are ferritic SS not generally suitable for welding?
- Q3. Why are some stainless steels stabilised – which elements are used for this?
- Q4. Name two (2) methods of avoiding hydrogen cracking in martensitic stainless steels.
- Q5. State three (3) methods of avoiding weld decay.
- Q6. State two (2) weldability problems connected with austenitic stainless steel.
- Q7. Why are austenitic electrodes sometimes used for welding carbon–manganese steels?
- Q8. Outline the metallurgical features of weld decay.
- Q9. Why are backing gases often specified when welding stainless steel?
- Q10. When welding stainless steel, large root gaps are often specified. Why?

## HEAT TREATMENT

Many metals must be given heat treatment before and after welding. The inspector's function is to ensure that the treatment is given and given correctly, to the details supplied.

Below are the types of heat treatment available. The temperatures mentioned are for steels.

| Process              | Temperature | Cooling                                   | Result                                                                                                                                                                   |
|----------------------|-------------|-------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Annealing:           | 920°C       | hold, furnace cool                        | improves ductility<br>decreases toughness<br>makes bending, etc easier<br>lowers yield stress                                                                            |
| Normalising:         | 920°C       | hold, air cool                            | relieves internal stress<br>improves mechanical properties<br>increases toughness                                                                                        |
| Quench, harden:      | 920°C       | hold, quench cool                         | hardens carbon steels<br>prevents carbide precipitation in austenitic steels<br>prevents temper brittleness when cooling after tempering<br>prepares metal for tempering |
| Temper:              | 550–700°C   | hold, air cool                            | increases toughness of quenched steels                                                                                                                                   |
| Stress relief:       | 550–700°C   | hold, air cool                            | relieves residual stresses<br>improves stability during machining<br>reduces hydrogen levels<br>prevents stress corrosion cracking                                       |
| Preheat for welding: | 50–250°C    | hold during welding, exceptionally higher |                                                                                                                                                                          |

N.B. This may be overall or local.

The inspector, in general, should ensure that:

- a) Equipment is as specified
- b) Equipment is in good condition, i.e. temperature control
- c) Procedures as specified is being used

e.g. Method of application  
Rate of heating and cooling  
Maximum temperature  
'Soak time'  
Temperature measurement (and calibration)

**DOCUMENTATION AND RECORDS.**

## QUESTIONS

### HEAT TREATMENT OF WELDMENTS

- Q1      Give the names of four (4) heat treatments which may be applied to steel weldments.
- Q2      State the maximum temperatures used when heat treating weldments.
- Q3      What temperature is used for tempering weldments?
- Q4      What is the objective of NORMALISING?
- Q5      Which heat treatment is used when maximum toughness is required?

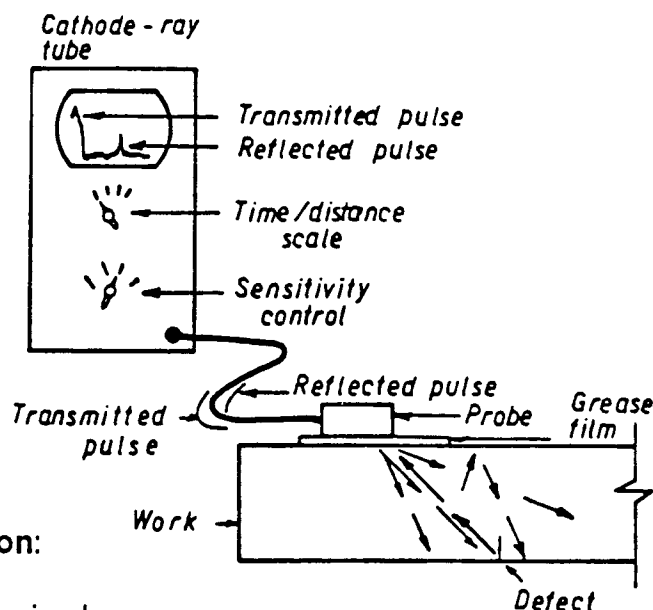
# SENIOR WELDING INSPECTOR

## HEAT TREATMENTS

- Q1. What is the objective of quenching?
- Q2. State two (2) results which may be expected from stress relief of welded products.
- Q3. State two (2) types of cracking which can result from heat treatment.
- Q4. What is the cause of temper-embrittlement? (Give time-temperature conditions).
- Q5. What is the temperature range for stress relief of carbon and carbon-low alloy steels?
- Q6. What would be the result of using temperatures of 1300°C in heat treatment?
- Q7. State the **objectives** of the following heat treatments:
- a) Normalising
  - b) Full stress relief
  - c) Tempering
  - d) Welding stress relief
- Q8. Why are components and structures welded at maximum temperature for long periods, i.e. high heat input – subject to a loss of toughness?
- Q9. A 2in. thick steel is to be butt welded and the welding engineer advises a preheat of 150°C in conjunction with the process parameters being used
- a) Show on a sketch the minimum area/zone of heating
  - b) How would the temperature be assessed?
- Q10. Why is PWHT often specified for low alloy steels (i.e. 1.0%Cr + 1%Mo)?

## NON DESTRUCTIVE TESTING

### Ultrasonic Inspection



**Type of operation:**

Manual or mechanised

**Equipment:**

Main unit containing pulse generator, display oscilloscope, probe (chosen to suit work).

**Mode of operation:**

A pulse of electrical energy is fed to the probe in which a piezo-electric crystal converts it to mechanical vibrations at an ultrasonic frequency. The vibrations are transmitted (via a layer of grease to exclude the air) through the work: if they encounter a defect some are reflected back to the probe, where they regenerate an electrical signal. A cathode ray tube trace is started when the original signal is sent, displays the reflected defect signal, and from it time, indicating distance from probe, and amplitude, indicating defect size, can be calculated.

**Materials:**

Most metal, except those with coarse or varying grain structure.

**Overall advantages:**

Immediate presentation of results  
No need to move personnel out  
Can be battery powered  
Depth locations of defects.

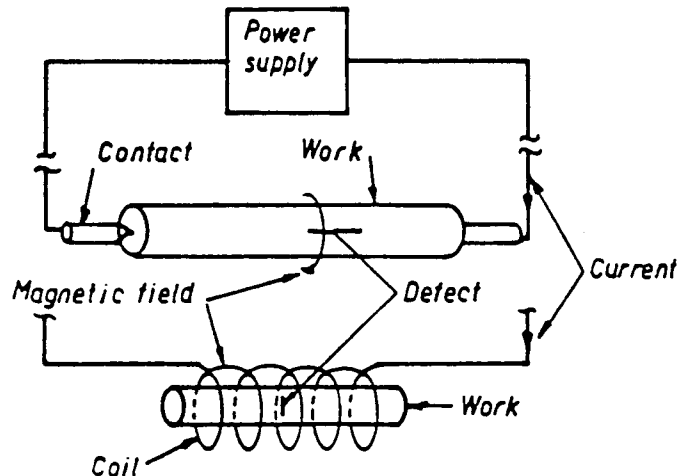
**Overall limitations:**

Trained and skilled operator required  
No pictorial record

**Safety**

Moderate care needed as for other electronic equipment.

## Magnetic particle Inspection



### Type of operation:

Manual or mechanised.

### Equipment:

Power supply  
 Contacts or coil  
 Ultra-violet lamp (optional)  
 Portable or fixed installation.

### Mode of operation:

The work is magnetised either by passing a current through it, or through a coil surrounding it. Defects on or near the surface disrupt the magnetic field (unless they are parallel to it). A magnetic particle fluid suspension is applied which concentrates around the defects. The work is viewed either directly or by ultra-violet lights using a dye which fluoresces; that is, emits visible light (this must be done where normal lighting is subdued). After testing, work may be demagnetised if required.

### Materials:

Magnetic materials only  
 Ferritic steels  
 Some nickel alloys

**Overall advantages:**

Direct indication of defect location  
Initial inspection by unskilled labour (go or no-go)  
Some indication of sub-surface defects but of low sensitivity  
Not critically dependent on surface condition.

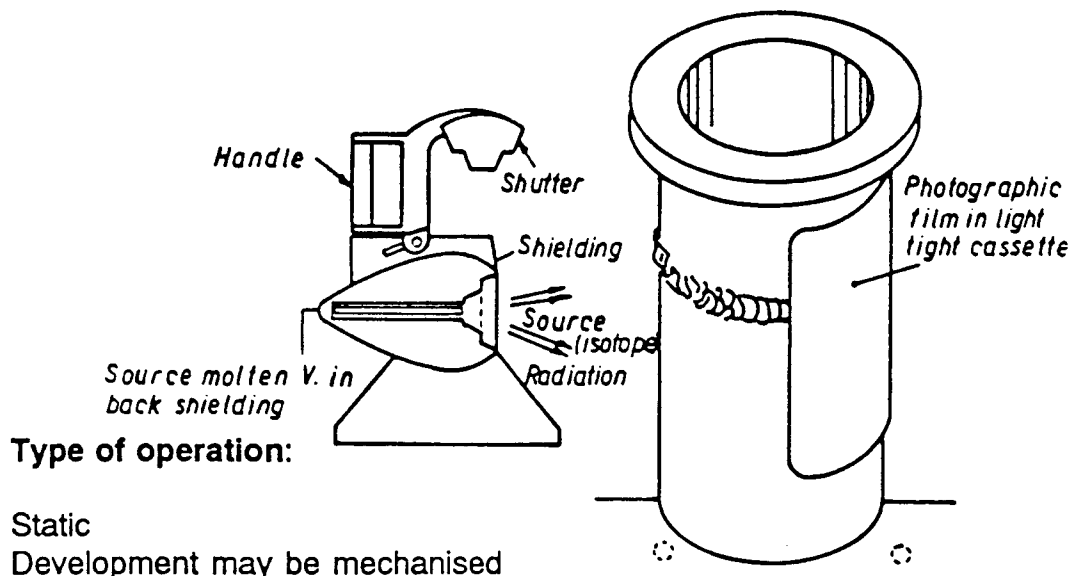
**Overall limitations:**

No use for non-magnetic materials  
Defect detection critically dependent on alignment across magnetic field  
Sub-surface flaws require special procedures.

**Safety:**

Moderate care needed in handling electric equipment and flammable fluids.

## Gamma radiography



### Equipment:

- Radioactive isotope in storage container
- Remote handling gear
- Lightproof cassette
- Photographic development facilities
- Darkroom and illuminator for assessment

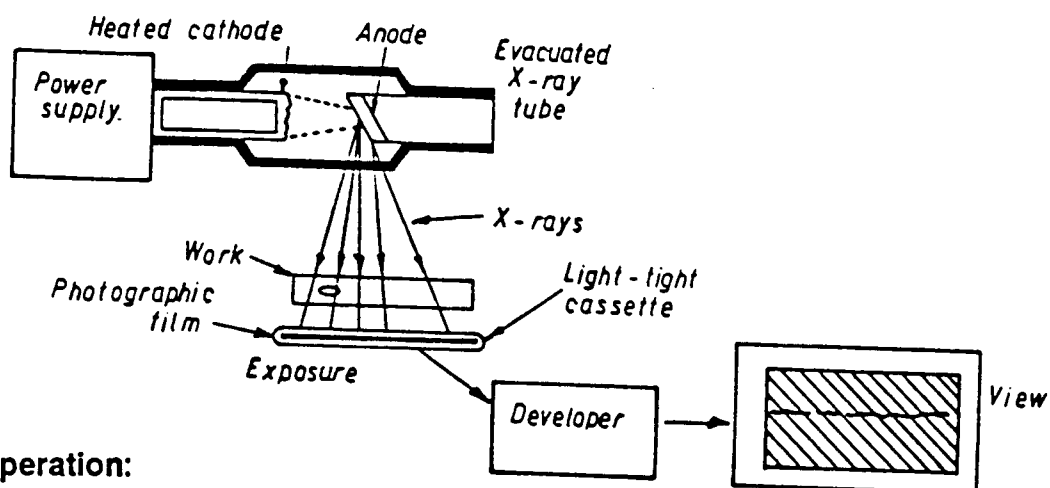
### Mode of operation:

Gamma-rays, similar to X-rays, but of shorter wavelength are emitted continuously from the isotope: it cannot be 'switched off', so that when not in use it is kept in a heavy storage container which absorbs radiation. They pass through the work to be inspected. Parts of the work presenting less obstruction to gamma-rays, such as cavities or inclusions, allow increased exposure of the film. The film is developed to form a **radiograph** with cavities or inclusions indicated by darker images. Section thickness increases (such as weld) appear as less dense images.

### Materials:

Most weldable metals may be inspected.

## X-radiographs



### Type of operation:

Static or transportable.

### Equipment:

X-ray tube  
Stand and control gear  
Light-proof cassette  
Photographic development facilities  
Dark room and illumination for assessment.

### Mode of operation:

X-rays are emitted from the tube and pass through the work to be inspected. Parts of the work presenting less obstruction to X-rays, such as cavities or inclusions, allow increased exposure of the film. The film is developed to form a **radiograph** with cavities or inclusions indicated by darker images. Section thickness increases (such as weld under-bead) appear as less dense images.

### Materials:

Most weldable metals may be inspected.

**Overall advantages:**

Accurate pictorial presentation of results  
Radiographs may be kept as a permanent record  
Not confined to welds

**Overall limitations:**

Personnel must be clear of area during exposure  
Cracks parallel to film may not show up  
Film expensive.



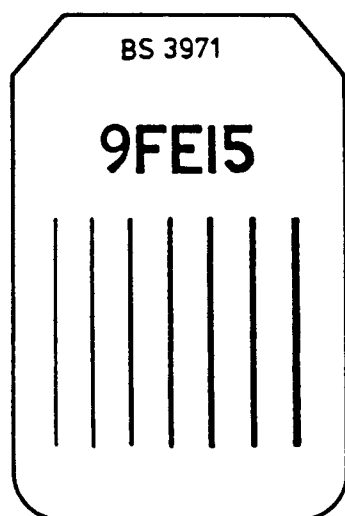
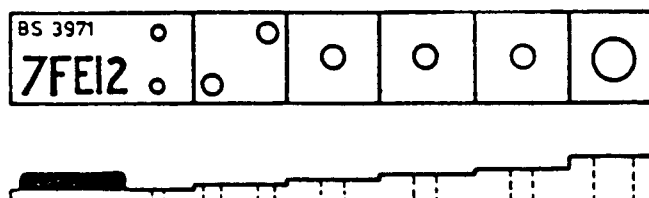
INTERNATIONAL  
RADIATION WARNING SYMBOL

**Safety:**

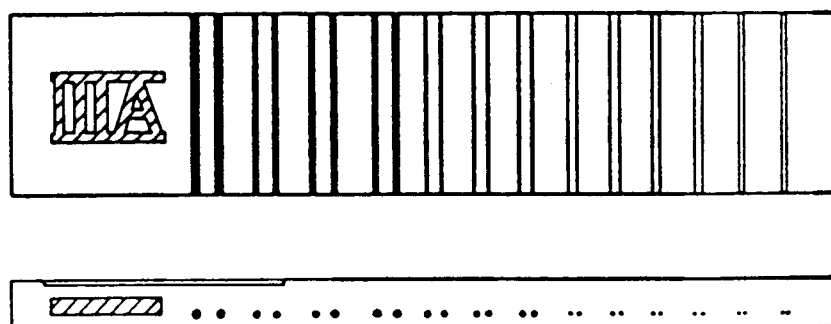
Cumulative radiation risk to personnel requires stringent precautions.

## EXAMPLE OF IMAGE QUALITY INDICATORS

### Step-hole type

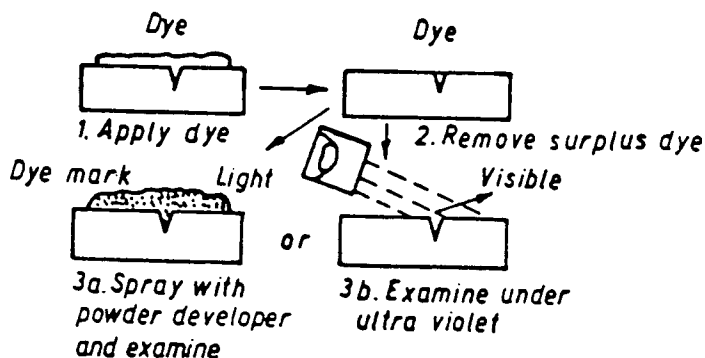


### Wire type



### Duplex type

## Dye penetrant detection



### Type of operation:

Manual or mechanised

### Equipment:

Min: Aerosols containing dye, developer etc.  
 Max: Tanks – work handling gear (in some cases ultra-violet lamp).

