Jointing of Pipework for Refrigeration Systems

Specification & Approval of Brazing Procedures

Manual Flame Brazing – Brazer Approval

Issue 6 v1.1 – February 2021

Contents

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 and approval 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. This revision has incorporated high strength copper alloy pipe in recognition of is adoption on R744 systems and is also applicable to A2L refrigerants.

The 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 BS EN 14276-1:2020 Pressure equipment for refrigerating systems and heat pumps (harmonised to PED 2014/68/EU), 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 (2014/68/EU) / Pressure Equipment Regulations 1999 (SI 1999/2001).

Acknowledgements

The BRA would like to thank the following people for their assistance in revising Issue 6 of this brazer procedure specification:

Stephen Benton – Cool Concerns Ltd
Jane Gartshore – Cool Concerns Ltd
Institute of Refrigeration – Technical Committee peer review

The author would like to thank the individuals have gave valuable feedback during the review stage of this documents revision.

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British Refrigeration Association
The jointing of copper pipework for refrigeration systems

1.0 Scope

1.1 This document outlines the brazing procedures required for the jointing of copper tube used for the refrigeration, air conditioning and heat pump industry and by which the knowledge, ability and experience of individuals is assessed to demonstrate their competence in undertaking brazing processes to the standard required. The brazer specification approval has been written in accordance with BS EN 14276-1:2020 Annex B.

The procedure is suitable for PED/PER SEP & Cat I joints on systems intended to operate with A1, A2L and A3 fluid groups. Joint Categories II and higher require recognised third party organisation (RTPO) approval of both the procedure and testing of the candidates test pieces, this procedure may be acceptable but should be agreed with the notified body before use.

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
j) Pressure Equipment Regulations 1999 (SI 1999/2001)

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 HSCA

High Strength Copper Alloy – A range of copper alloy tubing and fittings with elevated strength rating typically 80 barg, 120 barg and 130 barg. K65, Halcor and others are brand names for HSCA pipe and fittings.

3.4 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

3.5 Preliminary brazing procedure specification pBPS

Document containing the required variables of the brazing procedure but is not yet qualified.

3.6 Brazing procedure specification BPS

Document that has been qualified and provides the required variables of the brazing procedure to ensure repeatability during production brazing recorded in the BPAR.

3.7 Test Sample (pieces)

An assembly brazed in accordance with a BPS, 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

3.8 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 Centre (or company / manufacturer)

That entity or person who administers this scheme and is a member of the BRA.

3.10 Brazing procedure approval record
BPAR

Record of results from assessing the test pieces to the pBPS and acceptance criteria.

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:

BRA Model Task Procedures & Risk Assessments
BS EN 378-1:2016+A1:2020
BS EN 378-2:2016
BS EN 378-3:2016+A1:2020
BS EN 378-4:2016+A1:2019
British Compressed Gases Association Codes of Practice
BS EN 14324:2004
BS EN 14276-1:2020
BS EN 14276-2:2020
BS EN 12735-1:2020
BS EN ISO 13585:2012

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 manufacturer's 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 (PPE)

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 PPE 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 (latest versions).

b) Ferrous and non-ferrous metals including mild steel, heat and corrosion resistant steels. It is based on the following specification ASTM A106/ASME SA106 (latest version) and brass.

6.2 Filler Metal (for brazing)

Filler metals for brazing of joints on refrigeration systems are covered by BS EN ISO 17672:2016.

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, hydrogen with air or oxygen.

b) Regulators and gauges (single or two stage) - manufactured to BS EN ISO 2503:2009+A1:2015 or equivalent BS EN standard.

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

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 0.02 to 0.41mm.

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. HSCA fittings are specifically designed for use with HSCA (copper alloy tubing) and typically have a PS of 130 barg. Care should be taken to ensure the PS of the fittings is equal to or greater than the tubing they are being used to connect to.

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 7, 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/s 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. There shall be procedures for the maintenance and retention of training records.

