Jointing of Copper Pipework for Refrigeration Systems

Specification & Procedures for Manual Torch Brazing and Brazer Assessment

Issue 4 – May 2012

Foreword

Recognising the importance of brazed joints in maintaining the effective and efficient operation of refrigeration and air conditioning systems the BRA Commercial Contractors Section has developed this simple brazing procedure specification for jointing copper pipework for refrigeration systems.

The specification also incorporates a practical means of assessing an individual's competence to braze joints for refrigeration & air conditioning pipe work in accordance with national standards used by the industry and relevant legislation.

BRA hopes that this specification will continue to be the accepted industry standard and, as such, we commend it to you.

This specification has been endorsed by the Technical Committee of the Institute of Refrigeration.

This document has been written in accordance with EN14276-1:2006+A1:2011 Pressure equipment for refrigerating systems and heat pumps (harmonised to PED 97/23/EC), Annex B - Specification and approval of brazing procedures, brazers and brazing operators, as a suitable procedure to assess and approve individuals carrying out the jointing of copper pipework in accordance with Sound Engineering Practice (SEP) and the category 1 modules of the Pressure Equipment Directive (97/23/EC) / Pressure Equipment Regulations 1999 (SI 1999/2001).

Acknowledgements

The BRA would like to thank the following people for their assistance in revising this brazer procedure:

Stephen Benton – Cool Concerns Ltd
Jane Gartshore – Cool Concerns Ltd
David Paget – Lloyd's Register EMEA
David Tidball – FSW Ltd
Keith Duncan – Honeywell Control Systems Ltd
Paul Arrowsmith – WR Refrigeration Ltd

Disclaimer

FETA uses its best efforts to promulgate Standards and Guidelines for the benefit of the public in the light of available information and accepted industry practices but do not intend such Standards and Guidelines to represent the only methods or procedures appropriate for the situation discussed. FETA does not guarantee, certify or assure the safety or performance of any products, components, or systems tested, installed or operated in accordance with FETA's Standards or Guidelines or that any tests conducted under its Standards or Guidelines will be non-hazardous or free from risk.
FETA, and the individual contributors, disclaims all liability to any person for anything or for the consequences of anything done or omitted to be done wholly or partly in reliance upon the whole or any part of the contents of this document.

Contents

BRITISH REFRIGERATION ASSOCIATION
The jointing of copper pipework for refrigeration systems

1.0 Scope

1.1 This document describes the procedure known as the brazing and competences required for the jointing of copper tube as used in the process of constructing pipework systems within the refrigeration and air conditioning industry and by which the knowledge, ability and experience of individuals is brought together in order to assess their suitability for undertaking brazing processes in a safe and competent manner, maintaining the high standards required within the refrigeration and air conditioning industry.

The purpose of this procedure is to provide advice on the methodology of competence and the type of documentation required to verify best practice has been carried out. The procedure is suitable for PED categories SEP, 1, 2, 3 & 4 joints. SEP & Cat 1 can be self-certified by the centre, categories 2 and higher require third party approval and additional testing of the candidates test pieces would be necessary.

1.2 This document is not intended to provide a detailed account of methods for brazed joints and brazing, this is dealt with elsewhere (e.g. text books and other reference documentation). This document gives guidance on the information required to allow best practice and assessment for competence for the brazing of refrigeration copper pipework, and the necessary assessment of competence for those individuals undertaking these brazing processes. The joints described in this document cover the majority of field based brazed or silver soldered lap joints, copper to copper or copper to steel or brass in a size range typically ¼" to 4 1/8". If joint or material types differ from the range specified additional brazer procedure specifications and approvals will be required in accordance with BS EN 14276.

2.0 Regulations

2.1 The need to maintain safe working practices throughout any brazing process is paramount both in the workplace and when carrying out training and assessment. The following is a list of the regulations that apply to these processes at the time of writing:

a) Health & Safety at Work Act 1974
b) Management of Health & Safety at Work Regulations 2006
c) Carriage of Dangerous Goods (Classification, Packaging, and Labelling) and Use of Transportable Pressure Receptacle Regulations 2004
d) Manual Handling Operations Regulations 1992 (as amended)
e) The Control of Substances Hazardous to Health Regulations 2002 (as amended)
f) Personal Protective Equipment at Work Regulations 1992 (as amended).
g) Workplace (Health, Safety and Welfare) Regulations 1992 (as amended by the Quarries Miscellaneous Health and Safety Provisions Regulations 1995).
h) Environmental Protection Act 1990
i) Provision & Use of Work Equipment (PUWER) 1998

Note: The above list is not exhaustive.

3.0 Definitions

3.1 Brazing

A process of jointing generally applied to metals in which during or after heating, molten filler metal is drawn by capillary action, into or retained in the space between the closely adjacent surfaces of the components being joined. In general the melting point of the filler metal is above 450°C, but always below the melting point of the parent metal.

3.2 Parent Material

The materials that are to be joined which shall conform to the requirements of the relevant standards.

3.3 Filler Metals

The metal which in a molten state is drawn into and fills the space between the closely associated surfaces of the components being joined and which on cooling, forms a bond between these surfaces

3.4 Test or Assessment

A critical trial (often involving stress) or examination of one or more properties or characteristics of a material, product, or set of observations.

3.5 Test Sample

An assembly brazed in accordance with an approved brazing procedure, it may be one of the following

a) A brazed construction, either taken from production or made specifically for test purposes.
b) A brazed joint detached from a brazed construction
c) A simulation which will adequately replicate the brazed joint in the production assembly e.g., for approval testing

3.6 Approved Brazing Procedure

A documented brazing procedure which has been approved by an industrial, trade body or notified body.

3.7 Examining Authority

A third party who verifies the company's compliance with this recommended best practice.

3.8 Assessor

A competent person in the practices of brazing and the jointing of copper pipework for refrigeration systems, qualified ideally by means of a nationally recognized brazing

certificate or manufacturer's skills test and an appropriate nationally recognised assessor award.

3.9 Internal Authority

That person who administers this scheme within the company or organisation i.e., training manager, quality manager, internal verifier.

4.0 Associated Standards and References

4.1 In compiling this document, reference has been made to a number of standards publications and procedures. These are listed below:

a. BS EN ISO 9001 2008
b. B.R.A. Model Task Procedures & Risk Assessments
c. BS EN 378-1:2008
d. BS EN 378-2:2008 + A1:2009
e. BS EN 378-3:2008
f. BS EN 378-4:2008
g. British Compressed Gases Association Codes Of Practice
h. BS EN 14324:2004
i. BS EN 14276-1:2006+A1:2011
j. BS EN 14276-2:2007+A1:2011
k. BS EN 12735-1:2010

5.0 Health & Safety

As stated previously in section three of this document, health & safety awareness forms a most important part of carrying out any brazing process. In order that safe working practices are maintained the following issues associated with manual flame brazing must be addressed. A full risk assessment must be carried out for all the activities involved specific to the work area where the assessment is being carried out.