### Mode of operation:

A special dye is applied to the surface of the article to be tested. An interval of 1–10 min allows it to soak into any surface defects. The surface is then freed from surplus dye and the dye in the crack revealed by either:

- applying a white powder developer into which the dye is absorbed producing a colour contrast indication, or
- illuminating with ultra-violet light under which the dye fluoresces; that is, emits visible light. This must be done where normal lighting is subdued.

**Materials:**

Any

**Overall advantages:**

Low cost

Direct indication of defect location

Initial examination by unskilled labour (go or no go).

**Overall limitations:**

Surface defects only detected

Defects cannot readily be rewelded due to entrapped dye. Rough welds produce spurious indications.

**Further reading:**

Non-destructive testing

General Dynamics

Convair Div

San Diego

Calif

USA (1967)

**Safety:**

Low flash point dye and propellant gases.

## **QUESTIONS**

### **NON-DESTRUCTIVE TESTING**

- Q1      Name four (4) NDT methods
- Q2      State the two types of rays used in radiography and a limitation of each.
- Q3      What process uses mechanical vibrations to detect defects?
- Q4      Name a limitation of MPI.
- Q5      What is the main limitation of using the 'dye' method of inspection?

# **SENIOR WELDING INSPECTOR**

## **NON DESTRUCTIVE TESTING**

Generally scrutinise the following NDT Reports.

Answers follow Report.

WELD TEST REPORT: ULTRASONICS

NAME AND ADDRESS OF INSPECTING COMPANY: CAMBRIDGE NDT SERVICES

ABINGTON HALL, CAMBS.

WORK LOCATION: ABINGTON

DATE OF TEST: 10.08.91

REPORT REFERENCE NO: 3214-2

SHEET 1 OF 1 SHEETS

WELD IDENTIFICATION: 3324-1

MATERIAL: LOW CARBON STEEL

WALL THICKNESS: 25mm

TYPE OF JOINT: SINGLE VEE BUTT PLATE

WELD PROCESS: MMA FILL/TIG ROOT

WELD PREPARATION: 60° INCLUDED ANGLE

EXCESS WELD METAL: AS WELDED

2mm ROOT FACE

2mm ROOT GAP

ULTRASONIC TEST INFORMATION

ULTRASONIC FLAW DETECTOR: KRAUTKRAMER USM 2 - Serial No K021

| PROBES       | TYPE | SIZE      | FREQUENCY | ANGLE | SCANNING PROCEDURE                          |
|--------------|------|-----------|-----------|-------|---------------------------------------------|
| Twin comp    |      | 10mm dia. | 5MHz      | 0°    |                                             |
| Single shear |      | 10mm dia. | 5MHz      | 45°   | In accordance with<br>code or specification |
| Single shear |      | 10mm dia. | 5MHz      | 60°   |                                             |
| Single shear |      | 10mm dia. | 5MHz      | 70°   |                                             |

SENSITIVITY SETTING:

TWIN COMPRESSION SCAN - SECOND BACK WALL ECHO AT F S H

SINGLE SHEAR SCAN ANGLE - ECHO FROM 1.5MM DIA. HOLE AT MAXIMUM RANGE SET  
TO FULL SCREEN HEIGHT PLUS 2-4dBs TRANSFER LOSS

CALIBRATION PROCEDURE: TIME BASE CALIBRATED TO 100mm RANGE ON V2 CAL BLOCK

SPECIFICATION OR CODE:

REPORT

ACCEPTABLE TO SPECIFICATION

NAME ..A N OTHER..  
SIGNATURE *A. N. Other*  
DATE 12-8-91

WELD TEST REPORT: ULTRASONICS

NAME AND ADDRESS OF INSPECTING COMPANY: CAMBRIDGE NDT SERVICES

ABINGTON HALL, CAMBS.

WORK LOCATION: ABINGTON

DATE OF TEST:

REPORT REFERENCE NO: 3214-1

SHEET 1 OF 1 SHEETS

WELD IDENTIFICATION: 3324-2

MATERIAL: MILD STEEL

WALL THICKNESS: 25mm

TYPE OF JOINT: SINGLE VEE BUTT PLATE

WELD PROCESS: MMA FILL/TIG ROOT

WELD PREPARATION: 60° INCLUDED ANGLE

EXCESS WELD METAL: AS WELDED

2mm ROOT GAP

2mm ROOT FACE

ULTRASONIC TEST INFORMATION

ULTRASONIC FLAW DETECTOR: KRAUTKRAMER USM 2 - Serial No K021

| PROBES       | TYPE | SIZE      | FREQUENCY | ANGLE | SCANNING PROCEDURE                          |
|--------------|------|-----------|-----------|-------|---------------------------------------------|
| Twin comp    |      | 10mm dia. | 5MHz      | 0°    | In accordance with<br>code or specification |
| Single shear |      | 10mm dia. | 5MHz      | 45°   |                                             |
| Single shear |      | 10mm dia. | 5MHz      | 60°   |                                             |
| Single shear |      | 10mm dia. | 5MHz      | 70°   |                                             |

SENSITIVITY SETTING:

TWIN COMPRESSION SCAN -

SINGLE SHEAR SCAN ANGLE - 2-3mm OF GRASS AT MAXIMUM TESTING RANGE

CALIBRATION PROCEDURE: TIME BASE CALIBRATED TO 100mm RANGE ON V2 CAL BLOCK

SPECIFICATION OR CODE: TWI CODE 438

REPORT

ACCEPTABLE TO SPECIFICATION

NAME .. A N OTHER  
SIGNATURE ..  
DATE .. 12/8-96 ..  
Cambridge

WELD TEST REPORT: ULTRASONICS

NAME AND ADDRESS OF INSPECTING COMPANY: CAMBRIDGE NDT SERVICES

ABINGTON HALL, CAMBS.

WORK LOCATION: ABINGTON

DATE OF TEST: 10.08.91

REPORT REFERENCE NO: 3214-3

SHEET 1 OF 1 SHEETS

WELD IDENTIFICATION: 3324-3

MATERIAL: MILD STEEL

WALL THICKNESS: 25mm

TYPE OF JOINT: SINGLE VEE BUTT PLATE

WELD PROCESS: MMA FILL/TIG ROOT

WELD PREPARATION: 60° INCLUDED ANGLE

EXCESS WELD METAL: AS WELDED

2mm ROOT GAP

2mm ROOT FACE

ULTRASONIC TEST INFORMATION

ULTRASONIC FLAW DETECTOR: KRAUTKRAMER USM 2 - Serial No K021

| PROBES       | TYPE | SIZE      | FREQUENCY | ANGLE | SCANNING PROCEDURE                       |
|--------------|------|-----------|-----------|-------|------------------------------------------|
| Twin comp    |      | 10mm dia. | 5MHz      | 0°    |                                          |
| Single shear |      | 10mm dia. | 5MHz      | 45°   | In accordance with code or specification |
| Single shear |      | 10mm dia. | 5MHz      | 60°   |                                          |
| Single shear |      | 10mm dia. | 5MHz      | 70°   |                                          |

SENSITIVITY SETTING:

TWIN COMPRESSION SCAN - IN ACCORDANCE WITH ASME V ARTICLE 4, APP. B  
DAC plus 2dB

SINGLE SHEAR SCAN ANGLE -

CALIBRATION PROCEDURE: IN ACCORDANCE WITH ASME V ARTICLE 4, APP. B

SPECIFICATION OR CODE: TWI CODE 438

RECORDING THRESHOLD LEVEL EVALUATE SIGNALS ABOVE 20% DAC

REPORT

ACCEPTABLE TO SPECIFICATION

NAME .. A. N. WETHER  
SIGNATURE .....  
DATE .. 12.10.91 ..  


WELD TEST REPORT: PENETRANT TESTING

---

NAME AND ADDRESS OF INSPECTING COMPANY: CAMBRIDGE NDT SERVICES

ABINGTON HALL, CAMBS.

WORK LOCATION: ABINGTON

DATE OF TEST: 10.08.91

REPORT REFERENCE NO: 3422-3

SHEET 1 OF 1 SHEETS

WELD IDENTIFICATION: 734-1

MATERIAL: ALUMINIUM

WALL THICKNESS: 12mm

TYPE OF JOINT: FULL PEN TEE BUTT

WELD PROCESS: TIG

WELD PREPARATION: FULL PEN TEE BUTT

EXCESS WELD METAL: AS WELDED

TYPE OF JOINT: T-JOINT

---

TEST INFORMATION

PENETRANT TEST

MAGNETIC PARTICLE TEST

PENETRANT: COLOUR CONTRAST SOLVENT

MAGNETISING APPARATUS:

REMOVABLE

DETECTING MEDIUM:

REMOVER: SOLVENT REMOVER

ACCESSORIES: N/A

DEVELOPER: DRY POWDER

FIELD STRENGTH:

ACCESSORIES:

CONTACT TIME: 5 MINS

DEVELOPMENT TIME: 10 mins

MAG DIRECTION :

VIEWING CONDITIONS:

---

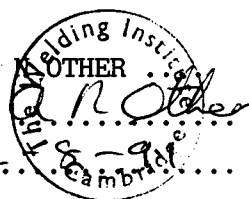
SPECIFICATION OR PROCEDURE: TWI CODE MAG/PEN 876

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REPORT

NO VISIBLE INDICATIONS

NAME .. A



SIGNATURE

DATE ..12..8..91..

WELD TEST REPORT: MAGNETIC PARTICLE INSPECTION

---

NAME AND ADDRESS OF INSPECTING COMPANY: CAMBRIDGE NDT SERVICES

ABINGTON HALL, CAMBS.

WORK LOCATION: ABINGTON

DATE OF TEST: 10.08.91

REPORT REFERENCE NO: 3422-2

SHEET 1 OF 1 SHEETS

WELD IDENTIFICATION: 734-2

MATERIAL: MILD STEEL

WALL THICKNESS: 12mm

TYPE OF JOINT: FULL PEN TEE BUTT

WELD PROCESS: TIG

WELD PREPARATION: FULL PEN TEE BUTT

EXCESS WELD METAL: AS WELDED

TYPE OF JOINT: T-JOINT

---

TEST INFORMATION

MAGNETIC PARTICLE TEST

PENETRANT TEST

MAGNETISING APPARATUS: ELECTROMAGNETIC  
YOKE (AC)

PENETRANT :

DETECTING MEDIUM: FLUORESCENT INK

REMOVER :

ACCESSORIES: BURMAH CASTRO FLUX

DEVELOPER :

INDICATOR (TYPE 1) UVA LIGHT

ACCESSORIES : N/A

FIELD STRENGTH: 3 CLEAR INDICATIONS

CONTACT TIME :

ON FLUX INDICATOR

DEVELOPMENT TIME :

DIAGONAL TO LONGITUDINAL

MAG DIRECTION : AXIS OF WELD

VIEWING CONDITIONS: 10 LUX OR LESS

---

SPECIFICATION OR PROCEDURE: TWI CODE MAG/PEN 876

---

REPORT

NO SIGNIFICANT DEFECTS

NAME .. A N OTHER

SIGNATURE

DATE .. 12 ..



WELD TEST REPORT: MAGNETIC PARTICLE INSPECTION

---

NAME AND ADDRESS OF INSPECTING COMPANY: CAMBRIDGE NDT SERVICES

ABINGTON HALL, CAMBS.

WORK LOCATION: ABINGTON

DATE OF TEST: 10.08.91

REPORT REFERENCE NO: 3422-1

SHEET 1 OF 2 SHEETS

WELD IDENTIFICATION: 734-3

MATERIAL: ALUMINIUM

WALL THICKNESS: 12mm

TYPE OF JOINT: FULL PEN TEE BUTT

WELD PROCESS: TIG

WELD PREPARATION: FULL PEN TEE BUTT

EXCESS WELD METAL: AS WELDED

TYPE OF JOINT: T-JOINT

---

TEST INFORMATION

MAGNETIC PARTICLE TEST

PENETRANT TEST

MAGNETISING APPARATUS: PRODS

PENETRANT :

DETECTING MEDIUM: BLACK INK WITH WHITE  
CONTRAST PAINT

REMOVER :

ACCESSORIES:

DEVELOPER :

FIELD STRENGTH: 5.3 AMPS AC rms per  
mm PROD SEPARATION

ACCESSORIES :

CONTACT TIME :

DEVELOPMENT TIME :

MAG DIRECTION : DIAGONAL TO LONGITUDINAL  
AXIS OF WELD

VIEWING CONDITIONS:

---

SPECIFICATION OR PROCEDURE: TWI CODE MAG/PEN 876

---

REPORT

ACCEPTABLE TO SPECIFICATION

NAME .. A N OTHER  
SIGNATURE ..  
DATE .. 12.8.91 ..



WELD TEST REPORT: RADIOGRAPHY

---

NAME AND ADDRESS OF INSPECTING COMPANY: CAMBRIDGE NDT SERVICES  
ABINGTON HALL, CAMBS.

WORK LOCATION: ABINGTON DATE OF TEST: 10.08.91

REPORT REFERENCE NO: 3116-3 SHEET 1 OF 1 SHEETS

WELD IDENTIFICATION: 442-3 MATERIAL: MILD STEEL

WALL THICKNESS: 8mm TYPE OF JOINT: SINGLE VEE BUTT PLATE

WELD PROCESS: MMA FILL/TIG ROOT WELD PREPARATION: 60° INCLUDED ANGLE

EXCESS WELD METAL: WELD GROUND FLUSH 2mm ROOT GAP  
WITH PARENT MATERIAL 2mm ROOT FACE

---

RADIOGRAPHIC INFORMATION :

KV or Isotope : IRIIDIUM 192

Focal spot or source size : 2mm x 1mm

Focus or source to film distance : 500mm

Exposure time : 15ci mins (555 G.Bq.mins)

Film : KODAK Industrex CX 10mm x 40mm

Screens : Pb - 0.12mm FRONT AND BACK

Development : STANDARD, TIME/TEMPERATURE PROCESSING

Technique : SWSI

Number of exposures : 1

---

Image Quality Indicator : BS 3971 9 Fe 15

Sensitivity : 3%

Density : WELD : 2.5 PLATE : 3.0

---

Specification or Code of Practice : TWI Code R/312

---

REPORT

ACCEPTABLE TO SPECIFICATION

NAME .. A N OTHER  
SIGNATURE   
DATE .. 12.8.91..



WELD TEST REPORT: RADIOGRAPHY

---

NAME AND ADDRESS OF INSPECTING COMPANY: CAMBRIDGE NDT SERVICES

ABINGTON HALL, CAMBS.

WORK LOCATION: ABINGTON

DATE OF TEST: 10.08.91

REPORT REFERENCE NO:

SHEET 1 OF 1 SHEETS

WELD IDENTIFICATION: 442-2

MATERIAL: MILD STEEL

WALL THICKNESS: 12mm

TYPE OF JOINT: SINGLE VEE BUTT PLATE

WELD PROCESS: MMA FILL/TIG ROOT

WELD PREPARATION: 60° INCLUDED ANGLE

EXCESS WELD METAL: AS WELDED

2mm ROOT GAP

WITH PARENT MATERIAL

2mm ROOT FACE

---

RADIOGRAPHIC INFORMATION :

KV or Isotope : 270 KV

Focal spot or source size : 3mm x 3mm

Focus or source to film distance : 914mm

Exposure time : 25mAm

Film : KODAK INDUSTREX CX 10mm x 40mm

Screens : Pb - 0.12mm FRONT AND REAR

Development : STANDARD, TIME/TEMPERATURE PROCESSING

Technique : D W S I

Number of exposures : 1

---

Image Quality Indicator : BS 3971 9AL15

Sensitivity : 2%

Density : WELD : 2.5

PLATE : 3.0

---

Specification or Code of Practice : TWI Code R/312

---

REPORT

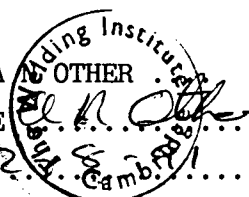
ACCEPTABLE TO SPECIFICATION

NAME .. A

OTHER

SIGNATURE

DATE .. 12.08.91



WELD TEST REPORT: RADIOGRAPHY

---

NAME AND ADDRESS OF INSPECTING COMPANY: CAMBRIDGE NDT SERVICES

ABINGTON HALL, CAMBS.