The company / manufacturer 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 when requested within a reasonable timescale.

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

Appendix 1 - Approval of Brazing Procedure Specification - BPS

This BRA specification has been revised in accordance with BS EN 14276-1:2020 Annex B – Specification and approval of brazing procedures.

It must be read in conjunction with BS EN 14276-1:2020 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. The selection of the test piece sizes can be found in Appendix 3. Sizes outside the range of the approval will need a specific BPS to be approved and the brazer tested in accordance with.

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 EN14276-1:2020 Annex B

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 17672:2016.

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

Vertical up joints qualify for all flow positions. For the pBPS (preliminary Brazer Procedure Specification) approval, 2 of each size and material vertical up joints specified in Appendix 3 (8 in total) shall be subjected (by the centre) to the below tests and satisfy the inspection criteria in Appendix 4.

The 'Tensile Test' shall be carried out by an approved (UKAS) test house so the centre can approve their pBPS. The Tensile Test should be carried out in accordance with ISO 5187 and EN ISO 6892-1. The BPAR (Brazer Procedure Approval Record) should reference the BPS.

The type and number of tests used in the brazing procedure specification qualification (centre approval) 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 EN14276-1:2020 Annex B

The tensile strength shall not be less than the minimum tensile strength of the weaker base metal in the annealed condition

or

If the test piece breaks in the base metal outside of the brazed area, 95% of the minimum tensile strength of the base metal in an annealed condition.

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

a) Visual examination
b) Metallographic examination

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

Appendix 2 - Sample Brazer Procedure Specification (BPS)

Brazing Procedure Specification in accordance with BS EN 14276-1:2020
Annex B - Specification & approval of brazing procedures

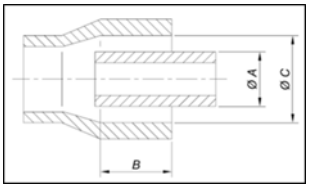
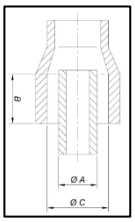
Manufacturers Name: xxxxxxxxxxxxxxxx **Date:** xx/xx/xxxx **BPS No:** BRA 1 **Reference:** BPAR: BRA 2021 **Brazing Process(s):** Pipe to Pipe (site or workshop)	**Diagram of Joints:** Originally from BS EN14276-1:2006 © BSI  
Joints: **Type of Joint(S):** Lap (tube insert) **Lap Length Range:** See Table 1 below	**Flow Position:** Flow Position(s): Horizontal & Vertical up flow (max angular deviation +/- 15^{O}) **Method of applying filler material:** Manual end feed by hand from rod
Base Metals: Copper EN12735-1:2020 Steel ASTM A 106 grade B schedule 40 (machined) Thickness Range: ¼" 22-15 SWG / - (SC/LC) 3/8"- 7/8" 22-15 SWG / Steel thickness 1.0mm to 4.0mm (SC/LC) 1-1/8"- 4-1/8" 20-9 SWG / Steel thickness 1.0mm to 4.5mm (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

Imperial OD pipe sizes	Minimum overlap Cu / Cu (B), mm	Recommended clearance (C-A), mm
1/4" 3/8" ½" 5/8" ¾" 7/8"	5	0.02 – 0.20
1-1/8" 1-3/8"	5	0.02 – 0.24
1-5/8" 2-1/8"	10	0.03 – 0.30
2-5/8" 3-1/8" 3-5/8" 4-1/8"	10	0.03 – 0.41

Imperial OD pipe sizes	Minimum overlap Cu / Fe or HSCA (B), mm	Recommended clearance (C-A), mm
1/4" 3/8" ½" 5/8" ¾" 7/8"	10	0.02 – 0.20*see note
1-1/8" 1-3/8"	15	0.02 – 0.24*see note
1-5/8" 2-1/8"	15	0.03 – 0.30*see note
2-5/8" 3-1/8" 3-5/8" 4-1/8"	15	0.03 – 0.41*see note

*for dissimilar metal test pieces need to consider the respective coefficient of expansion for the materials being used and larger joint clearances might be required.