5.1 Hazardous Materials & Gases

Both the oxygen and fuel gases, together with most materials used in the brazing process are hazardous to health. Operatives should make themselves aware of these hazards by being familiar with the Method Statements, Risk Assessments, C.O.S.H.H. and any specific site restrictions such as hot work permits and appropriate insurance cover.

5.2 Working processes

Working areas where brazing processes are to be performed must be well ventilated and free from fire risk. Fumes and gases detrimental to health are emitted from most brazing processes; these must be disposed of quickly, either by use of exhaust ventilation equipment or adequate circulation of fresh air throughout the working area. If necessary where these criteria cannot be assured operators should wear breathing apparatus.

The brazing process relies on the heat input being applied evenly below the melting temperature of the parent metal, but sufficient to reach the melting temperature of the filler metal. The following precautions should be taken to ensure safe operation.

a) Correct lighting up procedures (see manufacturers instructions).
b) Avoidance of handling hot work pieces.
c) The use of correct protective clothing wherever required.
d) Adequate ventilation.
e) Adequate & sufficient fire fighting equipment.

5.3 Personal Protective Equipment (P.P.E.)

When carrying out brazing processes precautions shall be taken to protect exposed parts of the head, body and clothing against heat and hot metal particles by wearing adequate protective clothing.

a) Gloves

These shall be worn to protect against heat and hot particles, and are usually made from chrome leather. Other proprietary brands are available made from a heat resisting material known as Kevlar

b) Body Protection

Flame retardant overalls should be worn wherever practical for all brazing operations. Additional arm protection may be needed in restricted work areas.

c) Eye Protection

It is necessary to protect the eyes against heat and glare which may cause eye strain, but more important from flying hot particles. There are various types of goggles or safety glasses. Operator preferences and visual activity will influence the individual's choice.

d) Head and Foot Protection

Where there is a risk of injury from falling objects and contact with hot work pieces etc, both these items of P.P.E. shall be worn.

5.4 Equipment Safety

All brazing equipment comprising regulators, flash back arrestors, hoses, torches, nozzles and cylinders shall be maintained and checked in accordance with the British Compressed Gases Association Code of Practice 7, both on a daily and annual basis, and recording of inspection maintained.

6.0 Materials

6.1 Parent Metals

The parent metal shall conform to the requirements of the relevant standard for application.

a) Copper and copper alloys. The specification covers seamless (refrigeration and air conditioning grade) copper tubes in soft, half hard and hard tempers, suitable for use in the refrigeration and air conditioning industry. It is based on the following specification: - BS EN 14276 Part 2 & BS EN 12735 Part 1

b) Ferrous and non-ferrous metals including mild steel, carbon and low alloy steels, alloy steels, stainless, heat and corrosion resistant steels and brass.

6.2 Filler Metal (for brazing)

Filler metals for brazing of joints on refrigeration systems are covered by
BS EN ISO 17672:2010.

6.3 Fluxes (for brazing)

Fluxes used in the jointing of copper pipework for refrigeration systems are required to be active over a lower temperature range (600°C to 750°C) and are normally based on alkali fluorides. In order to ensure complete flux coverage throughout the capillary joint the flux shall be applied to all joint surfaces before assembly. Following completion of a brazed joint the flux residue must be removed, as it may cause corrosion.

Note: The brazing filler metals shall mandatorily be associated with a flux defined by the manufacturer or the owner of the brand name for use with that particular alloy on the corresponding tubes and fittings. The use of coated or cored brazing rods can preclude the use of fluxes in a paste form prepared by self-mix. Flux compatibility shall be checked. Care should be taken with the use of fluxes in a paste form as the internal residue can have a deleterious effect on compressor components.

7.0 Jointing Techniques

The techniques employed shall be in accordance with BS EN 14324.

7.1 Work Equipment.

Work equipment used in the process of brazing copper pipework for refrigeration systems shall consist of the following items:-

a) Manual flame torch designed to burn mixtures of natural gas, propane, butane, acetylene, with air or oxygen.

b) Regulators and gauges (single or two stage) - manufactured to BS EN ISO 2503, gauges manufactured to BS EN 562 and ISO 5171.

c) Hoses and connections suitable for gas welding and related processes as specified in BS EN 560.

d) Supply of appropriate gases for fuel, oxidising and purging purposes.

e) Operator's personal protective equipment and any other safety equipment appropriate to the requirements of the process.

f) Sundry items for cleaning and preparation of joints prior to and after the jointing process.

7.2 Methods of Heating – General

a) Heat is generally applied using a single torch held in the operators hand but may apply to two or more operators heating a large work piece.

b) Heating for brazing depends on the capillary attraction for penetration of the filler alloy into the joint in order to achieve an effective joint.

c) Because of the high conductivity of copper, auxiliary heating may be required when working on pipes larger than 2 1/8" OD.

7.3 Methods of Heating - Brazing

a) Heating for brazing must be uniform over the whole joint area, so that when the brazing temperature is reached, the filler alloy melts and spreads to bond with the parent metal surfaces within the joint. Care must be taken to avoid local overheating.

b) The choice of the fuel - oxidant system to be used for the brazing process shall be the responsibility of the company or approved body carrying out the assessments or processes.

c) The burner is adjusted to achieve optimum flame conditions (neutral flame) and the torch manipulated to concentrate the heat at the optimum working distance from the component of greater mass. Filler rod is then applied intermittently to the entrance to the joint until the melting temperature of the rod is reached. The rod is then normally allowed to dwell on the joint until fusion of the filler material occurs.

d) The process may be used with copper phosphorus rods or pre-fluxed silver solder rods or non-fluxed silver solder rods with externally applied flux. Preplaced flux paste can be applied on the internal surfaces of a joint; this method applies particularly to joints of dissimilar parent metals.

7.4 Joint Preparation

a) The component parts of a joint should be clean and properly fitting. When required, oxide, grease or oil should be removed by chemical and mechanical methods, this may involve degreasing, scratch brushing and other similar processes.

b) Correct joint alignment must be maintained by the use of jigs or supports as necessary.

c) For a brazed joint to be effective the filler alloy must penetrate the overlap between the surfaces being jointed to the prescribed depth. To achieve this requires an accurate assembly of components, the use of a suitable brazing alloy and a satisfactory heat pattern.

The making of joints on site requires care and can frequently necessitate the use of forming tools (swaged joints). It should be emphasised that the presence of a fillet around the joint does not necessarily constitute a joint of satisfactory quality.

d) The joint clearance shall be specified in the brazer procedure specification but would typically range from 0.05 to 0.45mm.

7.5 Flanges

a) Where pipework is required to connect to other equipment and there is a need for some dismantling, flanges may be used. The method of jointing to the pipe is by silver soldering.

b) With large diameter pipe (above 2 1/8" OD) auxiliary heating may be necessary to achieve uniform heating over the whole area of the joint.