WORK LOCATION: ABINGTON

DATE OF TEST: 10.08.91

REPORT REFERENCE NO: 3116-1

SHEET 1 OF 1 SHEETS

WELD IDENTIFICATION: 442-1

MATERIAL: MILD STEEL

WALL THICKNESS: 25mm

TYPE OF JOINT: SINGLE VEE BUTT PLATE

WELD PROCESS: MMA

WELD PREPARATION: 60° INCLUDED ANGLE

EXCESS WELD METAL: AS WELDED

2mm ROOT GAP

2mm ROOT FACE

---

RADIOGRAPHIC INFORMATION :

KV or Isotope : IRIIDIUM 192

Focal spot or source size : 2mm x 1mm

Focus or source to film distance : 500mm

Exposure time : 40mAm

Film : KODAK INDUSTREX CX 10mm x 40mm

Screens : Pb - 0.12mm FRONT AND REAR

Development : STANDARD TIME/TEMPERATURE PROCESSING

Technique : SWSI

Number of exposures : 1

---

Image Quality Indicator : BS 3971 9Fe 15

Sensitivity : 2%

Density : WELD : 2.5 PLATE : 3.0

---

Specification or Code of Practice : TWI Code R/312

---

REPORT

ACCEPTABLE TO SPECIFICATION

NAME .. A N OTHER ..  
SIGNATURE *[Signature]*  
DATE .12.8.91.....

WELD TEST REPORT: ULTRASONICS

NAME AND ADDRESS OF INSPECTING COMPANY: CAMBRIDGE NDT SERVICES

ABINGTON HALL, CAMBS.

WORK LOCATION: ABINGTON

DATE OF TEST: 10.08.91

REPORT REFERENCE NO: 3214-2

SHEET 1 OF 1 SHEETS

WELD IDENTIFICATION: 3324-1

MATERIAL: LOW CARBON STEEL

WALL THICKNESS: 25mm

TYPE OF JOINT: SINGLE VEE BUTT PLATE

WELD PROCESS: MMA FILL/TIG ROOT

WELD PREPARATION: 60° INCLUDED ANGLE

EXCESS WELD METAL: AS WELDED

2mm ROOT FACE

2mm ROOT GAP

ULTRASONIC TEST INFORMATION

ULTRASONIC FLAW DETECTOR: KRAUTKRAMER USM 2 - Serial No K021

PROBES TYPE SIZE FREQUENCY ANGLE SCANNING PROCEDURE COUPLANT

|              |           |      |     |                                          |
|--------------|-----------|------|-----|------------------------------------------|
| Twin comp    | 10mm dia. | 5MHz | 0°  |                                          |
| Single shear | 10mm dia. | 5MHz | 45° | In accordance with code or specification |
| Single shear | 10mm dia. | 5MHz | 60° |                                          |
| Single shear | 10mm dia. | 5MHz | 70° |                                          |

SENSITIVITY SETTING:

TWIN COMPRESSION SCAN - SECOND BACK WALL ECHO AT F S H

SINGLE SHEAR SCAN ANGLE - ECHO FROM 1.5MM DIA. HOLE AT MAXIMUM RANGE SET TO FULL SCREEN HEIGHT PLUS 2-4dBs TRANSFER LOSS

CALIBRATION PROCEDURE: TIME BASE CALIBRATED TO 100mm RANGE ON V2 CAL BLOCK

SPECIFICATION OR CODE: NO SPEC. OR CODE

REPORT

ACCEPTABLE TO SPECIFICATION

Q.C. STAMP

NAME ..A N OTHER ..

SIGNATURE *a n other*

DATE ..1...8:91.....

WELD TEST REPORT: ULTRASONICS

NAME AND ADDRESS OF INSPECTING COMPANY: CAMBRIDGE NDT SERVICES

ABINGTON HALL, CAMBS.

WORK LOCATION: ABINGTON

DATE OF TEST: NO DATE

REPORT REFERENCE NO: 3214-1

SHEET 1 OF 1 SHEETS

WELD IDENTIFICATION: 3324-2

MATERIAL: MILD STEEL

WALL THICKNESS: 25mm

TYPE OF JOINT: SINGLE VEE BUTT PLATE

WELD PROCESS: MMA FILL/TIG ROOT

WELD PREPARATION:

60° INCLUDED ANGLE

EXCESS WELD METAL: AS WELDED

2mm ROOT GAP

2mm ROOT FACE

ULTRASONIC TEST INFORMATION

ULTRASONIC FLAW DETECTOR: KRAUTKRAMER USM 2 - Serial No K021

PROBES TYPE SIZE FREQUENCY ANGLE SCANNING PROCEDURE **COUPLANT**

|              |           |      |     |                                          |
|--------------|-----------|------|-----|------------------------------------------|
| Twin comp    | 10mm dia. | 5MHz | 0°  |                                          |
| Single shear | 10mm dia. | 5MHz | 45° | In accordance with code or specification |
| Single shear | 10mm dia. | 5MHz | 60° |                                          |
| Single shear | 10mm dia. | 5MHz | 70° |                                          |

SENSITIVITY SETTING:

TWIN COMPRESSION SCAN -

**2nd B.W.E. TO F.S.H.**

SINGLE SHEAR SCAN ANGLE -

2-3mm OF GRASS AT MAXIMUM TESTING RANGE

CALIBRATION PROCEDURE: TIME BASE CALIBRATED TO 100mm RANGE ON V2 CAL BLOCK

SPECIFICATION OR CODE: TWI CODE 438

REPORT

ACCEPTABLE TO SPECIFICATION

NAME ..A N OTHER ..

SIGNATURE ..

DATE ..12-91..



WELD TEST REPORT: ULTRASONICS

NAME AND ADDRESS OF INSPECTING COMPANY: CAMBRIDGE NDT SERVICES

ABINGTON HALL, CAMBS.

WORK LOCATION: ABINGTON

DATE OF TEST: 10.08.91

REPORT REFERENCE NO: 3214-3

SHEET 1 OF 1 SHEETS

WELD IDENTIFICATION: 3324-3

MATERIAL: MILD STEEL

WALL THICKNESS: 25mm

TYPE OF JOINT: SINGLE VEE BUTT PLATE

WELD PROCESS: MMA FILL/TIG ROOT

WELD PREPARATION:

60° INCLUDED ANGLE

EXCESS WELD METAL: AS WELDED

3-5mm ROOT GAP

2mm ROOT FACE

ULTRASONIC TEST INFORMATION

ULTRASONIC FLAW DETECTOR: KRAUTKRAMER USM 2 - Serial No K021

PROBES TYPE SIZE FREQUENCY ANGLE SCANNING PROCEDURE **COUPLANT**

|              |  |           |      |     |                                          |
|--------------|--|-----------|------|-----|------------------------------------------|
| Twin comp    |  | 10mm dia. | 5MHz | 0°  |                                          |
| Single shear |  | 10mm dia. | 5MHz | 45° | In accordance with code or specification |
| Single shear |  | 10mm dia. | 5MHz | 60° |                                          |
| Single shear |  | 10mm dia. | 5MHz | 70° |                                          |

SENSITIVITY SETTING:

TWIN COMPRESSION SCAN - IN ACCORDANCE WITH ASME V ARTICLE 4, APP. B

DAC plus 2dB

**6dB**

SINGLE SHEAR SCAN ANGLE -

**As above + 6dB**

CALIBRATION PROCEDURE: IN ACCORDANCE WITH ASME V ARTICLE 4, APP. B

SPECIFICATION OR CODE: TWI CODE 438

RECORDING THRESHOLD LEVEL EVALUATE SIGNALS ABOVE 20% DAC

REPORT

ACCEPTABLE TO SPECIFICATION

NAME .. **The Welding Institute** ..

SIGNATURE **No signature**

DATE **12.08.91**

WELD TEST REPORT: PENETRANT TESTING

NAME AND ADDRESS OF INSPECTING COMPANY: CAMBRIDGE NDT SERVICES

ABINGTON HALL, CAMBS.

WORK LOCATION: ABINGTON

DATE OF TEST: 10.08.91

REPORT REFERENCE NO: 3422-3

SHEET 1 OF 1 SHEETS

WELD IDENTIFICATION: 734-1

MATERIAL: ALUMINIUM

WALL THICKNESS: 12mm

TYPE OF JOINT: FULL PEN TEE BUTT

WELD PROCESS: TIG

WELD PREPARATION: FULL PEN TEE BUTT

EXCESS WELD METAL: AS WELDED

TYPE OF JOINT: T-JOINT

TEST INFORMATION

PENETRANT TEST

MAGNETIC PARTICLE TEST

PENETRANT: COLOUR CONTRAST SOLVENT

MAGNETISING APPARATUS:

REMOVABLE

DETECTING MEDIUM:

REMOVER: SOLVENT REMOVER SOLVENT NON AQUEOUS

WET DEVELOPER

ACCESSORIES: N/A

DEVELOPER: DRY POWDER

FIELD STRENGTH:

ACCESSORIES:

CONTACT TIME: 5 MINS 10-30 mins

DEVELOPMENT TIME: 10 mins Approx (30 max)

MAG DIRECTION :

VIEWING CONDITIONS:

MINIMUM 500 LUX-GOOD DAYLIGHT

SPECIFICATION OR PROCEDURE: TWI CODE MAG/PEN 876

REPORT

NO APPARENT FLAWS

NAME .. A. N. OTHER  
SIGNATURE .....  
DATE .. 1.8.89 ..

WELD TEST REPORT: MAGNETIC PARTICLE INSPECTION

NAME AND ADDRESS OF INSPECTING COMPANY: CAMBRIDGE NDT SERVICES

ABINGTON HALL, CAMBS.

WORK LOCATION: ABINGTON

DATE OF TEST: 10.08.91

REPORT REFERENCE NO: 3422-2

SHEET 1 OF 1 SHEETS

WELD IDENTIFICATION: 734-2

MATERIAL: MILD STEEL

WALL THICKNESS: 12mm

TYPE OF JOINT: FULL PEN TEE BUTT

WELD PROCESS: TIG

WELD PREPARATION: FULL PEN TEE BUTT

EXCESS WELD METAL: AS WELDED

TYPE OF JOINT: T-JOINT

TEST INFORMATION

MAGNETIC PARTICLE TEST

PENETRANT TEST

MAGNETISING APPARATUS: ELECTROMAGNETIC  
YOKE (AC)

PENETRANT :

DETECTING MEDIUM: FLUORESCENT INK

REMOVER :

ACCESSORIES: FOIL TYPE BRASS FLUX

DEVELOPER :

INDICATOR (TYPE 1) UVA LIGHT

ACCESSORIES : N/A

FIELD STRENGTH: 3 CLEAR INDICATIONS

CONTACT TIME :

ON FLUX INDICATOR

DEVELOPMENT TIME :

DIAGONAL TO LONGITUDINAL

MAG DIRECTION : 90° TO AXIS OF YOKE LEGS

VIEWING CONDITIONS: 10 LUX OR LESS

BLACK LIGHT INTENSITY 0.8mW/cm<sup>2</sup>  
AT WORK SURFACE

SPECIFICATION OR PROCEDURE: TWI CODE MAG/PEN 876

REPORT

NO APPARENT FLAWS

NAME .. A. N. Elter ..  
SIGNATURE ..  
DATE .. 10-8-91 ..  
Cambridge

WELD TEST REPORT: MAGNETIC PARTICLE INSPECTION

NAME AND ADDRESS OF INSPECTING COMPANY: CAMBRIDGE NDT SERVICES

ABINGTON HALL, CAMBS.

WORK LOCATION: ABINGTON

DATE OF TEST: 10.08.91

REPORT REFERENCE NO: 3422-1

SHEET 1 OF 2 SHEETS

WELD IDENTIFICATION: 734-3

MATERIAL: ALUMINIUM

WALL THICKNESS: 12mm

TYPE OF JOINT: FULL PEN TEE BUTT

WELD PROCESS: TIG

WELD PREPARATION: FULL PEN TEE BUTT

EXCESS WELD METAL: AS WELDED

TYPE OF JOINT: T-JOINT

TEST INFORMATION

WRONG NDT METHOD

MAGNETIC PARTICLE TEST

PENETRANT TEST

MAGNETISING APPARATUS: PRODS

PENETRANT :

DETECTING MEDIUM: BLACK INK WITH WHITE

CONTRAST PAINT

REMOVER :

ACCESSORIES:

DEVELOPER :

FIELD STRENGTH: 5.3 AMPS AC rms per

ACCESSORIES :

mm PROD SEPARATION

CONTACT TIME :

DEVELOPMENT TIME :

MAG DIRECTION : IN LINE WITH PRODUCTION

CONTACTS

VIEWING CONDITIONS:

MINIMUM 500 LUX - GOOD DAYLIGHT

SPECIFICATION OR PROCEDURE: TWI CODE MAG/PEN 876

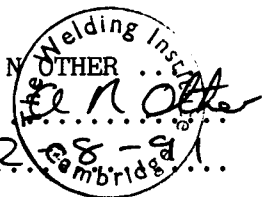
REPORT

ACCEPTABLE TO SPECIFICATION

NAME .. A N OTHER ..

SIGNATURE ..

DATE ... 12.08.91 ...



WELD TEST REPORT: RADIOGRAPHY

NAME AND ADDRESS OF INSPECTING COMPANY: CAMBRIDGE NDT SERVICES

ABINGTON HALL, CAMBS.

WORK LOCATION: ABINGTON

DATE OF TEST: 10.08.91

REPORT REFERENCE NO: 3116-3

SHEET 1 OF 1 SHEETS

WELD IDENTIFICATION: 442-3

MATERIAL: MILD STEEL

WALL THICKNESS: 8mm

TYPE OF JOINT: SINGLE VEE BUTT PLATE

WELD PROCESS: MMA FILL/TIG ROOT

WELD PREPARATION: 60° INCLUDED ANGLE

EXCESS WELD METAL: WELD GROUND FLUSH

**3-5mm ROOT GAP**

WITH PARENT MATERIAL

2mm ROOT FACE

RADIOGRAPHIC INFORMATION :

KV or Isotope : IRIDIUM 192 -

**RECOMMENDED MIN. THICKNESS 10mm STEEL**

Focal spot or source size : 2mm x 1mm

Focus or source to film distance : 500mm

Exposure time : 15ci mins (555 G.Bq.mins)

Film : KODAK Industrex CX 10mm x 40mm

Screens : Pb - 0.12mm FRONT AND BACK

Development : STANDARD, TIME/TEMPERATURE PROCESSING

Technique : SWSI

Number of exposures : 1

Image Quality Indicator : BS 3971 9 Fe 15

**(WRONG IQI eg. 4 Fe 10)**

Sensitivity : 3%

**NORMALLY 2% OR BETTER**

Density : WELD : 2.5

PLATE : 3.0

Specification or Code of Practice : TWI Code R/312

REPORT

ACCEPTABLE TO SPECIFICATION

NAME .. A MOTHER  
SIGNATURE *A. N. C.*  
DATE ... 10.08.91 ...  


WELD TEST REPORT: RADIOGRAPHY

NAME AND ADDRESS OF INSPECTING COMPANY: CAMBRIDGE NDT SERVICES

ABINGTON HALL, CAMBS.

WORK LOCATION: ABINGTON

DATE OF TEST: 10.08.91

REPORT REFERENCE NO: NO NUMBER

SHEET 1 OF 1 SHEETS

WELD IDENTIFICATION: 442-2

MATERIAL: MILD STEEL

WALL THICKNESS: 12mm

TYPE OF JOINT: SINGLE VEE BUTT PLATE

WELD PROCESS: MMA FILL/TIG ROOT

WELD PREPARATION: 60° INCLUDED ANGLE

EXCESS WELD METAL: AS WELDED

3-5mm ROOT GAP

WITH PARENT MATERIAL

2mm ROOT FACE

RADIOGRAPHIC INFORMATION :

KV or Isotope : 270 KV (TOO HIGH FOR MATERIAL THICKNESS)

Focal spot or source size : 3mm x 3mm

Focus or source to film distance : 914mm

Exposure time : 25mAm

Film : KODAK INDUSTREX CX 10mm x 40mm

Screens : Pb - 0.12mm FRONT AND REAR

Development : STANDARD, TIME/TEMPERATURE PROCESSING

Technique : D W S I (SWSI)

Number of exposures : 1

Image Quality Indicator : BS 3971 9AL15 (9 FE 15)

Sensitivity : 2%

Density : WELD : 2.5 PLATE : 3.0

Specification or Code of Practice : TWI Code R/312

REPORT

ACCEPTABLE TO SPECIFICATION

NAME .. A N OTHER  
SIGNATURE *A N Oth*  
DATE .... 10.08.91  
Cambridge

WELD TEST REPORT: RADIOGRAPHY

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NAME AND ADDRESS OF INSPECTING COMPANY: CAMBRIDGE NDT SERVICES

ABINGTON HALL, CAMBS.