Appendix 3 – Example Test Pieces Sizes

The test piece sizes, clearance and overlap have been selected in accordance with BS EN 14276-1:2020 Annex B.

Note: Schedule 40 steel has been selected for the below test pieces to give the thickness range approval needed, transition pieces for installation into live refrigeration systems need to be suitable for the application.

Range of sizes considered

- ¼" to 4-1/8" OD standard copper tube (6.4mm to 104.8mm) lap joints
- 3/8" to 2-1/8" HSCA, 80 bar and 120 bar versions
- Copper 22 SWG to 12 SWG (0.711mm to 2.642mm nominal)
- Steel wall thickness 1.0mm to 4.5mm

Recommended test piece joints

1/2" OD, 20 SWG / schedule 40 steel machined to suit:

- OD range covered: 1/4" to 7/8" Cu/Cu 3/8" to 7/8" Cu/Fe
- Copper wall thickness range covered: 22 to 15 SWG and HSCA 120 bar to 7/8"
- Steel wall thickness range covered: 1.0mm to 4mm

1-1/8" OD, HSCA 120 bar / schedule 40 steel machined to suit:

- OD range covered: 1-1/8" to 4-1/8" Cu/Cu 3/8" to 4-1/8" Cu/Fe
- Copper wall thickness range covered: 20 to 9 SWG and HSCA 120 bar to 2-1/8"
- Steel wall thickness range covered: 1.0mm to 4.5mm

Materials

Materials are grouped in table B.4 (BS EN 14276-1:2020 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 and I.3 (BS EN 14276-1 Annex I).

Different test pieces are required for:

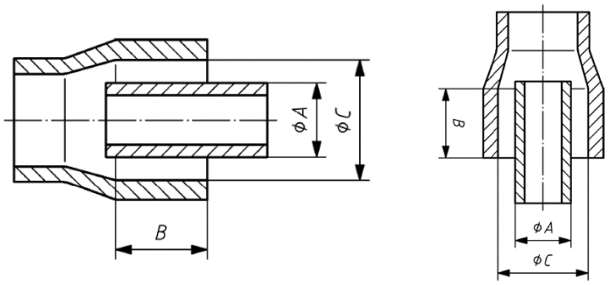
- Copper to copper (including alloys with zinc (brass), tin and nickel)
- Copper to steel

The following test pieces are not commonly required so are not included in this specification:

- 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

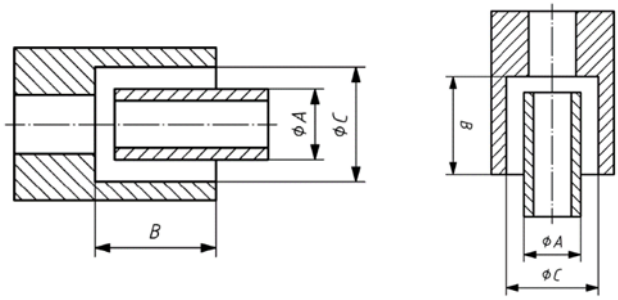
Below are the joint arrangements and dimensions for the test pieces:

Test Pieces 1, 2, 5 & 6, copper to copper lap joint (straight coupler or elbow) - 2 x Horizontal flow & 2 x Vertical up flow joints



	Test pieces 1 & 2 Horizontal & Vertical Up	**Test pieces 5 & 6 Horizontal & Vertical up**
	Small Commercial (1/4" to 7/8")	Large Commercial (1-1/8" to 4-1/8")
Size	½" 20 SWG	1-1/8" HSCA 120 Barg
Minimum fitting depth (B)	5mm	8mm
Recommended clearance (C-A)	0.02mm to 0.20mm	0.02mm to 0.24mm
Total length of test piece	400mm (2 x 200mm)	400mm (2 x 200mm)