7.6 Inert Gases

When heat is applied to copper pipe in the presence of air, oxides form on the inner and outer surfaces of the tube, this is not generally harmful but scale on the inside of the refrigeration pipework can cause blockage & damage once refrigerant and oil begin to circulate throughout the system. To overcome the formation of scale on the inside of the pipework a suitable inert gas such as oxygen free nitrogen (OFN) is passed through the pipework during the brazing process. A typical method to achieve this is outlined below:-

a. Pipework and components prepared for brazing with one end of pipework sealed (tube cap fitted and taped to pipe with an 8mm hole in the tube cap). If there are more than two ends of the pipework configuration then other ends need to be sealed in similar manner leaving just one "open" end for the introduction of the OFN.

b. Connect a suitable length of braided hose to an OFN cylinder through an appropriate low pressure regulator and flow meter; insert the other end of the tube into the open end of the pipework on which the brazing process is to be carried out.

c. Open the nitrogen cylinder and set the flow meter to the following suggested levels to introduce nitrogen to the pipework system at the rate of 5 to 10 l/min for diameters <1 1/8" and 10 to 15 l/min above. Ensure that pipework is not over pressurised. High flow rates of OFN can cause vortexes which trap oxygen within the system and can also over cool the joint being brazed, preventing full joint penetration. The entry point of the OFN must be sealed around the entry pipe to prevent the induction of air.

Note: Ensure the regulator outlet pressure does not exceed the flow meter's maximum inlet pressure, typically 2 barg.

7.7 Finishing of Joints

a) Flux residues should be removed by an environmentally acceptable method, as per manufacturer's recommendations. The degree of difficulty with which they can be removed will depend largely on the amount of flux left over from the brazing process; it will also depend on the avoidance of overheating and a minimum heating time.

b) As most fluxes are chemically active complete removal is essential if undesirable corrosion of parent metals is to be avoided. Removal of flux can be achieved by washing the outside of the joint(s) with a cloth saturated with cold water, after the assembly has cooled to normal ambient temperature (care must be exercised to avoid the introduction of moisture into the pipework). If flux still remains at this stage it must be removed by abrasive techniques. Finally the joint(s) should be finished by polishing with a non-metallic pipe abrasive.

8.0 Types of Joint

Three main configuration joints are used in the jointing of copper pipework for refrigeration systems, the pipe work connections all form lap type joints and are set out as follows:-

8.1 Expanded Joint

This type of joint is made by use of a forming tool such as a swager where the tube (pipe) is expanded to accept another length of tube of the same circumference. Care must be taken to ensure that tube is not expanded beyond the gap size specified.

8.2 Sockets & Fittings

There are several ranges of "Refrigeration" type capillary action fittings available from leading refrigeration wholesalers. These fittings are manufactured specifically for the refrigeration industry and are based on the "outside diameter" measurement of refrigeration grade copper tube. These fittings are not to be confused with the range of capillary fittings produced for the plumbing industry.

Accuracy in the fit up components is essential for a satisfactory joint and care must be exercised to ensure the clearance between the faces of components is not greater or less than specified.

8.3 Bi-Metal Joints & Flanges

Bi-metal sockets and flanges are usually used where there is a need for dismantling of the pipework system during maintenance and servicing operations e.g. Bolt on flanges and bi-metal sockets to service valves of a compressor or evaporator.

9.0 Brazer Approval

9.1 Brazed Joints

For the purpose of the specification and in order to address the wide range of joint sizes separate test pieces are provided for the assessment:

a) Small Commercial Refrigeration & Air Conditioning Systems
(Generally below 10 kW input power)

b) Large Commercial Refrigeration & Air Conditioning Systems
(Generally above 10 kW input power)

The assessment procedure shall remain the same for both categories, only sizes and changes in the use of certain components & materials will change, as indicated in the appropriate drawings. Typically the range of joints required for the >10kW category will include all of the <10kW category joints as well due to the range of brazer approval required.

It is important that the assessor and the candidate agree on the requirements of the brazer procedure specification prior to the commencement of the assessment, this agreement shall include such detail as the number and type of test pieces to be brazed, and the parent and filler materials to be used.

9.2 Underpinning Knowledge

Assessment shall be undertaken at all stages of the brazing process. The methodology chosen by the Candidate shall be assessed together with his/her understanding of the necessary requirements.

The assessment shall include the following:

a. Parent Materials;
b. Filler Materials;
c. Flux Types;
d. Types of Joints;
e. Preparation;

f. Cleaning;
g. Safe Working Practices;
h. Quality Control and Inspection; and
j. Defect Types.

A sample assessment is given in appendix 6, records of the assessment shall be maintained for audit. The assessment can be a multiple choice question paper or oral questions both of which can be centre derived.

9.3 Test Pieces - Assessment

The assessment will involve the assessor observing the candidate perform all the preparation and brazing processes for the test piece. On completion of the brazing process the candidate will prepare the test piece for inspection by the removal of all flux, and any general cleaning that the candidate feels is necessary (this will form part of the qualification criteria). The test piece will be subjected to examination as prescribed in Appendix 4.

9.4 Re-Assessment

A candidate will be permitted to complete a second set of test pieces. If the second test piece fails it should be deemed that the brazer needs further training before repeating the test.

10.0 Certification

The validity of approval begins on the date the test pieces are completed to the satisfaction of the assessor. The period of approval is 3 years provided that the brazer has had no interruption in brazing work for a period exceeding 6 months. If a period of 6 months is exceeded then re assessment would be required.

11.0 Auditing

The company or assessment centre shall maintain the quality assurance both for the assessment and the maintaining of records. These systems may preferably be audited either internally or by visiting independent assessors. Further information can be found in Appendix 7.

12.0 Records

Records of an individual's qualification of competence to braze joints shall be valid for no more than 3 years at a time. These shall be maintained ideally in accordance with BS EN ISO 9001 2008, the control of quality records.

There shall be procedures for the maintenance and retention of training records.

The company or assessment centre organisation shall produce and maintain a register of all individuals who have undergone assessment of qualification of brazed joints, re-assessment and re-appraisal. The register shall be updated regularly, not less than six monthly. This register shall be available for inspection by any assessing body without delay.

The company or organisation shall produce and maintain records of audits of all significant aspects of the brazing standard and competence for jointing of pipework for refrigeration systems. A copy of these audit records shall be available to any assessing body as and when requested, without delay.

Note: Records may be in any form, such as hard copy or electronic.

Appendix 1 - Centre Approval of Brazing Procedures (Brazing Procedure Specification - BPS)

This BRA specification has been revised in accordance with BS EN 14276-1:2006 + A1:2011 Annex B – Specification and approval of brazing procedures, brazers and brazing operators. **It should be read in conjunction with BS EN 14276 Annex B.**

It is intended that this procedure qualifies brazers to undertake lap joints through a range of pipe sizes from ¼" to 4 1/8" for copper to copper joints, copper to steel or copper to brass. As alternative piping materials become more widely available the range of specification and test pieces will have to be increased to include those material types. The selection of the test piece sizes can be found in Appendix 3.