WORK LOCATION: ABINGTON

DATE OF TEST: 10.08.91

REPORT REFERENCE NO: 3116-1

SHEET 1 OF 1 SHEETS

WELD IDENTIFICATION: 442-1

MATERIAL: MILD STEEL

WALL THICKNESS: 25mm

TYPE OF JOINT: SINGLE VEE BUTT PLATE

WELD PROCESS: MMA

WELD PREPARATION: 60° INCLUDED ANGLE

EXCESS WELD METAL: AS WELDED

2-3mm ROOT GAP

2mm ROOT FACE

---

RADIOGRAPHIC INFORMATION :

KV or Isotope : IRIDIUM 192

Focal spot or source size : 2mm x 1mm

Focus or source to film distance : 500mm

Exposure time : 40mAm

Ci mins or GBq mins

Film : KODAK INDUSTREX CX 10mm x 40mm

Screens : Pb - 0.12mm FRONT AND REAR

Development : STANDARD TIME/TEMPERATURE PROCESSING

Technique : SWSI

Number of exposures : 1

---

Image Quality Indicator : BS 3971 9Fe 15

Sensitivity : 2%

Density : WELD : 2.5 PLATE : 3.0

---

Specification or Code of Practice : TWI Code R/312

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REPORT

ACCEPTABLE TO SPECIFICATION

NAME .. A. N. OTHER  
SIGNATURE ..  
DATE ... 12-8-91 ...  
Cambridge

# SENIOR WELDING INSPECTOR

## N.D.T.

- Q1. State the names of five (5) NDT techniques.
- Q2. For each of the techniques given in 1, state its applicability to the following material:
- a) mild steel
  - b) Dural (4%Cu in Al)
  - c) 1¼%Cu, 1%Mo in Fe
  - d) annealed austenitic SS
  - e) ferritic SS
  - f) 90%Cu, 10%Ni
- Q3. For each of the techniques given in 1, state its applicability to detect suspected defects as follows:
- a) Laminations in 1.5mm sheet mild steel
  - b) Toe defects up to 3mm deep
  - c) Voids up to 1.5mm below the surface of weld metal
  - d) Susceptibility to lamellar tearing
  - e) Laps up to 1.5mm below the surface of bar material made from 0.2%C, 1.5%Mn in Fe
  - f) Lack of sidewall fusion in a single V butt
  - g) Surface cracks in machined mild steel surfaces
- Q4. The sketch below shows a joint in a plate which is to be radiographed for suspected lack of sidewall fusion. Draw a diagram of the radiographic technique to be used.
- Q5. The following 'couplants' may be used for UT inspection
- a) Water
  - b) Very thin oil (fuel oil)
  - c) Thick oil
  - d) Grease
  - e) Polycell paste
- Comment in each case on their effectiveness.
- Q6. For each of the techniques given in 1, state the main safety consideration.

- Q7. Surface defects are often considered to be more important than sub-surface defects. Comment briefly.
- Q8. Make a sketch of a UT technique, i.e. probe angles etc. to find possible lamellar tearing in a T-butt joint in 60mm thick material.
- Q9. Define the term 'penumbra'.
- Q10. Sketch four (4) radiographic techniques showing
- a) Film location
  - b) IQI location
  - c) Source location

# REPAIR BY WELDING

## INTRODUCTION

The repair of defects that occur during welding ranges from simple welding operations to improve weld profile to extensive metal removal and subsequent welding to rectify extensive cracking.

Repair of fabrication defects is generally easier than repair of service failures because the welding procedure used for fabrication may be followed during repair.

The repair of service failures may be difficult because access may be hazardous and the welding procedures used for the original fabrication may be impossible to apply.

This section considers the procedures and the underlying metallurgical principles for the repair of carbon and alloy steels, wrought and cast iron, and some non-ferrous alloys.

### Types of defects

Defects requiring repair by welding can be divided into two categories, 1) fabrication defects and 2) service failures.

#### Fabrication defects

The commonest defects that can occur during the making of a weld include porosity, slag inclusions, undercut consisting of a groove in the parent metal at the edge of a weld, lack of fusion between the weld and the parent metal or between runs of weld metal, incomplete penetration, and solidification cracking.

Defects that can occur during welding but which may not occur until up to 48 hours after welding are hydrogen induced cracking of the weld metal or the heat affected zone of the parent metal and lamellar tearing of the parent metal.

Repair by welding involving removal of defective areas and replacement by sound material can cost up to 10 times as much as depositing similar quantities of weld metal correctly in the first place. Therefore it is important to avoid unacceptable defects and it can be an economic proposition in many cases to carry out fairly large scale procedure tests before fabricating critical components.

Having taken all possible precautions to meet acceptance standards, defects inevitably occur, especially when welding is carried out manually rather than by a mechanised method.

To judge whether compliance with the requirements of a code of practice have been met, it is necessary to be able to detect any defects by non-destructive testing and also to determine their dimensions and orientation. Codes recognise that flawless welds are almost always impossible to attain and various levels of acceptance are laid down in respect of allowable porosity and inclusions etc.

Planar defects such as cracks or lack of fusion may nearly always be prohibited and the normal procedure is to repair the welds followed by re-inspection.

The repair procedure may be very simple and merely require the deposition of additional weld metal to rectify undercut but the repair of deep seated defects such as lamellar tearing can entail extensive excavation and rewelding. The welding procedure for the repair weld can often be very similar to the original welding in respect to preheat, type of consumable, and welding conditions. However, if cracking is present the welding conditions may have to be changed to avoid this defect in the repair weld. There are cases in which fabrication defects are not discovered until final inspection and if a sub-section originally welded in the flat position is incorporated into a large structure it is possible that repairs may have to be carried out in less favourable welding positions such as vertically or overhead.

In critical components the repair procedure may have to be qualified by procedure tests particularly if fracture toughness requirements are specified.

In cases where extensive rectification would be required to meet code requirements experience at The Welding Institute has shown that considerable savings in both cost and time can be obtained if the significance of the defects present is assessed on a fitness for purpose basis. This involves calculation of the maximum growth of defects under fatigue loading and of the required toughness levels of weld metal, parent plate and HAZ to avoid brittle fracture during the peak loadings of a structure.

The application of fitness for purpose criteria has in some cases resulted in inspection authorities accepting defects that exceed the limits of code requirements.

## **Service failure**

Service failure in the context of this paper consist of cracks caused mainly by fatigue, brittle fracture, stress corrosion or creep.

In some cases plant shut down may be necessary immediately a crack is discovered if, for example, it is found by leaking of a containment vessel, the crack having propagated from inside through the vessel wall.

In some rare cases a fatigue crack will relieve the stresses in a highly stressed area and will run out of steam and can be left without repair. In other cases fatigue crack growth can be monitored by periodical inspection until plant shut down for repair is convenient.

Brittle fracture is fortunately a relatively rare occurrence compared with fatigue, but when it occurs it can be fare more spectacular leading to disasters such as the breaking in half of ships, or the fragmentation of pressure vessels.

Whether repair is feasible depends on the proportion of the structure remaining intact, and repair can range from removal of the cracked area and welding to the pre-fabrication of new sub-sections which are welded into place. The latter expedient is considered to be rebuilding rather than repair.

The repair of service cracks may be difficult for one or all of the following reasons:

1. Access may be restricted, e.g. inside a mine winder.
2. Preheat and/or post weld heat treatments may be difficult or even impossible to apply, e.g. because of risk of damage to machined surfaces, plastic seals, electrical insulation etc. or presence of flammable materials.
3. The component cannot generally be rotated into the most convenient position for welding. Therefore potential welding may have to be used, e.g. circumferential seams of a pressure vessel may have to be repaired in the overhead position by manual welding whereas the vessel was originally fabricated by rotating it under a submerged arc welding machine. The change in welding process and position of welding could affect the fracture toughness. Therefore complex weld procedure tests may be required for the repair of critical items of plant.
4. The environment may be hazardous, e.g. heat, nuclear radiation, underground.

## **GENERAL TECHNIQUES FOR TYPICAL REPAIRS**

### **Metal removal**

The defect may be in a single run fillet weld requiring only a small amount of metal to be removed or it may be a large crack extending deep into parent metal.

For removing metal rapidly the most convenient method is air arc gouging in which the metal is melted by a carbon arc and is blown out of the cut by a stream of compressed air which passes through holes in a specially designed electrode holder.

Arc-air gouging can be used on both ferrous and non-ferrous metals but the surface finish is generally not as good as obtained by oxyacetylene gouging and the gouged surface finish allows the use of non-destructive testing by dye penetrant or magnetic particle inspection to check whether cracks or other defects have been completely removed.

Other thermal methods of metal removal, less commonly used, are oxygen-arc or oxyacetylene gouging. Mechanical methods include pneumatic chisels, high speed rotary tungsten carbide burrs and grinding wheels.

### **Groove shape**

The minimum amount of metal should be removed by economic reasons but it is necessary to produce a groove wide enough for access and manipulation of the welding electrode or filler wire.

Widths may have to be increased if a repair involves welding in the overhead position or if the surface of the groove has to be buttered with a layer of weld metal of one composition before filling the groove with weld metal of a different composition to prevent weld metal cracking.

While it is more common to carry out a repair with weld metal of one composition only, it may still be advantageous to use the buttering technique particularly in large grooves to reduce the effect of shrinkage across the joint. Each layer of weld metal has a larger free surface than it would if the weld consisted of horizontal layers as in normal fabrication practice and this allows contraction to take place freely with minimum strain on the parent metal. This reduces the risk of cracking in the weld or the HAZ and also reduces the tendency for distortion of the component.

## WELDING PROCESSES

The fusion welding processes commonly applied to repair welding are as follows :

1. Manual metal arc welding with flux coated electrodes.
2. Flux cored arc welding with coiled tubular electrodes, either gas shielded or self shielded.
3. MIG (metal inert gas) welding with coiled solid wire and inert shielding gas such as argon or helium.
4. MAG (metal active gas) welding with coiled solid wire and active shielding gas such as CO<sub>2</sub>, argon-CO<sub>2</sub> or argon-oxygen shielding gases.
5. TIG (tungsten inert gas) welding with a non consumable tungsten electrode and a separately fed filler wire.
6. Oxyacetylene welding

Table 1 shows the general order of preference for repair welding processes for common materials.

For most ferrous alloys manual metal arc welding is the preferred repair method because of its adaptability to difficult situations where access may be restricted, the angle of inclination of the electrode to the workpiece not being as critical as that of a welding gun in the semi-automatic MIG or MAG processes.

Flux cored arc welding is used extensively in steel foundries for repair of castings which can be positioned so that welding can be carried out in the flat position in which maximum welding current and deposition rates can be used.

MIG welding is generally favoured for non-ferrous materials and is the first choice for welding aluminium alloys because of ease of MIG welding aluminium compared with manual metal arc welding and for high welding quality.

## SUMMARY

Before a welding repair is carried out the need for repair must be carefully considered. If a component or structure contains defects of a known size, whether these are fabrication or service defects, a fitness for purpose evaluation may show them to be insignificant, thus saving the cost of repair.

When repair is shown to be necessary, the factors to be considered include the following:

1. The extent of repair and possible consequences such as distortion.
2. The access for welding and welding position
3. Requirements for preheat and/or post heat
4. Choice of welding consumables and welding procedure to avoid pre or post weld heat treatment.
5. The mechanical properties required in the weld metal and HAZ and the need for procedure tests.

Having suitable welding procedures and fulfilling the metallurgical requirements are the first two vital factors for a successful repair.

The third factor is a high level of welder and supervisory skill because the application of the first two factors under the difficult conditions under which some complex repairs are carried out depends on the expertise of these personnel.

## **QUESTIONS**

### **REPAIR WELDING**

- Q1      State six (6) points of importance of repair welding.
- Q2      Sketch a plan and side view of a typical repair excavation.
- Q3      State two (2) non-destructive test methods that may be applied to a repair.
- Q4      At what stage would each NDT method generally be used.
- Q5      State three (3) documents which the inspector should refer to when carrying out repairs.

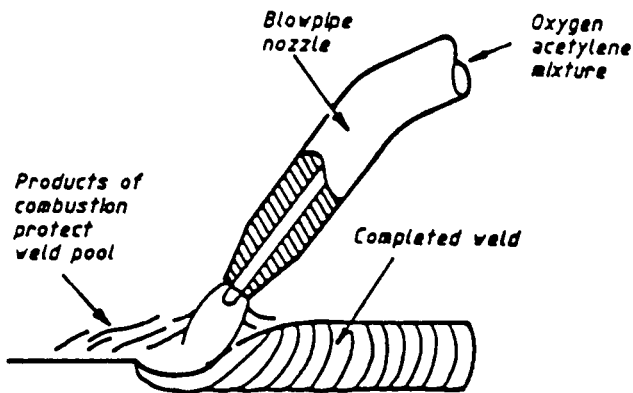
# **SENIOR WELDING INSPECTOR**

## **REPAIR WELDING**

- Q1. State two reasons why repair welding presents special problems.**
- Q2. What is the main advantage of using austenitic electrodes?**
- Q3. What is the main problem of weldability when using 18/8 type austenitic electrodes to repair ferritic steels?**
- Q4. What is the main advantage of using 29/10 type austenitic electrodes to repair ferritic steels?**
- Q5. Why is it recommended that 29/10 is used to butter and an 18/8 is used to fill when using austenitic electrodes for repair?**

# OXY FUEL GAS WELDING, CUTTING AND GOUGING

## GAS WELDING



### Mode of Operation

A fuel gas (usually acetylene) and an oxidant gas (oxygen) are mixed and burnt.

The operator must manipulate the blowpipe to give the correct weld pool size, and also add filler metal as required.

The melting is slow compared with arc processes, limiting the speed of work. The weld pool is shielded from atmospheric contamination by the burnt gas mixture which can be made mildly oxidising or reducing.

### Oxyacetylene (OA)

Typical defects associated with this process:

Unequal leg length fillet.

- Too concave butt weld profile.

Too convex butt weld profile.

Undesirable weld profile (lap, fillet).

Excessive penetration.

Excessive fusion of root edges.

Burnthrough.

Undercut along vertical member of fillet welded T joint.

Root run too large with undercut in butt joint.

Undercut both sides of weld face in butt joint.

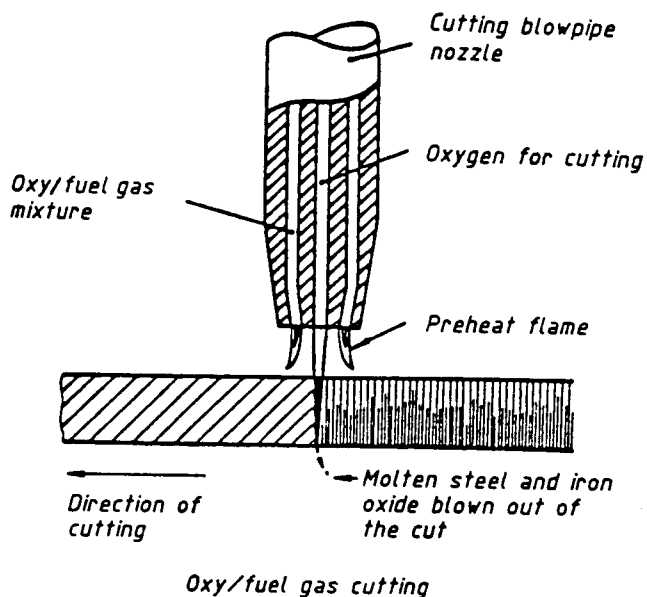
- Oxidised weld face.

- Overheated weld.

Incomplete root penetration in butt joints (single V or double V).

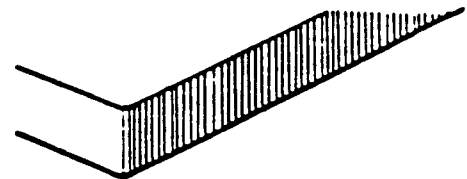
Incomplete root penetration in close square T joint.