Test Pieces 3, 4, 7 & 8, copper to Schedule 40 Steel lap joint - 2 x Horizontal flow & 2 x Vertical up flow joints



	Test pieces 3 & 4 Horizontal & Vertical Up	**Test pieces 7 & 8 Horizontal & Vertical Up**
	Small Commercial (1/4" to 7/8")	Large Commercial (1-1/8" to 4-1/8")
Size	½" 20 SWG (copper) ½" (Schedule 40 steel machined)	1-1/8" HSCA 120 Barg (Copper) 1-1/8" (Schedule 40 steel machined)
Minimum fitting depth (B)	10mm	15mm
Recommended clearance (C-A)	0.02mm to 0.20mm*see note	0.02mm to 0.24mm*see note
Total length of test piece	400mm (2 x 200mm)	400mm (2 x 200mm)

*for dissimilar metal test pieces need to consider the respective coefficient of expansion for the materials being used and larger joint clearances might be required.

Copper EN 12735-1:2020
Steel ASTM A 106 Grade B Schedule 40 steel (machined to suit)

Appendix 4 - Examination of Test Pieces (Brazer approval)

The test piece/s 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.

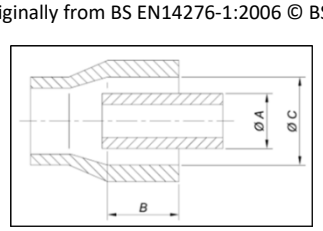
Acceptance criteria: No cracks are accepted and penetration should be 80% of the overlap.

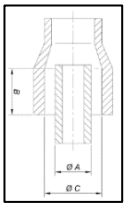
Adapted from BS EN14276-1:2020 Annex B

Appendix 5 – Sample Brazing Procedure Approval Record (BPAR)

Brazer procedure approval – in accordance with BS EN 14276-1:2020 Annex B

<table>
<tr>
<td>Manufacturers Name:
Brazers Name:
Examiner Name:
Signed:</td>
<td>BPAR: BRA 2021
BPS No: BRA 1
Brazing Process(s): Pipe to Pipe (site or workshop)
Date of Approval:</td>
</tr>
<tr>
<td>Joints:
Type of Joint(S): Lap (tube insert)
Lap Length Range: See Table 1 below
Position Qualified: All</td>
<td>Flow Position:
Flow Position(s): Horizontal & Vertical up flow (max angular deviation +/- 15^{O})
Method of applying filler material:
Manual end feed by hand from rod</td>
</tr>
<tr>
<td>Base Metals:
Copper EN12735-1:2020
Steel ASTM A 106 grade B schedule 40 (machined)
Thickness Range:
¼” 22-15 SWG / n/a (SC/LC)
3/8”- 7/8” 22-15 SWG / Steel thickness 1.0mm to 4.0mm (SC/LC)
1-1/8”- 4-1/8" 20-9 SWG / Steel thickness 1.0mm to 4.5mm (LC)</td>
<td>Brazing Flux:
CuP 2-15% - Self Fluxing
Ag 30-60% - Add flux type here