The parameters included in the BPS are separated into EV (Essential Variables) and NEV (Non-Essential Variables). An EV is a variable that if changed affects the mechanical properties of a joint and would require a brazer to be re qualified. A NEV is a variable that may change and will not require re qualification of the brazer.

A sample BPS can be found in Appendix 2, the table of EVs (Essential Variable) and NEVs (Non-Essential Variable) can be found below:

List of variables	**Torch Brazing**
Base metal material	EV
Thickness range	EV
Brazing process	EV
Joint design type	EV
Joint design clearances	EV
Flow position	EV
Brazing filler material	EV
Brazing filler form	EV
Brazing flux	EV
Fuel gas	NEV
Post braze heat treatment	EV
Preparation of joint	NEV
Post braze cleaning	NEV
Brazing tip size	NEV

Adapted from BS EN14276-1:2006

The brazer filler material is listed as an EV, however providing Copper Phosphorus (CuP) rod is used for similar joints and Silver Solder (Ag) rod is used for dissimilar joints the actual rod used does not need to be specified as they are in the same codification in ISO 17672:2010.

To minimise the number of test pieces horizontal flow joints will qualify the brazer for horizontal flow, vertical down, vertical up and flat flow joints. Therefore all test pieces will be lap joints brazed with the pipework in the horizontal position. Please see the below table for reference:

Test Position	**Flow Qualified**			
	Flat Flow	**Vertical down**	**Vertical up**	**Horizontal**
Flat flow	X	X	-	-
Vertical down	-	X	-	-
Vertical up	-	X	X	-
Horizontal	X	X	X	X

From BS EN14276-1:2006. © BSI

The tests used in brazing procedure and performance qualifications are defined in the below table:

	Visual examination	**Tensile test**	**Bend test**	**Peel test**	**Metallo-graphic examination**
Lap Joints	Yes	2	-	2[A]	-
[A] when the filler material has a tensile strength equal to or greater than that of the base material, a metallographic examination is required.					

Adapted from BS EN14276-1:2006

There will be 2 of each test piece size in Appendix 3 and they will be subjected to the above tests with the exception of the 'Tensile Test'. The 'Tensile Test' will be carried out by an approved (UKAS) test house and witnessed by an a recognised Third Party or Notified Body so the centre can approve their BPS (Brazer Procedure Specification) and will be included in the BPAR (Brazer Procedure Approval Record). The Tensile Test should be carried out in accordance with ISO 5187 and EN ISO 6892-1.

Provided none of the EVs (Essential Variables) change there will not be a requirement to re tensile test any subsequent assessment test pieces with a third party and only the visual and metallographic examinations need to be completed and examination is covered in Appendix 4.

Appendix 2 - Sample Brazer Procedure Specification (BPS)

Brazing Procedure Specification (BPS)
in accordance with BS EN 14276-1:2006+A1:2011 Annex B
Specification & approval of brazing procedures, brazers & brazing operators

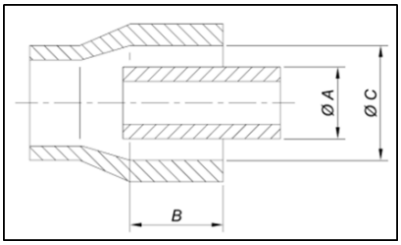
Centre Name: **Date:** xxxxxxxxxxxxxxxx xx/xx/xxxx **BPS No:** BRA 1 **Brazing Process(s):** Pipe to Pipe (site or workshop)	**Diagram of Joint:** From BS EN14276-1:2006. © BSI 
Joints: **Type of Joint(S):** Lap (tube insert) **Lap Length Range:** See Table 1 below	**Flow Position:** Flow Position(S): Horizontal (max angular deviation +/- 15^{O} Method of Applying Filler Material: Manual end feed by hand from rod
Base Metals: Copper EN12735-1:2010 Steel ASTM A 106 grade B schedule 40 Steel ASTM A 106 grade B schedule 80 Thickness Range: ¼"- 7/8" 22-16 SWG (SC/LC) 1 1/8"- 4 1/8" 21-10 SWG (LC)	**Brazing Flux:** CuP 2-15% - Self Fluxing Ag 30-60% - *Add flux type here* EN1045
Filler Materials: Copper to Copper: CuP 2-15% Copper to Steel: Ag 30-60% EN ISO 3677 BS EN ISO 17672:2010	**Post Braze Heat Treatment:** Copper to Copper: Cooled in still air Copper to Steel: Cooled in still air + flux removal with damp cloth
Brazing Process / Temperature: Flame Brazing (TB) Manual Torch Oxy acetylene / propane 0.5 barg min pressure Temp Range: >450^{O}C	**Technique:** Method of pre cleaning: Grit free abrasive sheet Torch Nozzle Size: Sizes 5 – 25 including Pepperpot Internal OFN purging during brazing process to prevent oxidisation

Table 1

Outside diameter (OD), mm	Includes imperial pipe sizes	Minimum fitting depth (B), mm	Clearance (C-A), mm
5 ≤ OD < 8	¼"	6	0.05 to 0.35
8 ≤ OD < 12	3/8"	7	
12 ≤ OD < 16	½" and 5/8"	8	0.05 to 0.45
16 ≤ OD < 25	7/8"	10	
25 ≤ OD < 35	1 1/8", 1 3/8"	12	0.05 to 0.55
35 ≤ OD < 45	1 5/8"	14	

Adapted from BS EN14276-1:2006

Appendix 3 – Test Pieces Selection & Sizes

The below information explains how the selection of test piece sizes has been arrived at in accordance with BS EN 14276-1:2006 Annex B.

Range of sizes considered

¼" to 4 1/8" OD copper tube (6.35 to 104.8 mm).
22 SWG to 10 SWG (0.711 mm to 3.25 mm nominal).

SWG

A test piece less than 3mm thick, will cover the range R1 in table B.5 (BS EN 14276-1:2006 Annex B). R1 covers a range 0.5e to 2 e, where e is the test piece thickness.

The tables below provide the actual range each SWG will cover, based on R1 above.

SWG	E	0.5 e	2 e	
22	0.711	0.3555	1.422	
21	0.813	0.4065	1.626	
20	0.914	0.457	1.828	20 SWG qualifies for 16 to 22 SWG
19	1.02	0.51	2.04	
18	1.22	0.61	2.44	
16	1.63	0.815	3.26	
14	2.03	1.015	4.06	
12	2.64	1.32	5.28	
10	3.25	1.625	6.5	

It can be seen that 20 SWG covers the range 22 to 16 SWG.

SWG	E	0.5 e	2 e	
22	0.711	0.3555	1.422	
21	0.813	0.4065	1.626	
20	0.914	0.457	1.828	
19	1.02	0.51	2.04	
18	1.22	0.61	2.44	
16	1.63	0.815	3.26	16 SWG qualifies for 10 to 21 SWG
14	2.03	1.015	4.06	
12	2.64	1.32	5.28	
10	3.25	1.625	6.5	

It can be seen that 16 SWG covers the range 21 to 10 SWG.