# THERMAL CUTTING FLAME CUTTING GAS CUTTING

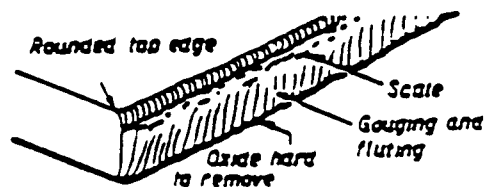


## Principles of cutting operation

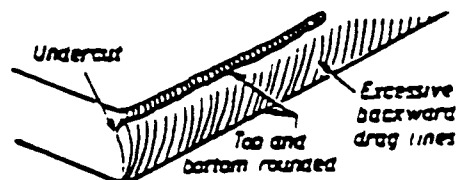
There are two operations in gas cutting. A heating flame is directed on the metal to be cut and raises it to bright red heat; this is known as the ignition point. When this point is reached a stream high-pressure oxygen is directed on to the hot metal. This oxidizes the metal and forms a magnetic oxide of iron ( $\text{Fe}_3\text{O}_4$ ). The melting point of this oxide is well below that of the iron, and it melts immediately and is blown away by an oxygen stream.



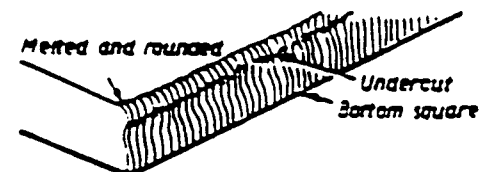
1. Correct cutting



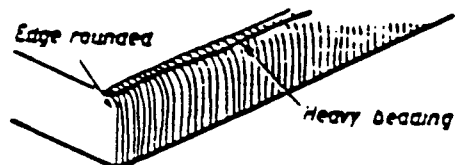
2. Speed too slow



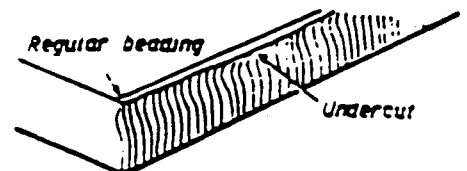
3. Speed too fast



4. Nozzle too high



5. Nozzle too low



6. Pressure of cutting oxygen too high

## QUESTIONS

### OXY FUEL GAS WELDING, CUTTING AND GOUGING

- Q1      What is the principal limitation of oxy/acetylene welding?
- Q2      Give three (3) flame types and their respective applications.
- Q3      Give three (3) typical defects found with oxy/acetylene welding.
- Q4      Give four typical defects found when cutting using the oxy/fuel process.
- Q5      Give four (4) points of safety which require inspection when cutting.

# **SENIOR WELDING INSPECTOR**

## **GAS WELDING**

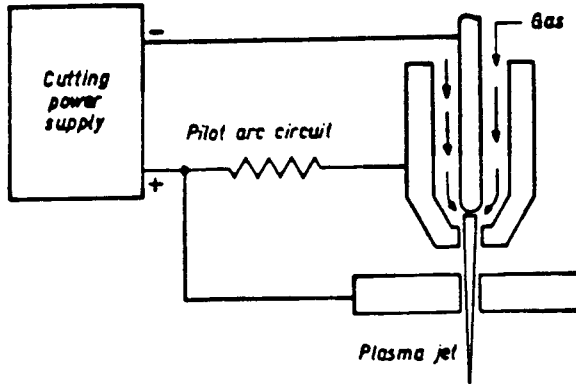
- Q1. State the chemical formula for acetylene.
- Q2. Acetylene is produced by the unity of which two chemicals.
- Q3. Give four (4) causes of undercut.
- Q4. Give four (4) causes of incomplete penetration.
- Q5. Why is a neutral flame used for "brazing" and not for "bronze welding".

## **GAS CUTTING**

- Q1. Discuss the use of single and multi stage regulators.
- Q2. Describe:
  - a) a flashback
  - b) a blowback
- Q3. List general safety requirements that should be followed when gas cutting.
- Q4. Name three (3) types of fuel gas that can be used for cutting/gouging operations.
- Q5. State typical parameters for flame cutting 25mm thick carbon steel.

# ARC CUTTING SYSTEMS

## PLASMA CUTTING



Type of operation: usually mechanised, but can be used manually

Equipment: power supply – similar to that needed for DC, TIG, but may have a higher output voltage  
gas supply  
plasma torch  
guidance system for mechanised operation

### Mode of operation

A TIG arc is constricted by positioning a small diameter orifice between the electrode and the work. The gas passing through the arc zone and the orifice is heated and would normally expand. The constriction prevents this and the gas is forced to accelerate through the orifice as a very hot gas column (plasma). The speed of the gas columns is near the speed of sound and will pierce (keyhole) metal. If there is relative motion between the torch and the work a cut will be produced. The plasma arc may be between the electrode and the work (transferred) or between the electrode and the nozzle (non-transferred).

### Operating parameters

Current: 100-300A  
Gas flow: 1.5-7m<sup>3</sup>/hr  
Thickness: up to 200mm  
Speed: 0.07-3m/min  
Access: good  
Portability: fair.

### Consumables

Argon or argon-hydrogen mixtures in cylinders of 7m<sup>3</sup> orifice nozzles  
Orifice nozzles  
Tungsten electrodes.

### Materials

Any metals except those of very high melting point  
Some thin non-metals.

### Typical applications

Cutting slabs in rolling mills  
Fabrications in stainless steel and aluminium materials.

### Overall advantages

Can cut materials to which it is difficult to apply other thermal processes, or mechanised cutting, such as aluminium, stainless steel and copper.

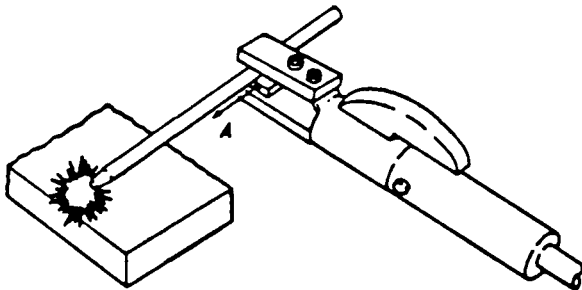
### Overall limitations

High equipment cost  
Cut edge not square  
Noisy.

### Safety

Arc emits visible and ultraviolet radiation  
Hot debris blown out  
Noise level may be high enough to require personnel to wear ear muffs.

## AIR-ARC CUTTING



*A = air jets which blow out metal from a molten pool*

Type of operation: manual

Equipment: rectifier set or motor-generator (as for manual metal-arc welding)  
special electrode holder with compressed air jet  
air supply

### Mode of operation

An arc is struck between the end of the electrode and the work. The molten metal is blown away by a compressed air jet attached to the electrode holder.

The process may be used for surface gouging or through cutting.

### Operating parameters

Current: 80-1600 A  
Air supply: up to  $1 \text{ MN/m}^2$  and  $1 \text{ m}^3/\text{min}$   
Thickness: up to 50 mm  
Access: fair  
Portability: good

### Consumables

Copper-coated carbon electrode 4.0-20 mm diameter.

### Materials

Wide range of metals.

### Typical applications

Gouging out surplus weld metal or surface and internal defects  
Preparation of J-edge for welding.

### Overall advantages

Can use same equipment as manual metal-arc welding, with minimal addition.  
Clean  
Fast cutting.

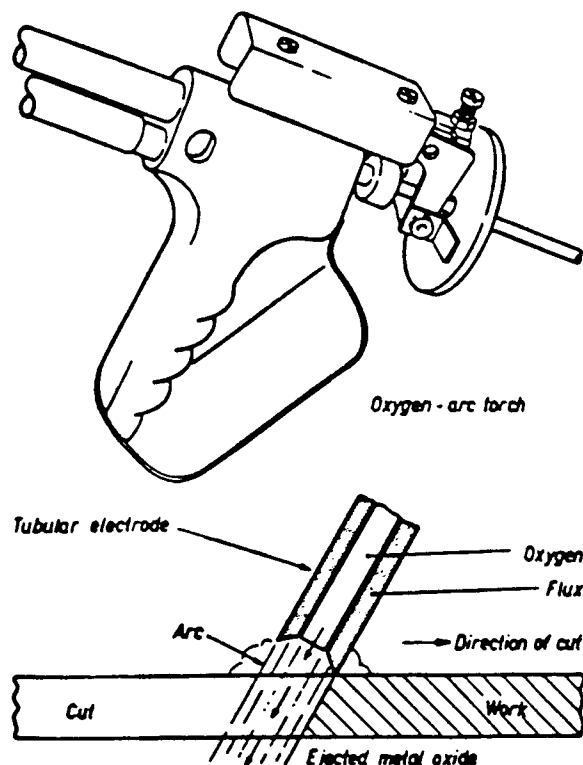
### Overall limitations

Inaccurate cut  
Wide cut  
Difficult to mechanise.

### Safety

Arc emits visible and ultraviolet radiation  
Hot debris blown out of cut.

## OXYGEN-ARC CUTTING



### Operating parameters

|              |                          |
|--------------|--------------------------|
| Current:     | 100-150A                 |
| Oxygen:      | 0.3-0.5MN/m <sup>2</sup> |
| Thickness:   | 6-50mm                   |
| Speed:       | 16-70m/hr                |
| Access:      | good                     |
| Portability: | good.                    |

### Consumables

Electrodes 5-8mm diameter  
Oxygen in cylinders of 7m<sup>3</sup>.

### Materials

Wide range of metals.

### Typical applications

Preparation for fabrication by manual metal-arc process  
Salvage and scrapping.

### Overall advantages

Simple equipment. Can also be used under water (with special electrodes).

### Overall limitations

Manual operation only  
Rough oxidised cut surface.

### Safety

Arc emits visible and ultraviolet radiation.  
Arcing on to oxygen cylinders must be avoided.  
Debris from cut may cause fires and burns.  
Risk of oxygen enrichment in enclosed spaces.

Type of operation: manual

Equipment: power supply as for manual metal-arc welding  
special electrode holder with oxygen passage  
oxygen regulator

### Mode of operation

An arc is struck between the end of a hollow, consumable electrode and the work.

Oxygen is blown down the electrode and the metal of the work burns away, and is blown downwards to form the cut.

A coating on the electrode stabilises the arc and burns off so that a cup is formed. The cup maintains the correct arc length.

## QUESTIONS

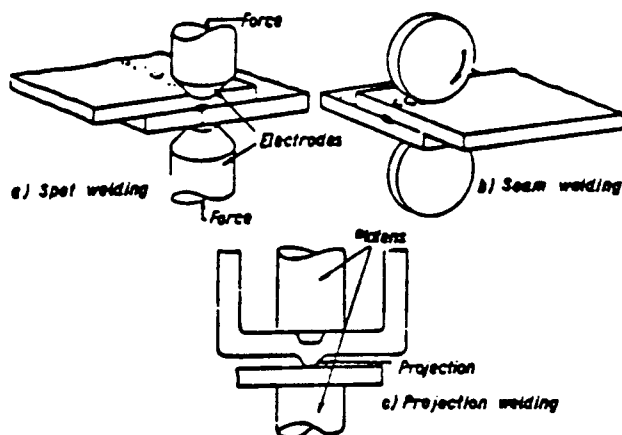
### ARC CUTTING AND GOUGING

- Q1      State three (3) safety precautions that must be observed when oxy/arc cutting.
- Q2      State three (3) safety precautions that must be observed when air arc cutting.
- Q3      Why must mechanical dressing follow arc air gouging operations.
- Q4      What type of current is essential for arc cutting.
- Q5      State two (2) methods of plasma arc cutting.

## **OTHER WELDING SYSTEMS**

Welding inspection also requires that inspection personnel have a reasonable understanding of other welding processes.

Overleaf are some of the other systems which you may come in contact with.



**Type of operation:** manual or mechanical positioning of work, then automatic

**Equipment:** controller  
timer  
transformer and sometimes a rectifier  
electrodes (copper alloy) with water cooling and force system

#### Mode of operation

A high current at a low voltage (4-6), flows through the two components between the electrodes. The electrodes are of high conductivity material, so that most of the heat is generated at the high resistance interface between the faying surfaces of the two components, which melt and form the weld.

The force applied by the electrodes excludes atmospheric contamination and keeps the faying surfaces in contact.

Mechanical stepping (stitch welding) or roller electrodes (seam welding) may be used to make a series of spots, either independent or overlapping.

The area of the weld is usually defined by the area carrying current in turn fixed by the area of the electrode faces. In projection welding, on the other hand, current flow is limited by raised areas on the work.

#### Operating parameters

Current range: 100-500 000 A; voltage 4-6  
Cycle time: 0.1-3sec (per weld)  
Range of thickness: 0.01-10mm

### Welding by pressure

## RESISTANCE WELDING

Electric resistant welding, erw.

Resistance, spot, seam or projection welding

Electrode

pressure:

7-70MN/m<sup>2</sup>

Types of joint:

Spot weld on lap joint. Overlapping spots may be used to give a stitch or seam weld

Welding position: any

Access:

fair

Portability:

portable equipment for light jobs, mains supply usually essential.

#### Consumables

Electrodes need replacement due to wear after about 1-10 000 welds, and may then be refaced. They are normally made from a copper alloy chosen to compromise between the conflicting requirements of high electrical conductivity and of reasonable wear resistance.

#### Materials

A wide range of metals, but copper is difficult.

#### Typical applications

Light fabrications from pressed sheet such as motor vehicle bodies domestic washing machine and refrigerator cabinets.

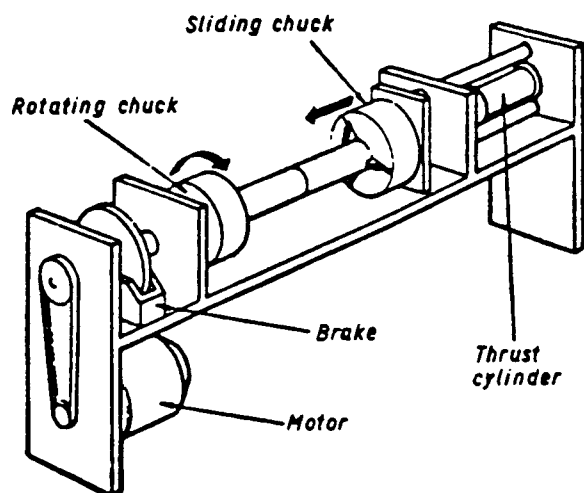
#### Overall advantages

High production rate  
No costly consumables  
Unskilled operation.

#### Overall limitations

Thick material needs large expensive equipment. Joints are usually in the form of a lap, component size and access is limited by machine dimensions. NDT is difficult, quality control is by process control.

## Welding with pressure FRICTION WELDING



Type of operation: mechanised

Equipment: motor to rotate one component  
brake  
axial force system, usually hydraulic  
timer/control system  
chucks for components

### Mode of operation

The two parts to be joined are clamped in chucks and one part is rotated up to welding speed. The second part is brought into contact with the rotating part under axial load. Rubbing friction between the abutting faces produces a hot plastic zone, some of which is extruded radially from the joint taking with it any oxides formed at the joint face. After a preset time rotation is stopped still maintaining or increasing the axial load. The result is a forged butt weld having an excess metal oxide 'flash' which may be removed.

The force system is usually hydraulic or pneumatic; a hydraulic drive may be used for the rotating member.

### Operating parameters

Rotational speed: 50 rev/min – 80 000 rev/min  
Axial pressure: 15–400 MN/m<sup>2</sup>  
Range of size: 1–150 mm diameter  
Cycle time: 5–500 sec  
Access: one member must be rotated  
Portability: fair.

### Consumables

Nil.

### Materials

Almost all metals and thermoplastics. Good for joining dissimilar metals.

### Typical applications

Internal combustion engine valves; head-to-stem joint of dissimilar metals  
Stud welding  
Rear axle casings, transmission and steering components for vehicles  
Electrical connections.

### Overall advantages

Produces welds consistently of high quality  
Fast joining of large area  
Suitable for wide range of materials  
Equipment is mechanical, working on simple principle.

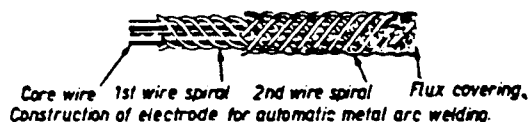
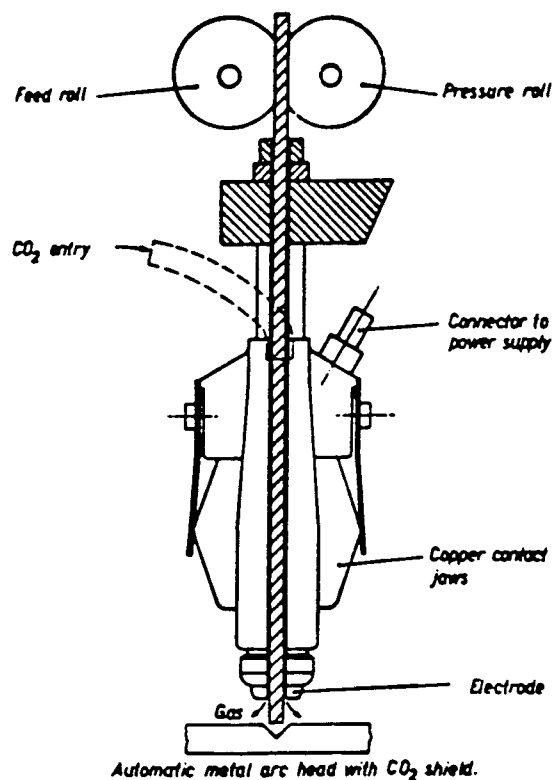
### Overall limitations

One component must be rotated (orbital welding will eliminate this)  
Angular alignment of completed weld not easily controlled.