EN1045</td>
</tr>
<tr>
<td>Filler Materials:
Copper to Copper: CuP 2-15%
Copper to Steel: Ag 30-60%
EN ISO 3677
BS EN ISO 17672:2010</td>
<td>Post Braze Heat Treatment:
Copper to Copper: Cooled in still air
Copper to Steel: Cooled in still air + flux removal with damp cloth</td>
</tr>
<tr>
<td>Brazing Process / Temperature:
Flame Brazing (TB) Manual Torch
Oxy acetylene / propane 0.5 barg min pressure
Temp Range: >450^{O}C</td>
<td>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</td>
</tr>
<tr>
<td>Clearance & Lap Tolerances – Table 1
Adapted from BS EN14276-1:2020
<table>
<tr><th>Imperial OD pipe sizes</th><th>Minimum overlap Cu / Cu (B), mm</th><th>Recommended clearance (C-A), mm</th></tr>
<tr><td>1/4” 3/8” ½” 5/8” ¾” 7/8”</td><td>5</td><td>0.02 – 0.20</td></tr>
<tr><td>1-1/8” 1-3/8”</td><td>5</td><td>0.02 – 0.24</td></tr>
<tr><td>1-5/8” 2-1/8”</td><td>10</td><td>0.03 – 0.30</td></tr>
<tr><td>2-5/8” 3-1/8” 3-5/8” 4-1/8”</td><td>10</td><td>0.03 – 0.41</td></tr>
</table>
<table>
<tr><th>Imperial OD pipe sizes</th><th>Minimum overlap Cu / Fe or HSCA (B), mm</th><th>Recommended clearance (C-A), mm</th></tr>
<tr><td>1/4” 3/8” ½” 5/8” ¾” 7/8”</td><td>10</td><td>0.02 – 0.20*see note</td></tr>
<tr><td>1-1/8” 1-3/8”</td><td>15</td><td>0.02 – 0.24*see note</td></tr>
<tr><td>1-5/8” 2-1/8”</td><td>15</td><td>0.03 – 0.30*see note</td></tr>
<tr><td>2-5/8” 3-1/8” 3-5/8” 4-1/8”</td><td>15</td><td>0.03 – 0.41*see note</td></tr>
</table>
</td>
<td>Diagram of Joint arrangement:
Originally from BS EN14276-1:2006 © BSI
 


</td>
</tr>
<tr><td>Qualifying joints vertical up flow (qualifies all joint positions)</td><td>Results / Notes</td></tr>
<tr><td>½” Cu to Cu vertical up flow</td><td>Pass / Fail</td></tr>
<tr><td>½” Cu to Cu vertical up flow</td><td>Pass / Fail</td></tr>
<tr><td>½” Cu to Steel vertical up flow</td><td>Pass / Fail</td></tr>
<tr><td>½” Cu to Steel vertical up flow</td><td>Pass / Fail</td></tr>
<tr><td>1-1/8” CuFe to CuFe vertical up flow</td><td>Pass / Fail</td></tr>
<tr><td>1-1/8” CuFe to CuFe vertical up flow</td><td>Pass / Fail</td></tr>
<tr><td>1-1/8” CuFe to Steel vertical up flow</td><td>Pass / Fail</td></tr>
<tr><td>1-1/8” CuFe to Steel vertical up flow</td><td>Pass / Fail</td></tr>
</table>

Appendix 6 – Sample Brazer Qualification Test Certificate

Manufacturers Name:
xxxxxxxx

Brazer Name:
xxxxxxxx

Examiner/Assessor Name:
xxxxxxx

Signed:
xxxxxxxx

Certificate 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: xxxxxxx **Valid:** 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 & Vertical up flow (max angular deviation +/- 15^{O})
Method of applying filler material:
Manual end feed by hand from rod

Base Metals:
Copper EN12735-1:2020
Steel ASTM A 106 grade B schedule 40 (machined)
Thickness Range:
¼" 22-15 SWG / n/a (SC/LC)
3/8"- 7/8" 22-15 SWG / Steel thickness 1.0mm to 4.0mm (SC/LC)
1-1/8"- 4-1/8" 20-9 SWG / Steel thickness 1.0mm to 4.5mm (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

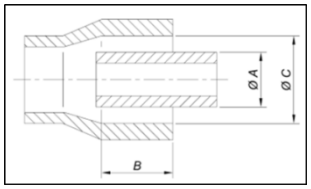
Technique:
Method of pre cleaning: Grit free abrasive sheet
Torch Nozzle Size: Sizes 5 – 25 including pepperpot
Internal OFN purging during brazing process to prevent oxidisation

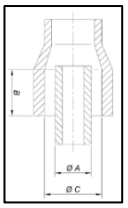
Clearance & Lap Tolerances – Table 1
Adapted from BS EN14276-1:2020