Pipe OD

Two test piece ODs will cover the range, using table B6 (BS EN 14276-1:2006 Annex B):

- A test piece between 10 mm and 25 mm diameter will cover the range 0.5 Ø to 2 Ø, where Ø is the outside diameter of the pipe;
- A test piece with a diameter greater than 25 mm will cover the range 25 mm and above.

The table below provides the actual range each OD will cover, based on table B.6.

OD, in	OD, in	OD, mm	0.5 OD	2 OD	
¼	0.250	6.35	3.175	12.7	
3/8	0.375	9.525	4.7625	19.05	
½	0.500	12.7	6.35	25.4	1/2" qualifies for 1/4" to 7/8"
5/8	0.625	15.875	7.9375	31.75	
7/8	0.875	22.225	11.1125	44.45	
1 1/8	1.125	28.575	14.2875	57.15	Any of these sizes qualifies for 1 1/8" to 4 1/8"
1 3/8	1.375	34.925	17.4625	69.85	
1 5/8	1.625	41.275	20.6375	82.55	
2 1/8	2.125	53.975	26.9875	107.95	
2 5/8	2.625	66.675	33.3375	133.35	
3 1/8	3.125	79.375	39.6875	158.75	
3 5/8	3.625	92.075	46.0375	184.15	
4 1/8	4.125	104.775	52.3875	209.55	
					below 10 mm applies here
					0.5 OD to 2 OD only applies to this test piece size
					25 mm and above applies here

It can be seen that two test piece ODs cover the range:

½" covers ¼" to 7/8";
1 5/8" covers 1 1/8" to 4 1/8".

Recommended test piece joints

Joint A
½" OD, 20 SWG
This will cover ¼" to 7/8" OD, 22 to 16 SWG.

Joint B
1 3/8" OD, 16 SWG
This will cover 1 1/8" to 4 1/8" OD, 21 to 10 SWG.

Materials

Materials are grouped in table B.4 (BS EN 14276-1:2006 Annex B) to minimise number of test pieces. A qualification for one material in the group applies to all others in the group.

Materials are specified in tables I.1, I.2 and I.3 (EN14276-1 Annex I).

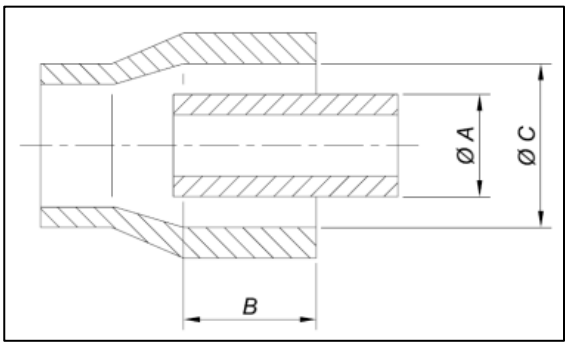
Different test pieces are required for:

Copper to copper (including alloys with zinc (brass), tin and nickel)
Copper to steel
Copper to austenitic steel
Copper to aluminium
Copper to copper-aluminium alloy
Copper-aluminium alloy to steel
Copper-aluminium alloy to austenitic steel
Copper-aluminium alloy to aluminium.

Test pieces in *italics* are not currently commonly required.

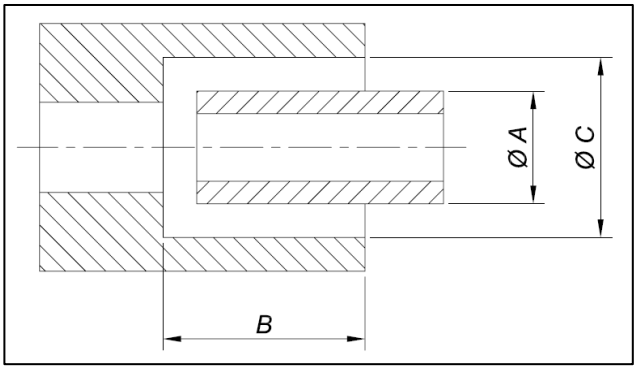
Below are the dimensional drawings for the test pieces:

Test Pieces 1 and 2, copper to copper joint (either a straight coupler or swaged) x 2 each



	Test piece 1	**Test piece 2**
	Small Commercial (up to 7/8") & Large Commercial	Large Commercial (up to 4 1/8")
Size	½" 20 SWG	1 3/8" 16 SWG
Minimum fitting depth (B)	8mm	14mm
Clearance (C-A)	0.05mm to 0.45mm	0.05mm to 0.55mm
Total length of test piece	400mm (2 x 200mm)	400mm (2 x 200mm)

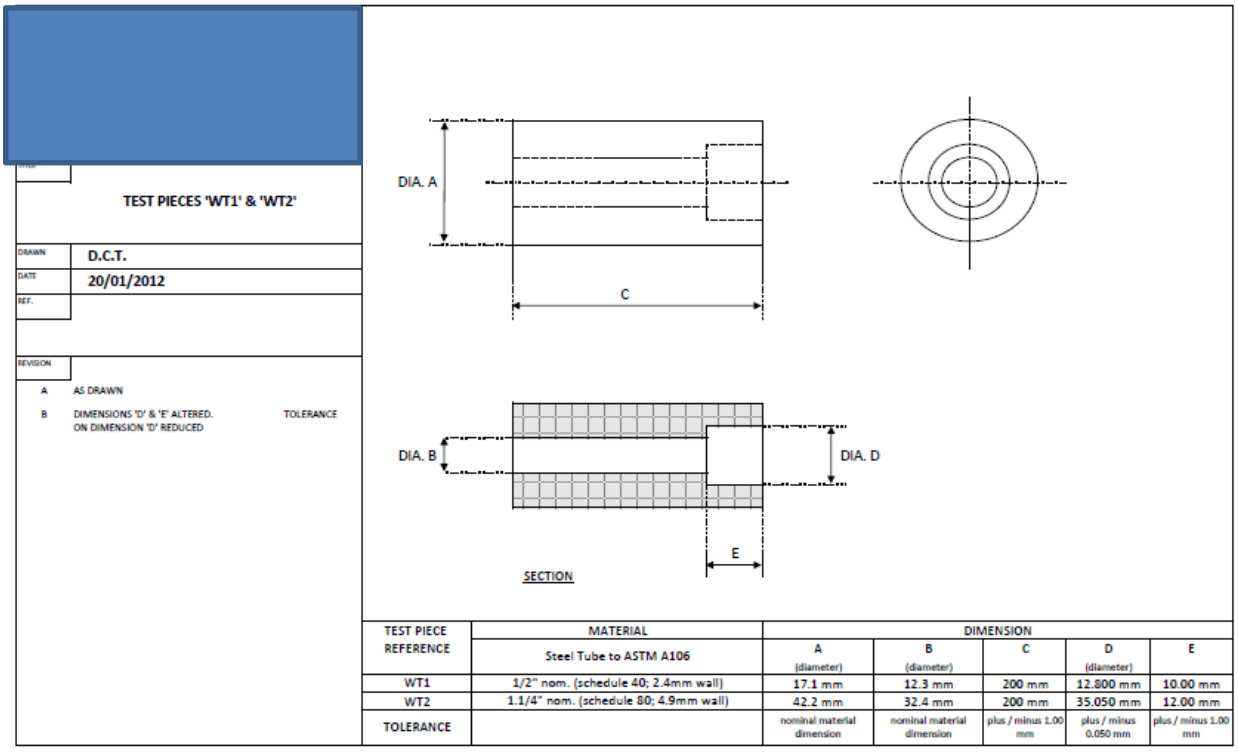
Test Pieces 3 and 4, Copper to Schedule 40/80 Steel joint x 2 each



