ANNEX 2

Statement of Evidence
Health effects arising from inhalation exposure to welding fume

Summary

Under HSE's wide-ranging initiative to bring about a reduction in occupational disease arising from exposure to dusts, gases, vapours and fumes, welders have been identified as an 'at risk' group. The initial stage in this process is to identify and set out the underlying evidence base for the potential ill-health effects arising from inhalation exposure. Hence, the purpose of this paper is to set out the current state of evidence and knowledge for the potential health effects arising from inhalation exposure to welding fume.

It should be noted that it is not the intention to review all the available data based upon primary literature sources, but rather to identify and summarise the current collective HSE knowledge about the main, inhalation health effects of welding fume, based where possible, on key review papers. Additionally, in some cases individual literature papers and statistical analyses have also been drawn upon.

Each identified potential health effect is laid out and discussed separately, but in no particular order in terms of its severity, time of onset or duration. The main, identified health effects considered are pneumonia, asthma, chronic obstructive pulmonary disease (COPD), lung cancer, metal fume fever (MFF), and lung function changes.

In studying the potential health effects arising from inhalation exposure to welding fume, a clear and consistent picture of increased mortality from pneumonia (pneumococcal and lobar) among working-age welders in England and Wales has been demonstrated over a number of decades. The magnitude of this increase was notable, with a greater than doubling in the number of such deaths being reported in this occupational group. Following cessation of exposure, there appears to be a reversal in this increased susceptibility to pneumonic infection among welders. Additionally, inhalation exposure to welding fume has been shown to be associated with hospital admissions related to infection with pneumonia (any type) in England and Wales between 2006 and 2007.

Asthma arising from inhalation exposure to 'fumes from stainless steel welding' is a prescribed disease under the DWP Industrial Injuries and Disablement Benefit (IIDB) Scheme. Under The Health and Occupation Reporting (THOR) network in Great Britain, 10 cases of occupational asthma in welders were reported for the period, 2005-2006. Equally, under THOR, stainless steel welding fumes have been identified as one of the most frequently suspected agents associated with occupational asthma. Additionally, the stainless steel welding fume constituents, chromium and nickel are known asthmagens. In direct contrast to this, it is noted that in 1999 and 2007, HSE when assessing inhalation exposure to stainless steel

welding fume as a potential cause of occupational asthma concluded that the evidence was insufficient to conclude that it was an asthmagen. Overall, the evidence that welding fume in general causes occupational asthma is conflicting. However, given that occupational asthma arising from exposure to stainless steel welding is a prescribed disease, HSE considers it inappropriate to exclude outright this potential ill-health effect.

An association of inhalation exposure to welding fume with chronic obstructive pulmonary disease (COPD) has been reported by a number of assessors. However, whilst the available evidence is suggestive of a causal link between exposure to welding fume and COPD, it is by no means conclusive. In fact, when assessed by the IIAC, welding was deemed not to meet the criteria for prescription as a causal factor of work-related COPD.

The International Agency for Research on Cancer (IARC) has classified occupational exposure to welding fumes as possibly carcinogenic to humans. Also, nickel and chromium VI compounds, which can be present in fume generated from welding stainless steel and other alloys, are designated as human carcinogens under the EU hazard classification scheme. In terms of the cancer burden that can be attributed to occupational exposure to welding fumes, a peer-reviewed, HSE-commissioned study from Imperial College London estimates that 152 attributable deaths from lung cancer (139 attributable deaths for men, 13 attributable deaths for women) were associated with occupational exposure to welding fumes in Great Britain in 2004.

It is well established that welding fume can cause metal fume fever (MFF). This is a common, short-duration, flu-like condition observed within 4-8 hours of inhalation exposure to welding fume, particularly (but, not exclusively) when welding galvanised metal. Metal oxides, especially zinc oxide are thought to be responsible. The respiratory symptoms associated with MFF have been suggested to be an early ‘marker’ for the subsequent development of occupational asthma, but, this remains unproven.