Imperial OD pipe sizes	Minimum overlap Cu / Cu (B), mm	Recommended clearance (C-A), mm
1/4" 3/8" ½" 5/8" ¾" 7/8"	5	0.02 – 0.20
1-1/8" 1-3/8"	5	0.02 – 0.24
1-5/8" 2-1/8"	10	0.03 – 0.30
2-5/8" 3-1/8" 3-5/8" 4-1/8"	10	0.03 – 0.41

Imperial OD pipe sizes	Minimum overlap Cu / Fe or HSCA (B), mm	Recommended clearance (C-A), mm
1/4" 3/8" ½" 5/8" ¾" 7/8"	10	0.02 – 0.20*see note
1-1/8" 1-3/8"	15	0.02 – 0.24*see note
1-5/8" 2-1/8"	15	0.03 – 0.30*see note
2-5/8" 3-1/8" 3-5/8" 4-1/8"	15	0.03 – 0.41*see note

Diagram of Joint arrangement:
Originally from BS EN14276-1:2006 © BSI





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"

Note: For full range approval ¼" to 4-1/8" all 8 joints SC/LC are required

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
Lap joint 1 - SC/LC	½" copper to ½" copper horizontal								
Lap joint 2 - SC/LC	½" copper to ½" copper vertical up flow								
Lap joint 3 - SC/LC	½" copper to ½" steel horizontal								
Lap joint 4 - SC/LC	½" copper to ½" steel vertical up flow								
Lap joint 5 – LC	1-1/8" HSCA 120 barg copper to 1-1/8" HSCA 120 barg copper horizontal								
Lap joint 6 – LC	1-1/8" HSCA 120 barg copper to 1-1/8" HSCA 120 barg copper vertical up flow								
Lap joint 7 – LC	1-1/8" HSCA 120 barg copper to 1-1/8" steel horizontal								
Lap joint 8 – LC	1-1/8" HSCA 120 barg copper to 1-1/8" steel vertical up flow								

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

Re-test	**(if required)**	**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**
Lap joint 1 - SC/LC	½" copper to ½" copper horizontal								
Lap joint 2 - SC/LC	½" copper to ½" copper vertical up flow								
Lap joint 3 - SC/LC	½" copper to ½" steel horizontal								
Lap joint 4 - SC/LC	½" copper to ½" steel vertical up flow								
Lap joint 5 – LC	1-1/8" HSCA 120 barg copper to 1-1/8" HSCA 120 barg copper horizontal								
Lap joint 6 – LC	1-1/8" HSCA 120 barg copper to 1-1/8" HSCA 120 barg copper vertical up flow								
Lap joint 7 – LC	1-1/8" HSCA 120 barg copper to 1-1/8" steel horizontal								
Lap joint 8 – LC	1-1/8" HSCA 120 barg copper to 1-1/8" steel vertical up flow								

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

Appendix 7 – Sample Question Bank

Name	Date	Small Commercial Large Commercial
Company name and address		
Assessor signature	Candidate signature (on completion)	
Pass / Fail (20/23)		

Answer **one** correct answer. Read the questions carefully and think about your answers, take your time!

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

- ☐ a. Food & drink
- ☐ b. Holiday Pay
- ☐ c. Personal Protective Equipment
- ☐ d. Un-safe Working Environment

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

- ☐ a. 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 Data Sheets
- ☐ b. Safety Data Sheets
- ☐ c. Site Data Sheets
- ☐ d. Tea Card Sheets

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

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

5. 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. Welding permit

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

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

7. 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

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

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

9. 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

10. 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

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

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

12. 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

13. 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

14. 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

15. 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

16. 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

17. What adjustment of flame should you have when brazing copper to copper?

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

18. Acetylene is which of the following?

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

19. 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

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

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

21. 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

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

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

23. 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

Assessor Feedback

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 - 5. This test will observe the following requirements:

- Health and Safety Requirements for the process including use of PPE 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 or eight joints following the criteria set down in Appendix 4.

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

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