	Test piece 3	Test piece 4
	Small Commercial (up to 7/8") & Large Commercial	Large Commercial (up to 4 1/8")
Size	½" 20 SWG (copper) ½" (schedule 40 steel)	1 3/8" 16 SWG (Copper) 1 3/8" (schedule 80 steel)
Minimum fitting depth (B)	8mm	14mm
Clearance (C-A)	0.05mm to 0.45mm	0.05mm to 0.55mm
Total length of test piece	400mm (2 x 200mm)	400mm (2 x 200mm)

Copper EN12735-1:2010
Steel ASTM A 106 grade B schedule 40 steel / 80 steel

Example dimensional drawing of steel socket



TEST PIECE REFERENCE	MATERIAL	DIMENSION				
	Steel Tube to ASTM A106	A (diameter)	B (diameter)	C	D (diameter)	E
WT1	1/2" nom. (schedule 40; 2.4mm wall)	17.1 mm	12.3 mm	200 mm	12.800 mm	10.00 mm
WT2	1.1/4" nom. (schedule 80; 4.9mm wall)	42.2 mm	32.4 mm	200 mm	35.050 mm	12.00 mm
TOLERANCE		nominal material dimension	nominal material dimension	plus / minus 1.00 mm	plus / minus 0.050 mm	plus / minus 1.00 mm

Appendix 4 - Examination of Test Pieces

The test piece shall be brazed in accordance with the BPS (Brazer Procedure Specification).

The completed test pieces should be subjected to the following examinations:

a) Visual examination;
b) Metallographic examination.

a) The visual examination should be in accordance with the below acceptance criteria:

- No base metal degradation (such as surface erosion) due to overheating
- No lack of filler material contour locally
- No drop of filler material
- No excess filler material
- No flux and flux residue
- Evidence of OFN purging

b) The metallographic examination (used as a substitute for peel test) should be in accordance with the below procedure and acceptance criteria:

Procedure: Two cuts in each specimen should be made and the surfaces ground and polished ready for macro examination up to 10x magnification.

Acceptance criteria: No cracks are accepted and penetration should be 80% of the overlap.

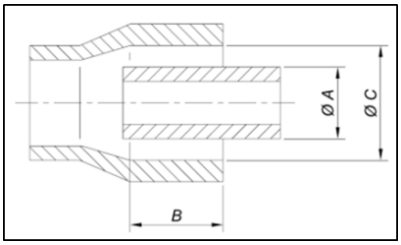
Adapted from BS EN14276-1:2006

Appendix 5 – Sample Brazing Procedure Assessment Record (BPAR)

Brazer approval – in accordance with BS EN 14276-1:2006+A1:2011 Annex B

Company/Assessment Centre Name: xxxxxxxx **Brazer Name:** xxxxxxxx **Examiner/Assessor Name:** xxxxxxx **Signed:** xxxxxxxx	**BPAR No:** xxxxxx *(certificate number here)* Small Commercial / Large Commercial (delete as necessary) **BPS No:** BRA 1 **Brazing Process(s):** Pipe to Pipe (site or workshop) **Date of Brazer Approval:** **Valid:** xxxxxxx 3 Years
Joints: **Type of Joint(S):** Lap (tube insert) **Lap Length Range:** See Table 1 below **Position Qualified:** All	**Flow Position:** Flow Position(S): Horizontal (max angular deviation +/- 15^{O} Method of Applying Filler Material: Manual end feed by hand from rod
Base Metals: Copper EN12735-1:2010 Steel ASTM A 106 grade B schedule 40 Steel ASTM A 106 grade B schedule 80 Thickness Range: ¼"- 7/8" 22-16 SWG (SC/LC) 1 1/8"- 4 1/8" 21-10 SWG (LC)	**Brazing Flux:** CuP 2-15% - Self Fluxing Ag 30-60% - *Add flux type here* EN1045
Filler Materials: Copper to Copper: CuP 2-15% Copper to Steel: Ag 30-60% EN ISO 3677 BS EN ISO 17672:2010	**Post Braze Heat Treatment:** Copper to Copper: Cooled in still air Copper to Steel: Cooled in still air + flux removal with damp cloth
Brazing Process / Temperature: Flame Brazing (TB) Manual Torch Oxy acetylene / propane 0.5 barg min pressure Temp Range: >450^{O}C	**Technique:** Method of pre cleaning: Grit free abrasive sheet Torch Nozzle Size: Sizes 5 – 25 including Pepperpot Internal OFN purging during brazing process to prevent oxidisation
Clearance & Lap Tolerances: Adapted from BS EN14276-1:2006 Table 1	**Diagram of Joint:** From BS EN14276-1:2006. © BSI

Outside diameter (OD), mm	Includes imperial pipe sizes	Minimum fitting depth (B), mm	Clearance (C-A), mm
5 ≤ OD < 8	¼"	6	0.05 to 0.35
8 ≤ OD < 12	3/8"	7	
12 ≤ OD < 16	½" and 5/8"	8	0.05 to 0.45
16 ≤ OD < 25	7/8"	10	
25 ≤ OD < 35	1 1/8", 1 3/8"	12	0.05 to 0.55
35 ≤ OD < 45	1 5/8"	14	



Confirmation of qualification by employer or other responsible person (every six months), required for the validity of this BPAR

Period from Approval	**6 months**	**12 months**	**18 months**	**24 months**	**30 months**
Date:					
Signature:					
Position or title:					

Test Results / Re Test Results

Range of Approval: SC = Small Commercial - ¼" to 7/8" LC = Large Commercial – 1 1/8" to 4 1/8"

Test 1		No Base metal degradation due to overheating	No lack of filler metal contour locally – un melted filler material around radius	No drop of filler Material – filler material not visible around radius	No excess of filler material	No flux & flux residue	Evidence of OFN purging	Metallographic Examination – 80% penetration, no cracks	Pass / Fail
Joint 1 - SC/LC	½" Copper to ½" Copper								
Joint 2 - SC/LC	½" Copper to ½" Copper								
Joint 3 - SC/LC	½" Copper to ½" Steel								
Joint 4 - SC/LC	½" Copper to ½" Steel								
Joint 5 – LC	1 3/8" Copper to 1 3/8" Copper								
Joint 6 – LC	1 3/8" Copper to 1 3/8" Copper								
Joint 7 – LC	1 3/8" Copper to 1 3/8" Steel								
Joint 8 – LC	1 3/8" Copper to 1 3/8" Steel								