### Safety

Usual precautions for moving machinery.

## Fusion welding AUTOMATIC METAL-ARC (Fusarc Welding)



Type of operation: mechanised or automatic

Equipment: welding head, control panel  
electrode feed unit  
(may have additional CO<sub>2</sub>  
for shielding)  
Electrode reel.  
power source, transformer  
rectifier or generator —  
AC/DC up to 1000A  
work moving equipment  
and/or head moving  
equipment

### Mode of operation

An arc is maintained between a fluxed electrode and the work. The arc length is controlled by a variable speed motor and feed roll

system. The arc may have an additional CO<sub>2</sub> gas shield. The weld is protected and controlled by the flux coating as in MMA.

### Operating parameters

Current range: 200–1000A  
Deposition rate: 1–15kg/hr  
Range of thickness: 6mm upwards  
Types of joint: butt and fillet  
Welding positions: butt joints flat, fillets,  
flat and HV

Access and .  
portability: good.

### Consumables

Wire wound, flux-coated electrode 2.75–7.5mm on wire diameter. Supplied in coils of 13.5–22.5kg weight. The electrode composition can be selected to suit the parent metal. CO<sub>2</sub> gas in some cases.

### Materials

Only carbon, low alloy high tensile and stainless steels.

### Typical applications

Medium scale fabrication, pipework, shipbuilding, chemical plant.

### Overall advantages

Good deposition rate, good quality weld metal.  
Tolerant to poor fitup and open air work.

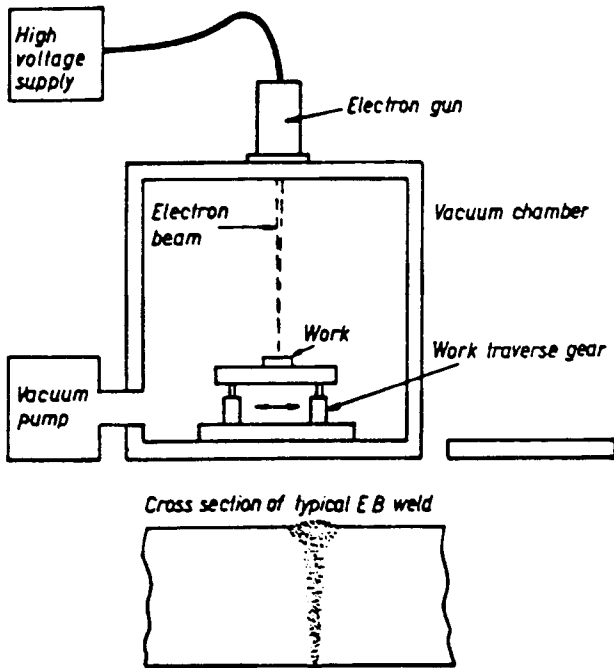
### Overall limitations

Open arc. Electrode needs careful handling.  
Limited penetration.

### Safety

Intense arc. Copious fumes.

## Fusion welding ELECTRON BEAM



### Operating parameters:

Current range: 10-500mA  
 Voltage range: 10-150kV  
 Range of thickness: 0.2-100mm  
 Types of joint: mostly butt  
 Welding positions: limited by equipment  
 Access: good but work must normally be lifted into and out of a fixed chamber  
 Portability: poor.

### Consumables

Filler wire may be added as necessary.

### Materials

Any metal compatible with vacuum when molten.

### Typical applications

Gear clusters/shaft joint  
 Turbine blade root joint  
 Full machined components (low distortion)  
 Difficult-to-weld materials.

### Overall advantages

Excellent penetration. Low distortion  
 No weld metal contamination  
 High welding speeds  
 Ability to weld many normally unweldable materials.

### Overall limitations

High equipment cost  
 Vacuum necessary  
 Extreme accuracy needed in work preparation.

### Safety

X-radiation emitted, but normally absorbed by chamber walls  
 High voltage  
 Operators can be trapped in large chambers.

Type of operation: automatic or mechanised

Equipment: high voltage power supply  
 electron gun  
 vacuum chamber  
 vacuum pump  
 traversing unit, for work or gun

### Mode of operation

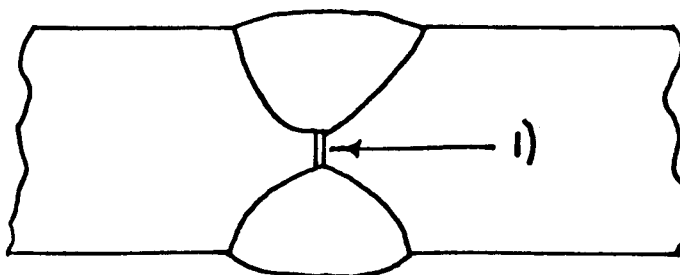
The workpiece is heated by the bombardment of a beam of electrons produced by an electron gun.

Filler metal may be added if necessary.

Though the work is normally within a vacuum chamber, electron guns are currently under development which will allow a beam to travel a short distance through air.

## INTERNAL DEFECTS & THEIR INTERPRETATION

During interpretation it is necessary to identify associated defects, e.g. example 1.



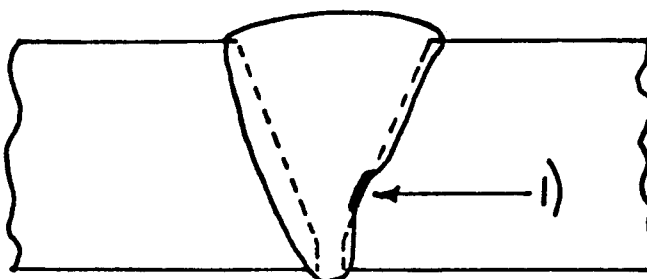
### Report 1: Incomplete root penetration and root fusion

In the above sketch incomplete root penetration can be seen but, because of the loss of penetration, incomplete root fusion is also present.

Planar defects such as incomplete sidewall, incomplete inter-run and incomplete root fusion are very often associated with the presence of a non metallic inclusion, typically slag for MMA and SA and deoxidiser residue for MIG and TIG (ferritic steels).

e.g. example 2.

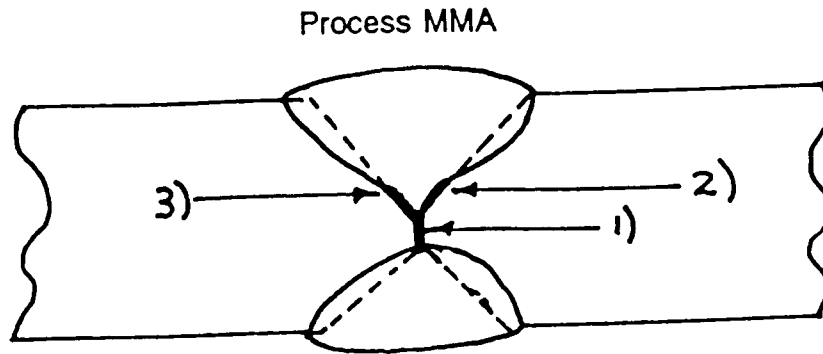
Process MAG



In this example incomplete sidewall fusion is present. Because the defect also has width it can largely be associated with a 'silica' inclusion.

**Report 1: Incomplete sidewall fusion with associated silica dioxide inclusion (and dimension).**

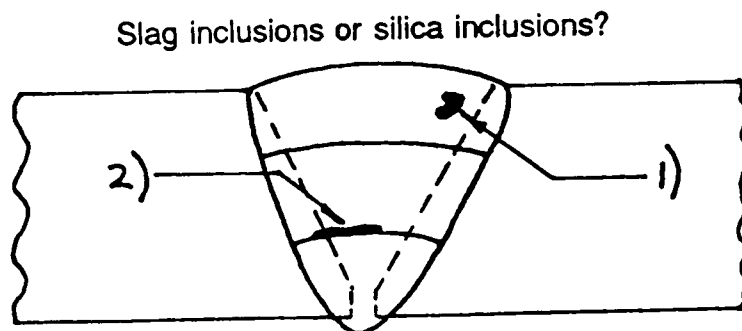
The sketch below shows a root penetration/fusion defect caused because of either insufficient root gap or no back gouging; on examination incomplete sidewall fusion has resulted because of poor access, e.g. example 3.



- Report: 1) Incomplete root penetration and root fusion  
 2) Incomplete sidewall fusion\*  
 3) Incomplete sidewall fusion\*

\*Your judgement will be necessary in order to determine any associated inclusion.

As previously mentioned, slag and silica inclusions are associated with specific processes. With regard to interpretation the Inspector must confirm the welding process in order to make an accurate assessment. This may be by reference to the welding procedure or by assessment of the weld face. Slag inclusions will be clearly volumetric against silica inclusions which will have length and limited width, e.g. example 4..

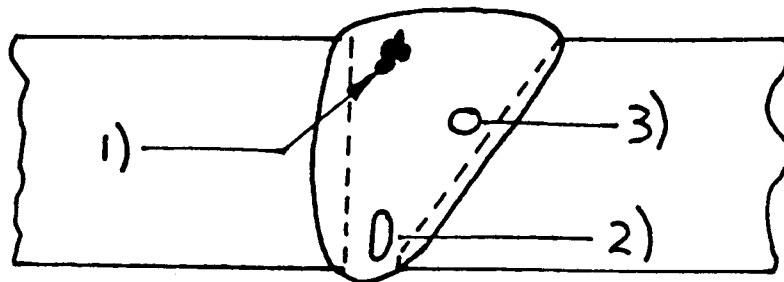


- Report: 1) Slag Inclusion  
 2) Silica Inclusion (Incomplete Interpass fusion may also be present)

In general terms, slag inclusions are non uniform in their shape, also very often the slag is still visible.

Gas inclusions, on the other hand, are generally uniform in their shape and are of a metallic appearance,  
e.g. example 5.

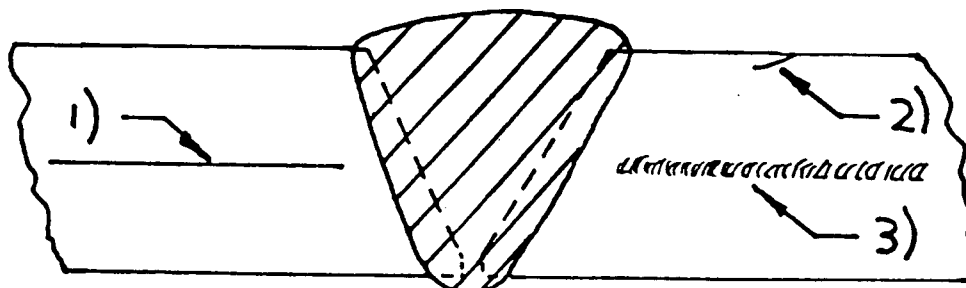
Gas inclusions (pores), porosity or solid inclusions?



|         |    |                      |                     |
|---------|----|----------------------|---------------------|
| Report: | 1) | Slag Inclusion       | }                   |
|         | 2) | Elongated gas cavity | }                   |
|         | 3) | Gas pore             | }                   |
|         |    |                      | dimensions required |

The inspector should report any parent metal defects (laps, laminations and segregation bands)  
e.g. example 6.

Parent metal defects



|         |    |                                                                           |
|---------|----|---------------------------------------------------------------------------|
| Report: | 1) | Laminations (straight and narrow)                                         |
|         | 2) | Lap (near surface of material)                                            |
|         | 3) | Segregation band (similar to lamination but lacks definite edges (hazy)). |

\*Above are examples for reference, greater detail will be provided during the course.

## FRACTURE IDENTIFICATION

For the CSWIP examination the candidate is presented with two fracture specimens, on examination the candidate must state :

1. The welding defect(s)?
2. The main or primary mode of failure?
3. The second or final mode of failure?
4. The failure in weld or parent material?

### 1. DUCTILE FAILURE:

Recognition: a) rough torn  
b) @ 45° to load

Comments: Normal mode of failure for mild steel. "Necking" will occur before failure.

Application (e.g. tensile and bend tests).

### 2. FATIGUE FAILURE:

Recognition: a) Smooth  
b) Bounded by a curve  
c) @ 90° to the load

Comments: This is found in products subject to cyclic loading.

Application (e.g. fatigue tests).

### 3. BRITTLE FAILURE:

Recognition: a) surface is rough but **not** torn  
b) vee markings develop away from start point  
c) @ 90° to load  
d) some plastic deformation may result.

Application: (e.g. charpy and C.T.O.D. tests)

# **SENIOR WELDING INSPECTOR**

## **FRACTURE SURFACES**

- Q1.** Give the typical features of a ductile failure.
- Q2.** Give the typical features of a brittle fracture.
- Q3.** Give the typical features of a fatigue failure.

## **SAFETY**

### **GENERAL LEGAL REQUIREMENTS**

All construction and demolition work is subject to the Health and Safety at Work Act and to certain provisions of the Factories Act. This information sheet sets out some of the basic legal requirements which may apply to you.

### **NOTIFICATION**

#### **Work on construction sites**

You must notify your local Health and Safety Executive (HSE) office of your site if you are starting a 'building operation' (including demolition or maintenance work) or 'work of engineering construction', the work will take six weeks or more and notice has not already been given (e.g. by a main contractor).

#### **Accidents, dangerous occurrences and ill health**

The local HSE office must be notified if:

- (a) a person dies as a result of an accident caused by or connected with work on the site (whether or not that person was at work);
- (b) a person suffers a listed 'major injury' accident (this includes accidents where a person is admitted to hospital for more than 24 hours) or a health condition as a result of an accident caused by or connected with work on the site (whether or not that person was at work);
- (c) a listed 'dangerous occurrence' takes place because of or in connection with the work (e.g. collapse/partial collapse of a scaffold more than 5m high and certain buildings and structures);
- (d) a person at work is prevented from working for three or more days as a result of an injury or illness caused by an accident at work;
- (e) a person at work is affected by a 'specified disease' (e.g. lead poisoning, pneumoconiosis, vibration, white finger), diagnosed by a doctor, and that person had been doing particular types of work.

If the person affected is your employee, *you* must notify HSE. In all other cases it is usually the responsibility of the main contractor.

## **SAFETY SUPERVISOR**

Every contractor who carries out 'building operations' or 'works of engineering construction' and normally employs a total of 21 or more workers must specifically appoint, in writing, one or more people to act as safety supervisor(s). Small contractors usually pay for the part time services of an outside safety supervisor who may work for a safety group or specialist safety company.

### **Duties**

The safety supervisor will advise the contractor/employer on how to comply with the law and will regularly supervise work to see that it is carried out safely.

The safety supervisor must be sufficiently experienced in the type of work being done, be suitably qualified and have enough time and authority to carry out his duties properly.

## **SAFETY POLICY**

Every employer who has five or more employees must prepare a written safety policy. It must be revised as appropriate and brought to the attention of all employees.

## **WELFARE**

Every contractor on site must ensure that adequate welfare facilities are available for his employees. These should include as a minimum:

- (a) adequate washing facilities
- (b) adequate toilets
- (d) drying sheds, huts, rooms or other accommodation for sheltering during bad weather, storing clothes and taking meals (including tables and chairs, facilities for boiling water and a supply of wholesome drinking water).

## **FIRST AID**

Every employer and self-employed person on site must ensure that adequate first aid is available. It is sensible for all contractors to make arrangements with the main contractor to provide first aid (if possible).

First aid arrangements will vary with the degree of risk on the site but should usually include as a minimum:

- (a) adequately stocked first aid box(es);
- (b) a trained first aider(s) (though for small sites it is sufficient to appoint a person to take charge of the first aid box and any situation where serious injury or major illness occurs (responsibilities should include phoning for an ambulance);
- (c) information for workers on site about first aid arrangements, including the location of the nearest telephone.