There is a reasonable body of data relating transient effects upon lung function with inhalation exposure to welding fume. However, the implications of these changes in lung function parameters in relation to the development of long-term respiratory disease, including occupational asthma are unclear.

Introduction

During welding and hot cutting (‘hot work’) operations, fumes are produced which are collectively known as welding fume. Depending upon the type of welding process being performed, the resultant fume generated is a complex and highly variable mixture of gases and particulates. Given the respirable size range of the particulate matter it has the potential to reach the deep lung (alveoli), and be deposited upon inhalation. The composition of welding fume and size of particles is determined by a number of factors including, the welding process, the composition of the base metal and consumable electrode, the presence of shielding gases and the temperature employed.

When welding with stainless steel electrodes and some other alloys, the fumes generated can contain up to 20% chromium (both hexavalent and trivalent forms) and 10% nickel (Antonini, 2003). Iron is the main constituent (>80%) when mild steel is welded, with no chromium or nickel being present.

Health Effects

As welding fume is so variable in its composition, the potential health effects that can result from inhalation exposure will also vary as a consequence. The approach adopted here is to review the evidence about health effects relating to welding fume (or welding) as defined in generic terms, rather than considering specific constituents of welding fume or specific kinds of welding process. However, there are a few notable exceptions where the available evidence presented relates specifically to stainless steel welding.

Each identified potential health effect is laid out and discussed separately, but in no particular order in terms of its severity, time of onset or duration. The main, identified health effects considered are pneumonia, asthma, chronic obstructive pulmonary disease (COPD), lung cancer, metal fume fever (MFF), and lung function changes.

<u>Pneumonia</u>

Analyses of mortality data in England and Wales stretching back as far as 1949, show that welding is recorded significantly more frequently than expected as an occupation on the death certificates of those dying from pneumonia. Statistics for the period 1979-80/1982-90 published in the Occupational Health Decennial Supplement 1995 showed an excess of male deaths from pneumococcal and unspecified lobar pneumonia (75 deaths vs. 40 expected – Proportional Mortality Ratio: PMR 186). Increased mortality was restricted to pre-retirement age men (ie. under 65 years; 55 deaths vs. 22 expected - PMR 255), with a similar mortality pattern being observed in a number of other occupational groups (furnacemen and moulders) exposed to metal fume.

An analysis based on the most recent Decennial Supplement which includes deaths during 1991 to 2000 in England and Wales (Palmer et al, 2009), found mortality excesses among working-age men (aged 16-64), in occupations associated with exposure to metal fume, for pneumococcal and lobar pneumonia (54 deaths vs. 27 expected – PMR 198), and from other pneumonias (71 deaths vs. 52 expected), especially viral and other bacterial pneumonia. No excess was found from these causes at older ages or from bronchopneumonia at any age. This equates to an estimated excess of 2.7 deaths a year for pneumococcal/lobar pneumonia, and 1.9 for other pneumonias (excluding bronchopneumonia).

In a relatively recent population based case-control study of pneumonia in the West Midlands (Palmer et al, 2003), pneumonia was associated with reported occupational exposure to metal fume in the previous year [adjusted odds ratio

(OR) = 1.6; 95% confidence interval (CI): 1.1-2.4], but not in earlier periods, with the highest risks seen for lobar pneumonia and recent exposure to ferrous fume (OR = 2.3; 95% CI: 1.2-4.3).

Together these findings suggest that inhalation of metal fume increases susceptibility to pneumonic infection, particularly among welders, but that cessation of exposure leads to a reversal of this effect.
In order to assess the potential scale of pneumonia morbidity attributable to welding fume, HSE carried out an attributable fraction calculation using data from a number of sources (Wilkinson and Darnton, 2009, personal communication). There is considerable uncertainty in the resulting estimates because of a number of underlying assumptions, but they suggest that each year of the order of 40 to 50 hospital admissions (and about 2 deaths) due to any form of pneumonia are attributable to exposure to welding fume. The figure for attributable deaths is of the same order as that calculated by Palmer et al. (2009).