Test 2		No Base metal degradation due to overheating	No lack of filler metal contour locally – un melted filler material around radius	No drop of filler Material – filler material not visible around radius	No excess of filler material	No flux & flux residue	Evidence of OFN purging	Metallographic Examination – 80% penetration, no cracks	Pass / Fail
Joint 1 - SC/LC	½" Copper to ½" Copper								
Joint 2 - SC/LC	½" Copper to ½" Copper								
Joint 3 - SC/LC	½" Copper to ½" Steel								
Joint 4 - SC/LC	½" Copper to ½" Steel								
Joint 5 – LC	1 3/8" Copper to 1 3/8" Copper								
Joint 6 – LC	1 3/8" Copper to 1 3/8" Copper								
Joint 7 – LC	1 3/8" Copper to 1 3/8" Steel								
Joint 8 – LC	1 3/8" Copper to 1 3/8" Steel								

Assessor Print:		**Assessor Signed:**	**Date: / /**

Appendix 6 – Sample Question Bank

Name	Date	Small Commercial Large Commercial
Company name and address		
Assessor signature	Candidate signature (on completion)	
Pass / Fail (40/45)		

Think carefully about your answers and take your time. Read the questions carefully, remember some questions might have **more than one correct answer**!

1. Which of the below does your employer need to provide you with under the Health & Safety at Work Act?

☐ a. Training

☐ b. Holiday Pay

☐ c. Personal Protective Equipment

☐ d. Safe Working Environment

2. Which of the below are your primary responsibilities under the Health & Safety at Work Act?

☐ a. Use and do not misuse PPE

☐ b. To look after yourself only

☐ c. To be responsible for your own and others Health & Safety

☐ d. Ignore risk assessments if you feel they are not relevant

3. Which of the below data sheets will indicate the risk to you of the substances you might be using?

- [ ] a. White sheets
- [ ] b. COSHH Data sheets
- [ ] c. SITE Data sheets
- [ ] d. TREM Cards

4. Which of the below are important when you are brazing?

- [ ] a. The area is level
- [ ] b. The area is well ventilated
- [ ] c. You are inside
- [ ] d. The electricity is isolated

5. Which list of PPE below is most appropriate when brazing?

- [ ] a. Gloves, overalls and trainers
- [ ] b. Gloves, goggles, overalls and steel toe capped foot protection
- [ ] c. Goggles
- [ ] d. Hat, Gloves and knee protection

6. Which permit to work would you obtain before brazing – if required?

- [ ] a. Cold work permit
- [ ] b. Hot work permit
- [ ] c. Permit not to work
- [ ] d. Brazing permit

7. What colour is an acetylene cylinder?

- [ ] a. Maroon
- [ ] b. Black
- [ ] c. Red
- [ ] d. Grey

8. What colour is an oxygen cylinder?

- [ ] a. Maroon
- [ ] b. Black with a white shoulder
- [ ] c. Black
- [ ] d. Grey with a black shoulder

9. What pressure would you expect to find in a new oxygen cylinder?

- [ ] a. 230 bar
- [ ] b. 1 bar
- [ ] c. 25 bar
- [ ] d. 500 psi

10. Which thread would you find on an acetylene cylinder?

- [ ] a. Right hand
- [ ] b. Parallel
- [ ] c. Left hand
- [ ] d. Tapered

11. Which thread would you find on an oxygen cylinder?

- [ ] a. Right hand
- [ ] b. Parallel
- [ ] c. Left hand
- [ ] d. Tapered

12. Where would you ideally store oxygen and acetylene cylinders?

- [ ] a. Inside
- [ ] b. Outside, caged, upright & secure
- [ ] c. Outside in shed or garage
- [ ] d. Outside, caged, laying down

13. Should you store full and empty cylinders separately?

- [ ] a. No
- [ ] b. Yes always
- [ ] c. Sometimes
- [ ] d. None of the above

14. Which of the below methods could you use to move cylinders on site?

- [ ] a. Roll them along the ground
- [ ] b. Use correct bottle trolley
- [ ] c. Bounce the cylinders
- [ ] d. Churn the cylinders

15. Which of the below statements is most accurate when transporting oxy acetylene cylinders in a vehicle?

- [ ] a. Regulators and lines removed, upright, secure, well ventilated, have dry powder fire extinguisher and safety data sheets
- [ ] b. Upright, secure, regulators left connected, dry powder fire extinguisher
- [ ] c. Secure, well ventilated, have dry powder fire extinguisher and safety data sheets
- [ ] d. Transport oxygen and acetylene cylinders in separate vehicles

16. What is the main risk of an oxygen enriched environment?

- [ ] a. You will asphyxiate
- [ ] b. Materials could burn much more easily
- [ ] c. You will struggle to catch your breath
- [ ] d. None of the above

17. What is acetylene dissolved in?

- [ ] a. Oxygen
- [ ] b. Acetone
- [ ] c. Water
- [ ] d. Air

18. What would be the effect of lubricating an oxygen regulator with oil or grease?

- [ ] a. Confusion
- [ ] b. Combustion
- [ ] c. Exhaustion
- [ ] d. Corrosion

19. Which best describes the two gauges on a regulator?

- [ ] a. HP gauge showing cylinder pressure & LP Gauge showing working (line) pressure
- [ ] b. HP gauges showing bottle pressure and bottle contents
- [ ] c. LP gauges showing line pressures
- [ ] d. LP gauge showing cylinder pressure & HP Gauge showing working (line) pressure

20. What colour is the oxygen regulator and lines?

- [ ] a. Black
- [ ] b. Blue
- [ ] c. Red
- [ ] d. Maroon

21. What Colour is a nitrogen cylinder

- [ ] a. Black
- [ ] b. Grey with black shoulder
- [ ] c. Black with white shoulder
- [ ] d. Any colour marked with 'N'

22. What does a 'Flash Back' arrestor prevent?

- [ ] a. Over pressurising cylinders
- [ ] b. Flame leaving the cylinder when ignited
- [ ] c. Flame entering the cylinder
- [ ] d. Cuts off the cylinder when laid down

23. What would you use to cut refrigeration pipework?

- [ ] a. Hacksaw
- [ ] b. Stanley knife
- [ ] c. Pipe cutter
- [ ] d. Cut off disk

24. Why do we purge nitrogen (oxygen free) through refrigeration pipework while we braze it?

- [ ] a. To stop oxidisation / scale build up on the outside of the pipework
- [ ] b. To pressure test the pipework
- [ ] c. To stop oxidisation / scale build up inside the pipework
- [ ] d. To act as a flux for the solder

25. Which of the below statements is correct?

- [ ] a. A fitting or swage should be clean and have a tight fit
- [ ] b. A fitting should be clean and have 1.0mm clearance
- [ ] c. Pipe and fittings should be butt jointed
- [ ] d. There is no need to clean joints at all