**EXCLUSION OF CHILDREN AND OTHERS FROM WORK AREAS**

Where possible erect a fence to enclose the site or construction work. The fence should be at least 2m high and difficult to climb up. Where this is not possible, e.g. on a partly occupied new housing site, take special precautions, particularly in the case of children, to:

- (a) protect them from the dangers of excavations, (including shallow ones filled with water), holes or openings and badly stacked materials;
- (b) prevent tampering with vehicles and plant, electricity supplies, gas cylinders and hazardous chemicals. One way of doing this is to provide secure compounds;
- (c) prevent access to higher levels.

**FURTHER INFORMATION**

HSE booklet HS(R)23 *A Guide to Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 1985* ISBN 0 11 883858 X (see also leaflets HSE11 and HSE17)

HSC Guidance on Health and Safety Advisory Services for the Construction Industry:

Part 1 – *The need for advice and the services available* ISBN 0 11 883725 7

Part 2 – *The safety adviser: selection, training and professional standards*  
ISBN 0 11 883726 5

HSE *Writing your health and safety policy statement* ISBN 0 11 883882 2

HSE Guidance Note GS7 *Accidents to children on construction sites* ISBN 0 11 883055 4

HSC Leaflet 1AC/L1 *Guidance on the implementation of safety policies*

HSC Leaflet 11 *Reporting an injury or a dangerous occurrence*

HSC Leaflet 17 *Reporting a case of disease: a brief guide to the Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 1985*

HSE Booklet HS(R)11 *First aid at work* ISBN 0 11 883446 0

*Construction Safety* (an easy to read two volume safety manual)

*The Construction Regulations 1961 and 1966* (an easily understood guide to the Regulations)

Both published by the Building Advisory Service and available from: Construction

Safety, Crompton Way, Crawley, Sussex RH10 2QP (tel 0293 26911)

*Construction Regulations Handbook* published by the Royal Society for the Prevention of Accidents, Cannon House, The Priory, Queensway, Birmingham B4 6BS (tel 021 2332461)

Construction: list of HSC/E References (available free from HSE enquiry points).

## **LAW**

Factories Act 1961

Reporting of Injuries, Diseases and Dangerous Occurrences Regulation 1985

Construction (General Provisions) Regulations 1961

Construction (Health and Welfare) Regulations 1966

Health and Safety (First Aid) Regulations 1981

Health and Safety at work etc Act 1974.

## **ERECTION OF SCAFFOLDING**

### **Stability**

The stability of a scaffold will be affected by how it is used. Therefore it is important that the right design of scaffold is erected for your intended work. Adequate stability is normally achieved for most scaffolds by tying them to the structure that they are serving. At least one 'tie' may be needed for every 32m<sup>2</sup> of scaffolding. More 'ties' will be required if the scaffold is sheeted (due to wind forces) or equipment such as hoists attached to it.

The scaffold itself must be braced to prevent it from collapsing like a stack of cards.

The uprights (standards) must always rest on steel base plates. If the ground is soft it should be well levelled and compacted and timber sole plates used to spread the load. Bricks and other loose material are quite unsuitable for bases.

### **Guard rails and toe boards**

Scaffold platforms from which a person may fall more than 2m should have guard rails and toe boards. Brick guards or other suitable vertical protection should be provided where materials may fall from the scaffold (through scaffold fans, netting or sheeting may be more effective in certain circumstances).

### **Width of the working platform**

If the platform is too narrow it will be difficult to work from and the chances of falling off will be greatly increased. The platform of a general purpose scaffold should be at least four boards wide. However, platforms used only for light work such as painting may be three boards wide, provided no materials are deposited on them.

Many accidents happen because a scaffold board is removed from a working platform for use elsewhere. This creates two unsafe working platforms. **Never** work from platforms which are not fully boarded.

## **OVERLOADING**

Never overload a scaffold – the consequences can be disastrous.

## **TRAINING**

Effective training of scaffolders is an important factor in preventing accidents among both scaffolders themselves and those who use scaffolds. The Construction Industry Training Board (CITB) run training schemes for all levels of scaffolders.

## **ACCESS**

Note that children pose a special problem. Many have been injured because they have fallen from scaffolds or caused them to collapse. Whenever scaffolds are left unattended it is essential to prevent access, e.g. by removing all ladders at ground level and where necessary by erecting hoardings around the bottom of scaffolds.

**AFTER ERECTION OF SCAFFOLDING**

The scaffold must be inspected before use and at least once a week, sometimes daily, to make sure that it remains fit for use, e.g. ties still in place, standards not bent or undermined, platforms fully boarded, guardrails complete etc. The inspections must be carried out by a 'competent person' and the results recorded in Register Form 91 (blue register – available from HMSO).

A contractor who uses someone else's scaffold must make sure that it is safe before using it.

Before dismantling begins check that all ties are in place and that the scaffold is stable. Do not remove the ties until the scaffold has been dismantled down to that level.

All scaffolding must be "tagged".

**FURTHER INFORMATION**

HSE Guidance Note BS15 *General access scaffolds* ISBN 0 11 883545 9

HSE Guidance Note GS7 *Accidents to children on construction sites* ISBN 0 11 883055 4

British Standard BS 5973: 1981 *Code of Practice for access and working scaffolds and special scaffold structures in steel*

National Association of Scaffolding Contractors *Scaffolders' and users' guide to safe access scaffolding*, BEC Publications, Federation House, 2309 Coventry Road, Sheldon, Birmingham B26 3PL

CITB, Bircham Newton, Kings Lynn, Norfolk PE31 6RH (tel 0553 776677)

**LAW**

Construction (Working Places) Regulations 1966 Health and Safety at Work etc. Act 1974

## **SAFETY IN EXCAVATIONS**

Trenching work can be very dangerous. The biggest cause of accidents is the collapse of the sides – anyone inside the trench may be crushed, buried or trapped.

Even the most experienced have been caught out by the sudden collapse of a trench, so in all but the most shallow trenches (less than 1.2m deep) you should plan to provide supports for the sides.

### **PLANNING**

All excavation work must be **planned** before digging begins on site. Make sure that there are enough trench sheets, props, walings or other suitable materials to support the length of trench to be exposed, together with an additional supply for unforeseen events, (for example when the ground becomes very bad and sheets have to be placed closer together). The trench support must be installed without delay as the excavation progresses.

**Never** work ahead of the support.

### **SUPERVISION**

The work should be supervised by a 'competent person' and operatives doing the work should be given clear instructions.

### **CHOICE OF PRECAUTIONS TO PREVENT COLLAPSE – SHALLOW TRENCHES**

1. Battered (sloped) trench sides will generally be temporarily stable if sloped back to a 'safe angle' (for deeper trenches the sides may have to be 'benched').
2. sheeting, waling and strutting (traditional)
3. sheeting, waling and strutting (hydraulic struts)
4. Proprietary support systems, e.g. hydraulic frames, boxes and plate lining systems.

### **AVOIDING DANGER WHEN PLACING SUPPORT FOR A TRENCH**

1. Where soil and sheeting arrangements allow, install the sheeting before you excavate to final depth (i.e. typically install support when trench less than 1.2m deep). The excavation and installation of sheeting should proceed by stages until full depth is achieved; or
2. Use a proprietary support system that can be installed from the top surface;  
or
3. Adopt other safe working practices.

## **INSPECTING TRENCHES**

An excavation should usually be inspected by a 'competent person' at least once a day where people are employed to work in it and thoroughly examined by a 'competent person' (including in particular the support systems) at least once a week. Records should be kept in Register Form 91 (blue register available from HMSO).

## **OTHER CAUSES OF ACCIDENTS**

1. Workers may be struck by material falling into excavations. Remove loose rock etc. store material away from excavations and wear safety helmets. A scaffold board wedged along the outside of the trench sheets may also help.
2. Workers may fall into excavations. Erect suitable barriers, using projecting trench sheets as uprights, where possible. Barriers should be high enough to prevent falls.
3. Unsafe access.
4. Vehicles may be driven into the excavation. Use adequate stop blocks and barriers.
5. Asphyxiation or poisoning caused by fumes and gases.

## **FURTHER INFORMATION**

CIRIA Technical Note 95 *Proprietary Trench Support Systems* 1982 by E B Mackay

CIRIA Report 97 *Trenching Practice* by D J Irvine and R J H Smith 1983 ISBN 0 86017 192 2 available from the Publications Dept., CIRIA, 6 Storey's Gate, Westminster, London SW1P 3AU Tel. 01 222 9981.

British Standard BS 6031: 1981 *Code of Practice for earthworks*

## **LAW**

Construction (General Provisions) Regulations 1961

Health and Safety at Work etc. Act 1974

## **CONFINED SPACES**

Ignorance of the dangers of 'confined spaces' has led to the deaths of a number of construction workers. In many cases, attempted rescue has ended in tragedy with the death of the poorly equipped rescuer as well.

### **WHAT IS A CONFINED SPACE?**

A closed tank with restricted access may be the obvious example of a 'confined space', but it also includes open manholes, trenches, pipes, flues, ducts, ceiling voids, enclosed rooms such as basements, and other places where there is inadequate natural ventilation.

### **WHAT MAKES A CONFINED SPACE DANGEROUS?**

1. The work being done in the confined space can make the space dangerous. Examples are:
  - (a) Some painting work, the application of certain coatings and attempts to clean areas with such liquids as degreasing agents. These can produce dangerous amounts of solvent vapour which can cause dizziness and impair judgement (e.g. a person working at heights will be more likely to fall). These effects can persist, making it dangerous to drive a car. Inhaling enough solvent can cause collapse and even death. Such solvents are also often flammable, so there is a serious risk of fire as well.
  - (b) Operations such as welding. These produce fumes and gases that can push out the available air, causing collapse and even death;
  - (c) LPG appliances and petrol or diesel engines which can lead to the build up of poisonous carbon monoxide gas. There is also a risk of fire resulting from leakages of LPG from hoses or cylinders.
2. Some 'confined spaces' may be hazardous themselves.
  - (a) Confined spaces may fill partly with fumes and gases
  - (b) Sludges and other residues in tanks, pits etc. if disturbed, may partially fill those 'confined spaces' with dangerous gases.
  - (c) Rusting of metalwork (e.g. tanks) and similar natural processes may consume so much oxygen that there is not enough left to breathe causing the collapse of any person inside the space.

## PRECAUTIONS

If work in a 'confined space' could be potentially dangerous, entry must be strictly controlled (preferably through a permit-to-work system) and detailed precautions taken.

1. Where the work being carried out could cause danger:
  - (a) Keep the hazard out of the 'confined space', e.g.
    - (i) Do not use petrol or diesel engines inside the space (site them outside in a well ventilated area);
    - (ii) Avoid paints and adhesives which give off dangerous solvent vapours (e.g. use water based adhesives).
  - (b) If this cannot be done, provide adequate ventilation (forced ventilation may be required) to remove or dilute the dangerous gases and provide fresh air.

Tests may also be required to identify any dangerous amounts of flammable or poisonous gases.
2. Where the 'confined space' itself may be dangerous (regardless of any work carried out):
  - (a) Test for adequate levels of oxygen dangerous amounts of flammable and/or poisonous gases (proprietary meters and lamps are available). Do not enter the space if these tests show that the air is dangerous inside. Provide forced ventilation to remove or dilute the gases and supply fresh air. Retest to make sure that the air inside is safe to breathe. Continue testing while any person is inside the space;
  - (b) Ensure that anyone entering the space has received proper training and instruction in the precautions to be taken inside;
  - (c) Ensure that someone remains outside to keep watch and to communicate with anyone inside;
  - (d) Rescue harnesses should be worn by all people inside the 'confined space', with lifelines attached, if possible;

- (e) Rescue procedures should be included in the training of the workers. Don't rely on one person alone to lift injured or unconscious people out of a 'confined space' during rescue, unless they are equipped with special lifting appliances. Keep rescue equipment, including emergency breathing apparatus, near the entrance;
- (f) Never attempt to clear fumes or gases with pure oxygen.
- (g) Do not rely on canister respirators in 'confined spaces'.

## CONSTRUCTION SITE SAFETY CHECKLIST

These four pages list the main points to consider when you are checking the safety of a site.

It is not a comprehensive list. More detailed information can be found in HSE summary sheets for small contractors (available free from HSE area offices) and in various priced publications available from HMSO bookshops.

For further advice on health and safety contact your local HSE area office (look under Health and Safety Executive in the phone book).

### SAFE ACCESS

- Can everyone reach their place of work safely, i.e. are there good roads, gangways, passageways, passenger hoists, staircases, ladders and scaffolds?
- are all walkways level and free from obstructions such as stored material and waste?
- are there adequate barriers or other edge protection to stop falls from open edges of buildings, gangways etc?
- are holes and openings securely fenced off or provided with fixed, clearly marked covers?
- is there adequate artificial lighting when work is carried on after dark or inside buildings?
- is the site tidy, and materials stored safely?
- are there proper arrangements for collecting and disposing of scrap?

### LADDERS

- are ladders the right equipment to use for the job, or should a scaffold be provided?
- are all ladders in good condition?

- are ladders secured near the top (even if they will be used for only a short time)?
- if ladders cannot be secured at the top, are they secured near the bottom, weighted or footed to prevent slipping?
- do the ladders rise at least 1.07m (3ft 6in) above their landing places or the highest rungs used? If not, are there adequate handholds?

### **TUBULAR SCAFFOLDS**

- is there proper access to the scaffold platform?
- are all uprights provided with base plates (and, where necessary, timber sole plates) or prevented in some other way from slipping or sinking?
- have any uprights, ledgers, braces or struts been removed?
- is the scaffold secured to the building in enough places to prevent collapse?
- if any ties have been removed since the scaffold was erected have additional ties been provided to replace them?
- are the working platforms fully boarded?
- are boards free from obvious defects such as knots, and are they arranged to avoid tipping or tripping?
- are there effective barriers or warning notices to stop people using an incomplete scaffold, e.g. one that is not fully boarded?
- are there adequate guard rails and toe boards at every side from which a person could fall more than 1.98m (6ft 6in)?
- where the scaffold has been designed and constructed for loading with materials are these evenly distributed?
- does a competent person inspect the scaffold regularly i.e. at least once a week and always after bad weather?
- are the results of inspections recorded (including defects that were put right during the inspections) and the records signed by the person who carried out the inspections?

## **EXCAVATIONS**

- has an adequate supply of timber, trench sheets, props or other supporting material been delivered to the site before excavation work begins?
- is this material strong enough to support the sides?
- is a safe method used for putting in timbering i.e. one that does not rely on people working within an unsupported trench?
- if the sides of the excavation are sloped back or battered, is the angle of batter sufficient to prevent collapse?
- is the excavation inspected daily, and the timbering or other support weekly?
- is there safe access to the excavation e.g. by a sufficiently long ladder?
- are there barriers to stop people falling in?
- is the excavation affecting the stability of neighbouring buildings?
- are stacked materials, spoil or plant stored near the edge of the excavation likely to cause a collapse at the side?
- if vehicles tip into the excavation, are properly secured stop blocks provided?

## **CRANES AND LIFTING APPLIANCES**

- is the crane inspected weekly, and thoroughly examined every 14 months by a competent person?
- are the results of inspections recorded?
- is there a test certificate?
- is the driver trained, competent and over 18?
- are the controls (levers, handles, switches etc.) clearly marked?
- do the driver and banksman find out the weight of the load before trying to lift it?

- . if it is a jib crane with a capacity of more than 1 ton, does it have an efficient automatic safe load indicator that is inspected weekly?
- . if it is a hydraulic excavator being used as a crane, is the maximum safe load clearly marked and are hydraulic check valves fitted where required by the Certificate of Exemption?
- . is the crane on a hard level base?
- . has the banksman/slinger been trained to give signals and to attach loads correctly and does he know the lifting limitations of the crane?
- . if it can vary its operating radius, is the crane clearly marked and its safe working loads and corresponding radii?
- . is the crane maintained regularly?

## **ELECTRICITY**

- . are all portable electric tools and equipment supplied from 110V transformers, or have special measures been taken to protect them from mechanical damage and wet conditions?
- . can you see any signs of damage to or interference with equipment, wires and cables?
- . are all connections to power points made by proper plugs?
- . are connections to plugs properly made so that the cable grip holds the cable firmly and prevents the earth wire from being pulled out?
- . are there any overhead electric lines? Where anything might touch the lines or cause arcing (cranes, tipper lorries, scaffolding etc.) has the electricity supply been turned off, or other precautions taken to prevent such contact with the lines?
- . have underground electricity cables been located (with a cable locator and cable plans), marked, and precautions taken to avoid contact with them?

