THE SAFE USE OF OXY-PROPANE PREHEATING

1 This Information Document (ID) contains internal guidance which has been made available to the public. The guidance is considered good practice (rather than compulsory) but you may find it useful in deciding what you need to do to comply with the law. However, the guidance may not be applicable in all circumstances and any queries should be directed to the appropriate enforcing authority.

2 This document addresses the physical risks and hazards associated with the use of open flame propane fuelled preheating nozzles (see Figure 1), when used prior to welding to heat a weld preparation, which forms an enclosed space.

BACKGROUND

3 There have been several instances of explosion, one resulting in a fatality, where unburned fuel gas has collected inside steel fabricated structures during preheating. HSE has subsequently undertaken research into the passage of unburned gas through the welding gap and published the results. (See paragraph 20(1) for details of the Contract Research Report (CRR)).

4 The CRR concludes that the welding gap can interfere with the flame from a preheating nozzle by allowing the passage of unburned gas through the gap. This can then result in the formation of an explosive atmosphere in any enclosed space behind the welding gap.

5 For the purposes of this ID, an ‘enclosed space’ is that space within a fabrication in which the atmosphere can potentially become explosive as a result of applying a preheating torch to a weld preparation. This document does not advise on work within confined spaces.

INTRODUCTION

6 Before undertaking arc welding, steelwork often has to be preheated to ensure that the weld does not fail because of hydrogen cracking. The methods for achieving this include using an oxy-fuel gas nozzle. The preferred sizes of these copper heating nozzles, (Figure 1) are known as 3H and 5H. Propane is generally used as the fuel at a consumption rate of about 2 and 4 litres/sec respectively. As an alternative to the 3H and 5H nozzles, fuel gas/entrained air nozzles are used.

7 The authors of the CRR made the following observations of fabrication practice. Weld preparation gaps range from 3-10 mm in width. However, there may be circumstances where larger gaps (up to 10 mm) are found because of distortion and or poor dimensional match between sections to be welded. The typical nozzle to workpiece distance for preheating is about 50 mm (CRR section 2.4 refers), which gives the highest heat input. During the process the torch is moved across the gap to heat up the metal for about 25 mm on either side of the joint. The research work

questions the appropriateness of these dimensions. Longer working distances, about 150 mm, are often used during the early stages of preheating to remove surface moisture.

FLAMMABLE GAS CHEMISTRY

8 The burning of propane (hydrocarbons) is a complicated chemical process in which several different reactions occur at the same time. Part of the process of burning propane is called oxidation and it results in a massive release of energy which is used to heat up the metal. However, if the reaction does not take place with the correct amount of oxygen in the mixture, there will be some unburned gas remaining in the flame. The CRR gives further details of the combustion process.

THE EFFECTS OF THE WELD PREPARATION GAP

9 The research has shown that as a lighted nozzle is played over the weld preparation gap, various amounts of unburned gas pass between the plates. Where the weld is intended to seal an enclosed space, then the passage and accumulation of such gas can form an explosive atmosphere within the enclosure. The mechanism is as follows:

(1) Unburned fuel passes through the gap and this results in a fuel-rich atmosphere being created on the opposite side of the weld preparation. Whilst the outside of the flame appears to be burning correctly, in fact in the middle of the flame it is not.

(2) Because there is not enough oxygen, the gas in this mixture does not burn properly behind the weld preparation. (Sometimes gas can be seen burning at the weld preparation edge when the preheating nozzle is removed).

(3) Once the nozzle is removed the unburned gas behind the preparation begins to cool and, in doing so, draws air in from the surroundings. (In large structures, such as vertical tubular fabrications, this air can come from within the fabrication itself).

(4) During cooling, gas enters the explosive range and will explode if a new source of ignition is introduced such as a preheating torch or a welding arc.

10 Large enclosed spaces, such as the support legs for oil platforms, are just as likely as small ones to contain a flammable atmosphere. Although unburned gas accumulates more quickly during the use of an oxygen-deficient flame, this occurs regardless of flame quality.

11 The following factors increase the possibility of unburned gas passing through the weld gap:

(1) Incorrect procedures are used to light the flame. The correct way to light a torch is to hold it pointing down to trap the heavier-than-air gas

against a horizontal surface. The torch should also be lit quickly to minimise the amount of unburned fuel released. Attempts should not be made to light torches where raw fuel can enter an enclosed space.

(2) The wrong torch nozzle sizes are used. Gas flow rates vary with nozzle size and operators should select the heat output of the nozzle to match the size or area of the preparation.

(3) Operators are not competent to use the equipment. This may occur because no training is thought necessary for such 'low technology' equipment.