26. When an oxy-acetylene flame is burning what is the approximate temperature of the flame?

- [ ] a. 100°C
- [ ] b. 300°C to 500°C
- [ ] c. 1000°C
- [ ] d. 2500°C to 3000°C

27. What filler rod do we use to braze copper to steel?

- [ ] a. Soft solder
- [ ] b. Copper phosphorous
- [ ] c. Silver solder
- [ ] d. Silver solder & flux

28. How would you temporarily shut down an oxy acetylene torch flame?

- [ ] a. Close the acetylene valve on the torch and then the oxygen valve
- [ ] b. Close the oxygen valve of the torch and then the acetylene valve
- [ ] c. Put the torch down
- [ ] d. Close the acetylene regulator on the cylinder followed by the oxygen cylinder regulator

29. A joint is ready to be brazed when …

- [ ] a. The flame melts the filler rod
- [ ] b. The parent metal is the correct colour (cherry red)
- [ ] c. Vapour appears from the filler rod
- [ ] d. The filler rod starts to flow

30. A regulator is closed when….

- [ ] a. The pressure adjusting screw is wound all the way out
- [ ] b. The pressure adjusting screw is mid way
- [ ] c. The pressure adjusting screw is wound all the way in
- [ ] d. The regulator cannot be closed by adjusting it

31. Which of the following should you use to light an oxy acetylene torch?

- [ ] a. Another lit oxy acetylene flame
- [ ] b. Spark gun
- [ ] c. Cigarette
- [ ] d. Butane cigarette lighter

32. If you observe any damage to your oxy acetylene equipment you would…

- [ ] a. Carry on using the equipment for the time being
- [ ] b. Stop using the equipment until the offending part is repaired or replaced
- [ ] c. Report it to you supervisor and carry on using the equipment
- [ ] d. Change the cylinders

33. What would you do if your acetylene cylinder started to warm up?

- [ ] a. Stand it in a bucket of water and carry on
- [ ] b. Isolate the cylinder, evacuate the area and call the fire brigade
- [ ] c. Re move the cylinder to outside
- [ ] d. Nothing, it will cool down on its own

34. What adjustment of flame should you have when brazing?

- [ ] a. Oxidising
- [ ] b. Carburising
- [ ] c. Neutral
- [ ] d. Arcing

35. Acetylene is which of the following?

- [ ] a. Heavier than air
- [ ] b. Non flammable
- [ ] c. Lighter than air
- [ ] d. Odourless

36. If you were brazing in an area with electrical hazards which fire extinguishers could you use?

- [ ] a. Water
- [ ] b. $C0_2$
- [ ] c. Foam
- [ ] d. Dry Powder

37. What approximate pressure do you set your line pressure to prior to brazing?

- [ ] a. 0.01 bar
- [ ] b. 0.5 bar to 1.0 bar
- [ ] c. 10 bar to 20 bar
- [ ] d. 1.5 bar to 3.0 bar

38. What type of filler rod would you most likely use to join copper to copper connections?

- [ ] a. Arc welding rods
- [ ] b. Silver solder & flux
- [ ] c. Copper phosphorus rods
- [ ] d. 0.5mm MIG wire

39. Why does the acetylene cylinder have to upright to operate correctly?

- [ ] a. To allow the air to rise to the top
- [ ] b. So pure acetylene gas enters the regulator
- [ ] c. So pure liquid acetylene enters the regulator
- [ ] d. Doesn't matter if the cylinder is upright or not

40. Which of the below makes up the largest percentage in copper phosphorus rod?

- [ ] a. Silver
- [ ] b. Copper
- [ ] c. Phosphorus
- [ ] d. Zinc

41. What legislation covers the road transport of compressed gases?

- [ ] a. DVLA
- [ ] b. RDA
- [ ] c. ADR
- [ ] d. IEE16th Edition

42. What is the number of transport units applied by the legislation when carrying a calculated mixed load of products?

- [ ] a. 20
- [ ] b. 50
- [ ] c. 333
- [ ] d. 1000

43. Which of the below products fall into the category of asphyxiants?

- [ ] a. Oxygen
- [ ] b. Nitrogen
- [ ] c. Argon
- [ ] d. Helium

44. Which of the below products fall into the category of flammable?

- [ ] a. Acetylene
- [ ] b. Nitrogen
- [ ] c. Propane
- [ ] d. Argon

45. Which of the below fire extinguishers would be most suitable to carry when your load falls below the full scope of ADR

- [ ] a. 9 kg $C0_2$
- [ ] b. 2 Ltr Foam
- [ ] c. 2 kg Dry Powder
- [ ] d. 9 Ltr Water

Appendix 7 - Guide to Assessment (Additional Guidance)

1.0 General:

Since the introduction of this code of practice there have been several requests for some guidance. It is hoped that the following information will achieve this.

2.0 Assessment:

The assessment is designed to prove competence for a person performing manual flame brazing techniques for the jointing of copper pipework for refrigeration and air conditioning systems, particularly as the proof of competence for health and safety and quality reasons.

2.1 Practical Assessment: The practical assessment will take the form of a practical test as prescribed in Appendix 1 - 4. This test will observe the following requirements:

- Health and Safety Requirements for the process including use of P.P.E. and any other safety equipment that may be necessary.
- Correct setting up of brazing equipment for the test including the use of nitrogen for purging.
- Preparation and assembly of test piece prior to brazing operations.
- Correct procedures for lighting brazing equipment including satisfactory nitrogen purging.
- Safe working practices during the brazing process.
- Safe shutting down procedures on completion of brazing process.
- Cleaning and finishing of the joints of the test piece after brazing process is completed.
- The inspection of each of the four joints of the piece following the criteria set down in Appendix 01 Sheet 3.

2.2 Knowledge Evidence:

Knowledge evidence will be tested by means of a multiple choice paper or oral questioning.

3.0 Materials:

Materials used for the assessment shall be of a suitable standard, and conform to relevant industry specifications for materials used in the jointing of copper pipework for refrigeration systems.

4.0 Certification:

The Company or Centre carrying out assessments for the jointing of Copper Pipework for Refrigeration Systems shall issue a certificate to candidates who successfully complete the assessment. The Brazer Procedure Approval Record can

follow any format, but should contain all the relevant information as set out in Appendix 5 together with the company or centre name and address. The certificate shall be signed by the assessor and also by a responsible independent person from within the company or centre such as a director or quality assurance manager. The certificate shall be valid for a period of three years and shall carry the expiry date and unique test record number.

5.0 Quality Assurance and Records:

The company or centre shall maintain records of assessments and a register of all individuals who have undergone assessment for each level of competence. The assessments, records and equipment shall be audited on a regular basis by the company or centre's quality assurance system. The whole scheme may be monitored by visiting independent assessors or verifiers from accreditation and awarding bodies.

Produced and published by the British Refrigeration Association, the Refrigeration division of the Federation of Environmental Trade Associations

2 Waltham Court
Milley Lane
Hare Hatch
Reading
Berks RG10 9TH

Tel 0118 940 3416
Fax 0118 940 6258
Email info@feta.co.uk
www.feta.org.uk