**FIRE****General**

- does your site have the right number and type of fire extinguishers? Where are they needed?
- are there adequate escape routes? Are they kept clear?
- do your workers know what to do in an emergency?

**Flammable liquids**

- is there a proper store area?
- is the amount of flammable liquid on site kept to a minimum for a day's work?
- is smoking prohibited? Are other ignition sources kept away from flammable liquids?
- are properly constructed safety containers used?

**Compressed gases (e.g. LPG, acetylene)**

- are cylinders stored properly?
- is the cylinder valve fully closed when the cylinder is not in use?
- are cylinders sited outside huts?

**Other combustible material**

- are there proper waste receptacles?
- is waste material removed regularly?

**NOISE**

- is other plant or machinery fitted with silencers?

- do workers wear ear protection if they have to work in very noisy surroundings?

## **HEALTH**

- have harmful materials been identified and precautions taken?
- are safety information sheets available from the supplier?
- is safety equipment provided and used?
- are other workers who are not protected kept out of danger areas?
- in confined spaces, has the atmosphere been tested and a fresh air supply provided if necessary? Are emergency procedures in place for rescue from the confined space?

## **PROTECTIVE CLOTHING**

- is equipment provided to protect the head, eyes, hands and feet?
- does the equipment meet at least the minimum standard required by law?
- do workers wear their protective equipment?

## **WELFARE**

- has a suitable toilet been provided?
- is there a clean washbasin, soap and towel?
- is there a hut where clothes can be dried?
- is wet weather gear provided for those who have to work in wet conditions?
- is there a site hut where workers can sit and make tea?
- is there a first aid box?

## **FLAME CUTTING AND WELDING WITH COMPRESSED GASES**

### **THE MAIN DANGERS**

- 1 Fires caused by leakage of fuel gas (propane, acetylene etc.), usually from damaged or badly joined sections of hose.
- 2 Cylinder explosions caused by fire or impact damage. Fragments may be flung over a wide area.
- 3 Fires caused by accidental leakage of oxygen from hoses or cutting torches. Sometimes a person may release oxygen deliberately to try to clear fumes from the air. When there is too much oxygen in the air just one spark may set clothing alight. Oily or greasy clothes may catch fire spontaneously.
4. Flashback caused by the operator trying to light the cutting torch when there is a mixture of oxygen and fuel gas in one hose.
5. Explosions or fires caused by flame cutting or welding drums, tanks etc that contain flammable materials (e.g. solvents), even in small amounts.
6. Breathing in dangerous fumes during cutting or welding operations.
7. Nearby flammable materials catching fire.

### **TRANSPORTING AND STORING CYLINDERS**

Treat acetylene cylinders in the same way as propane cylinders. You may store the two types together.

When transporting oxygen cylinders, adequately secure them in an upright position to prevent damage to the valve. Do not store them with fuel gas cylinders.

Transport cylinders in open vans where possible. Limit the amount of any flammable material carried (e.g. a can of petrol) and keep it well away from the cylinders. Closed vans will need a high standard of ventilation built into the sides, at least.

**Never** keep cylinders in poor ventilated areas – dangerous levels of gas or oxygen may build up.

### **HANDLING CYLINDERS**

Never roll a cylinder along the ground or handle it roughly. Wherever possible use a proper cylinder trolley.

## EQUIPMENT

Use a good quality hose and check it every day for signs of damage. Keep the hose length as short as possible (5m maximum for welding and 20m maximum for cutting). If lengths of hose have to be joined (e.g. after removal of damaged sections) use proper hose couplers with proprietary hose clamps. Do not use makeshift couplers made from pipe and twisted wire – they are liable to leak or come apart. Use a proper coupler to connect the hose to the cylinder regulator. **Never** use a naked flame to check cylinders and hose connectors for leaks – use soapy water instead. If you find a leak at a cylinder and you cannot stop it, take the cylinder to a safe place in the open air and contact your supplier for advice.

Fit non–return valves to each hose to help reduce the risk of flashback.

Keep oil and grease away from oxygen cylinders, hoses and work clothes. Oxygen build up can lead to sudden, fierce fires.

## USING CYLINDERS

### Lighting up procedure

Follow the manufacturer's recommended procedure. When purging hoses (to reduce the risk of flashback) make sure the area is well ventilated.

### Cutting drums and tanks

**Do not permit the cutting or welding of drums, tanks etc unless you are sure that they are safe.** If they contain even a small amount of petrol, solvent, oil or other flammable liquid, sludge or solid they may explode. To avoid this danger such containers need to be thoroughly cleaned (e.g. by steam), tested and certified 'gas free' by a competent person before any hot cutting or welding is carried out. This cleaning and testing is a job for a specialist company.

Alternatively the container may either be:

- (a) completely filled with water and the top removed; or
- (b) cold cut, provided that suitable precautions are taken to prevent sparks.

Cold cutting needs more care than method (a), which is preferable.

For tank repairs you may be able to use cold setting resins.

**Fumes**

The most common problem lead poisoning caused by flame cutting steel that is coated with lead based paint, but welders and burners can get metal fume fever through working with plated metal. Cadmium plated materials are especially dangerous.

Nitrous fumes produced during all welding and cutting operations can build up very quickly in poorly ventilated areas such as excavations, pits, small basements, tanks etc. Workers have died after breathing in such fumes for as little as 15 minutes.

In poorly ventilated areas forced ventilation is essential. Workers who carry out welding or cutting where there is a risk of breathing in dangerous fumes will have to wear approved respirators.

**FIRE FIGHTING AND PROTECTIVE EQUIPMENT**

Remove flammable materials from the work area and provide suitable fire fighting equipment. Workers should wear suitable eye protection and protective clothing to protect them from burns etc.

**FURTHER INFORMATION****HSE publications**

HSE Guidance Note GS29/3 *Health and safety in demolition work techniques*  
ISBN 0 11 883609 9

HSE Guidance Note CS15 *Cleaning and gas freeing tanks containing flammable residues* ISBN 0 11 883518 1

HSE Guidance Note MS15 *Welding* ISBN 0 11 883184 4

HSE Guidance Note EH29 *Control of lead: outside workers* ISBN 0 11 883395 2

HSE leaflet IND(G) 35(L) *Hot work on tanks and drums*

HSE leaflet *Fires and explosions due to the misuse of oxygen*

*Certificate of Approval Respiratory protective equipment*

F2486 ISBN 0 11 883923 3

(all available from HMSO bookshops).

**Manufacturer's information booklets**

BOC Ltd has produced two booklets: *Safe under pressure* and *Handbook of operating instructions*. Available from: BOC Ltd, The Priestly Centre, 10 Priestly Road, Surrey Research Park, Guildford, Surrey GU2 5XY (Tel. 0483 579857)

Air Products Ltd has produced a booklet called *Welding and cutting gases*. Available from Air Products Ltd, Hersham Place, Molesey Road, Walton on Thames, Surrey KT12 4RZ (Tel. 0932 249200).

## **LAW**

Construction (General Provisions) Regulations 1961

Highly Flammable Liquids and Liquefied Petroleum Gases Regulations 1972

Control of Lead at Work Regulations 1981 (and Approved Code of Practice)

Health and Safety at Work etc Act 1974

## **SAFETY**

- Q1. State ten (10) topic areas of safety and comment on potential problems.
- Q2. State the general requirements for welding in containment vessels.
- Q3. State four (4) safety precautions that should be observed in "site welding" activities.
- Q4. State the general safety requirements for access equipment.
- Q5. State the general safety requirements for pipeline operations.

# AMERICAN WELDING SOCIETY STANDARD WELDING SYMBOLS\*

| Basic Welding Symbols and Their Location Significance |            |              |                    |                |                                          |                 |                                                                                                                                                                                         |                        |             |
|-------------------------------------------------------|------------|--------------|--------------------|----------------|------------------------------------------|-----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------|-------------|
| Location Significance                                 | Fillet     | Plug or Slot | Spot or Projection | Stud           | Seam                                     | Back or Backing | Surfacing                                                                                                                                                                               | Flange Corner          | Flange Edge |
| Arrow Side                                            |            |              |                    |                |                                          |                 |                                                                                                                                                                                         |                        |             |
| Other Side                                            |            |              |                    | Not used       |                                          |                 | Not used                                                                                                                                                                                |                        |             |
| Both Sides                                            |            | Not used     | Not used           | Not used       | Not used                                 | Not used        | Not used                                                                                                                                                                                | Not used               | Not used    |
| No Arrow Side or Other Side Significance              | Not used   | Not used     |                    | Not used       |                                          | Not used        | Not used                                                                                                                                                                                | Not used               | Not used    |
| Location Significance                                 | Groove     |              |                    |                |                                          |                 |                                                                                                                                                                                         | Scarf for Brazed Joint |             |
|                                                       | Square     | V            | Bevel              | U              | J                                        | Flare-V         | Flare-Bevel                                                                                                                                                                             |                        |             |
| Arrow Side                                            |            |              |                    |                |                                          |                 |                                                                                                                                                                                         |                        |             |
| Other Side                                            |            |              |                    |                |                                          |                 |                                                                                                                                                                                         |                        |             |
| Both Sides                                            |            |              |                    |                |                                          |                 |                                                                                                                                                                                         |                        |             |
| No Arrow Side or Other Side Significance              |            | Not used     | Not used           | Not used       | Not used                                 | Not used        | Not used                                                                                                                                                                                | Not used               |             |
| Supplementary Symbols                                 |            |              |                    |                | Location of Elements of a Welding Symbol |                 |                                                                                                                                                                                         |                        |             |
| Weld-All Around                                       | Field Weld | Melt-Thru    | Consumable Insert  | Backing Spacer | Contour                                  |                 |                                                                                                                                                                                         |                        |             |
|                                                       |            |              |                    |                | Flush                                    | Convex          | Concave                                                                                                                                                                                 |                        |             |
|                                                       |            |              |                    |                |                                          |                 |                                                                                                                                                                                         |                        |             |
| Basic Joints                                          |            |              |                    |                |                                          |                 |                                                                                                                                                                                         |                        |             |
| Identification of Arrow Side and Other Side of Joint  |            |              |                    |                |                                          |                 |                                                                                                                                                                                         |                        |             |
| Butt Joint                                            |            | Corner Joint |                    |                |                                          |                 |                                                                                                                                                                                         |                        |             |
|                                                       |            |              |                    |                |                                          |                 |                                                                                                                                                                                         |                        |             |
| T-Joint                                               |            | Lap Joint    |                    |                | Edge Joint                               |                 | Process Abbreviations                                                                                                                                                                   |                        |             |
|                                                       |            |              |                    |                |                                          |                 | Where process abbreviations are to be included in the tail of the welding symbol, reference is made to Table 1. Designation of Welding and Allied Processes by Letters, of AWS A2.4-86. |                        |             |
|                                                       |            |              |                    |                |                                          |                 | AMERICAN WELDING SOCIETY, INC.<br>550 N.W. LeJeune Rd., Miami, Florida 33126                                                                                                            |                        |             |

| Typical Welding Symbols                  |                                                     |                                                         |
|------------------------------------------|-----------------------------------------------------|---------------------------------------------------------|
| <b>Double-Fillet Welding Symbol</b><br>  | <b>Chain Intermittant Fillet Welding Symbol</b><br> | <b>Staggered Intermittant Fillet Welding Symbol</b><br> |
| <b>Plug Welding Symbol</b><br>           | <b>Back Welding Symbol</b><br>                      | <b>Backing Welding Symbol</b><br>                       |
| <b>Spot Welding Symbol</b><br>           | <b>Stud Welding Symbol</b><br>                      | <b>Seam Welding Symbol</b><br>                          |
| <b>Square-Groove Welding Symbol</b><br>  | <b>Single-V Groove Welding Symbol</b><br>           | <b>Double-Bevel-Groove Welding Symbol</b><br>           |
| <b>Symbol with Backgouging</b><br>       | <b>Flare-V Groove Welding Symbol</b><br>            | <b>Flare-Bevel-Groove Welding Symbol</b><br>            |
| <b>Multiple Reference Lines</b><br>      | <b>Complete Penetration</b><br>                     | <b>Edge Flange Welding Symbol</b><br>                   |
| <b>Flash or Upset Welding Symbol</b><br> | <b>Melt-Thru Symbol</b><br>                         | <b>Joint with Backing</b><br>                           |
| <b>Joint with Spacer</b><br>             | <b>Flush Contour Symbol</b><br>                     | <b>Convex Contour Symbol</b><br>                        |

\*It should be understood that these charts are intended only as shop aids. The only complete and official presentation of the standard welding symbols is in A2.4.

## **Certification Scheme for Welding and Inspection Personnel**

### **Phase 6: Senior Welding Inspectors and Welding Inspectors**

#### **Codes, Standards and Specifications**

The following is a list of Codes/Standards and Specifications to which candidates for the above examinations may use. They may be selected by the candidate or the candidate's employer.

The candidate is required to have a good working knowledge of his/her chosen Code/Standard or Specification. In addition, they should also be aware and in possession of any such specifications that may be cross referenced by their main application Code/Standard, relating to Materials, Consumables, Welding procedure/Welder qualifications, destructive and non destructive testing etc.

The candidate should ensure that the selected code, Standard/Specification is up to date, and wherever possible contains the latest amendments.

The use of any document not listed, may be permitted by contacting the Approvals Examiner responsible. In certain circumstances a copy for scrutinising may be requested before permission is given.

To be accepted for examination, candidates for Welding Inspector must have had **at least three years experience related to the duties required**, under qualified supervision.

Candidates need to be in satisfactory physical condition and the person completing the application form will be required to signify that the candidate's health and eyesight are adequate to enable him to carry out his duties.

**British**

|                |                                                                                                                                             |
|----------------|---------------------------------------------------------------------------------------------------------------------------------------------|
| <b>BS 1113</b> | Specification for design and manufacture of Water-tube steam Generating Plant (including superheaters, reheaters and steel tube economies). |
| <b>BS 2633</b> | Specification for Class 1 arc welding of ferritic steel pipework for carrying fluids.                                                       |
| <b>BS 2654</b> | Specification for manufacture of vertical steel welded storage tanks with butt-welded shells for the petroleum industry.                    |
| <b>BS 2971</b> | Specification for Class II arc welding of carbon steel pipework for carrying fluids.                                                        |
| <b>BS 3351</b> | Specification for piping systems for petroleum refineries and petro-chemical plants.                                                        |
| <b>BS 4515</b> | Specification for process of welding of steel pipelines on land and offshore.                                                               |
| <b>BS 4677</b> | Specification for arc welding of austenitic stainless steel pipe work for carrying fluids.                                                  |
| <b>BS 5500</b> | Specification for unfired fusion welded pressure vessel.                                                                                    |
| <b>BS 6235</b> | Code of practice for fixed offshore structures.                                                                                             |

**American**

- ANSI/ASME B31-3: Chemical plant and petroleum refinery piping.
- API 1104: Standard for welding pipelines and related facilities (16th Edition).
- ASME VIII division 1: Boiler and Pressure vessel code.
- ANSI/AWS D1.1: Structural Welding Code (Steel)
- ABS Rules for Building and Classing Steel vessels (American Bureau of Shipping).

In addition the following are permissible:

- AESS 6021:  
Parts 1 and 2 Fusion welded fabrication in Austenitic Stainless steel.
- NF 0081/1&2: NF Standard, Fabrication of stainless steel
- British Engineering Standard BGC/PS/P2 1981. Specification for field welding of steel pipelines and installations.
- MOD/NAVY DGS – NAS 3 Acceptable standard for welds  
DGS – GS – 3003 General Welding Specification
- Det Norske Veritas: Rules for the design, construction and Inspection of offshore structures.

# **CSWIP SENIOR WELDING INSPECTOR**

**TECHNOLOGY PAPER 5 FROM 7 QUESTIONS**

**MANDATORY QUESTION: "SIGNING OFF OF A PRODUCT" +  
SUPERVISORY PART  
1 HR 15 MINUTES**

**ENGINEERING DRAWINGS: SCRUTINY OF WELD SYMBOLS  
1 HR.**

**FRACTURE ASSESSMENT REPORTING ON TWO FRACTURES AND THEIR  
PROBABLE CAUSE(S) OF FAILURE  
1 HR.**

**NDT REPORTS: 3 NDT REPORTS FOR SCRUTINY  
1 HR.**

**ALSO REQUIRED:**

**RADIOGRAPHIC INTERPRETER  
PRACTICAL AND THEORY**