(4) The nozzles are not properly maintained. A standard preheating torch is an unwieldy piece of equipment and it is easy to damage the nozzle by casual impact. The body of the nozzle is made from copper and impacts not only damage the front face of the nozzle, but also tend to loosen the screw thread attaching it to the torch extension. This results in an escape of unburned gas.

OPEN FLAME PREHEATER BURNER PREDICTED CHARACTERISTICS

12 When a narrow gap is placed in the path of the flame, the mixture entering the gap will have the composition of the flame at that point. During the experimental stages of the CRR, predictions of the flame temperature, fuel fraction, and oxygen fraction were made. These predictions showed the hottest part of the flame, 4750 degrees centigrade, was within the first third of its length as it left the nozzle. This is also the most fuel rich portion of the flame, ie the area with least oxygen (oxygen depletion).

13 This indicates that the shorter the stand-off distance, the greater the rate of build up of unburned fuel gas behind the weld preparation. Because of the vast amounts of heat available it is possible to have a longer stand-off distance, which still has sufficient energy to adequately preheat the weld. The greater stand-off distance also gives the fuel and oxygen a greater opportunity to mix and reach an ideal balance, ie 'a normally adjusted flame'. Even so the research has shown that a fuel-rich atmosphere will always be generated in the enclosed space using the open flame process, it will simply take longer to form at greater stand-off distances.

14 In summary, the research indicates that unburned fuel gas can be expected in all open flame preheating processes, currently employed using an effective preheat flame length. Operators can greatly affect the rate of build up of unburned fuel in an enclosed space (see paragraph 17), but it does not appear they can prevent it. Users of open flame preheating process should give detailed consideration to the recommendations contained in this ID.

RECOMMENDATIONS

15 Wherever reasonably practicable, designers and their clients should make use of alternative designs of fabrication to those which require the formation, by welding, of an enclosure.

16 Alternatively, wherever reasonably practicable, other techniques of pre-heating should be substituted in preference to the use of fuel gas. Depending upon the temperature requirements of the preheating these can include radiant preheat gas burners or electrical induction heaters.

17 Where this cannot be achieved such as in repair or maintenance, then the following precautions should be adopted.

(1) The correct lighting procedures and flame setting (see paragraph 11(1)).

(2) The correct handling of preheater nozzles to prevent damage.

(3) Weld preparation gaps of approximately 5 mm minimum width should be sought. Evidence shows a 3 mm gap passes more unburned gas than a 5 mm gap.

(4) The nozzle face to preparation (stand-off) distance should be the greatest practicable; in any case not less than two-thirds of the length of the preheater flame and a minimum of 150 mm.

(5) A safe system of work for the use of preheaters should be drawn up.

(6) Where reasonably practicable, the atmosphere within the enclosed space should be tested using a flammable gas detector before the welding arc is struck or preheating restarted. It is advised that welding/heating does not proceed at levels greater than 10% of the lower explosive limit (LEL).

(7) If reasonably practicable, the atmosphere within the enclosed space should be supplemented with make up air at a volume sufficient to maintain the flammable gas component in the enclosed space to below 10% of its lower explosive limit (LEL).

(8) Nozzles should be maintained in good condition and there should be no leakage of fuel from the rear of the nozzle heads. Hammering the face of the nozzle deforms the castellations and blocks up the jets.

(9) Hoses, regulators, flame arrestors and torches should all be routinely inspected for operational integrity.

18 Operators and supervisors should be properly trained in these precautions and the hazards associated with the use of fuel gas, including how an explosive atmosphere can form after preheating.

LEGAL REQUIREMENTS

19 Although the use of oxy-propane preheating equipment is covered by several sets of legislation, the Management of Health and Safety at Work Regulations 1992 are particularly important. These Regulations require, amongst other things, that the

risks from work activities should be assessed in order to determine what health and safety precautions are needed. This ID and CRR gives information on the risks created by open flame preheating processes; risks which may not have been properly assessed before. If there is any doubt about the adequacy of the precautions used, then the risk assessment should be reviewed.

REFERENCES

20 The following publications provide further information.

(1) HSE Contract Research Report No 78/1995 *An investigation into the passage of unburnt gas through welding gaps during the use of oxy-propane preheating torches* (ISBN 0 7176 0985 5).

(2) HS(G)139 *The safe use of compressed gases in welding, flame cutting and allied processes* (ISBN 0 7176 0680 5).

(3) HS(G)129 *Health and safety in engineering workshops* (ISBN 0 7176 0880 8).

They are available from HSE Books, PO Box 1999, Sudbury, Suffolk, CO10 6FS, telephone 01787 881165, fax 01787 313995.

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FIGURE 1
A
B
C
A) 4H Oxy-Propane Pre Heating Nozzle
B) Modified Air Entraining Oxy-Propane Pre Heating Nozzle
C) Propane Air Pre Heating Nozzle