Asthma

In 2007, HSE undertook an assessment of the available evidence for stainless steel welding fume exposure being a cause of occupational asthma (Ball, 2007). This was subsequent to a previous analysis by HSE in 1999, in which it was concluded that the persistent respiratory symptoms noted in welders following such exposures were due to an irritant, rather than an allergic response. In addition, although occupational asthma cases linked to stainless steel welding had been identified from the literature, the numbers of these were small compared to the large number of workers involved in welding activities. In the 2007 assessment, the conclusion reached by HSE was similar to that arrived at in 1999 that, ‘On balance, the evidence for stainless steel as a cause of occupational asthma is not considered sufficient to meet the stringent criteria that have been adopted to distinguish between substances that can initiate specific airway hypersensitivity de novo (asthmagens) and those that cause symptoms by exacerbating an underlying airway condition’. As a result of this, stainless steel welding fume was judged by HSE as not having sufficient underlying evidence to warrant its inclusion in HSE’s Asthmagen?Compendium, or as meeting the EU criteria for classification as an asthmagen.

Notwithstanding the above conclusion reached by HSE regarding the non-inclusion of stainless steel welding fume in the Asthmagen?Compendium, it is worth remembering that the fumes contain chromium and nickel, which are themselves known asthmagens.

Since 1990, ‘fumes from stainless steel welding’ have been included among the list of causative agents for occupational asthma for which Industrial Injuries and Disablement Benefit (IIDB) can be paid within the provisions of the Department for Work and Pensions Social Security Administration Act 1992. This reflects the view of the Industrial Injuries Advisory Council (IIAC) at the time that there was sufficient evidence to recommend that a causal link between asthma and stainless steel welding fume can be reasonably presumed where it is suggested by the clinical features of individual cases. During the 10-year period, 1999-2008 there were 95 new cases of occupational asthma attributed to fumes from stainless steel welding where IIDB was awarded.

Statistics based on cases recorded by chest physicians under The Health and Occupation Reporting (THOR) network in Great Britain, show that during the 10-year period, 1999-2008 there were an estimated 22 cases of occupational asthma due to stainless steel welding (based on 11 actual cases), and 81 estimated cases due to 'other welding fumes' (based on 37 actual cases). Together these account for 2.5% of all estimated cases of occupational asthma recorded over the period. The most recent figures available by occupation show that there were an estimated 4 cases of occupational asthma per year in welding trades over the period 2006-2008 (http://www.hse.gov.uk/statistics/tables/thorr05.htm).

Incident cases of occupational asthma identified through the IIDB and THOR schemes will underestimate the true scale of occupational asthma. There is considerable uncertainty about the degree of underestimation, particularly for individual agents. However, some evidence (such as epidemiological estimates of the proportion of asthma attributable to occupation and cases identified by GPs) suggest that the overall incidence of occupational asthma in Great Britain may be an order of magnitude higher than that based on THOR (http://www.hse.gov.uk/statistics/causdis/asthma/index.htm).

In summary, while the evidence about whether welding fume can initiate asthma in itself may not be sufficient to meet stringent criteria for classification as an asthmagen, statistics from the IIDB and THOR schemes show that exposures to welding fume have made an important contribution to the burden of disease identified as occupational asthma by clinicians seeing individual cases.

Chronic Obstructive Pulmonary Disease (COPD)

COPD is an 'umbrella' term that embraces chronic bronchitis and/or emphysema. The main characteristic of COPD is an irreversible limitation on airflow and subsequent decline in lung function which is usually progressive.

The Institute for Environment and Health (IEH) in 2005 reviewed the available literature relating to occupational exposure and the risk of developing chronic bronchitis and emphysema (CBE ie. COPD). This was done from the perspective of the IIDB Scheme in order to identify any circumstances where there is clear evidence of at least a doubling of the risk of COPD. The report's author, Dr.Lesley Rushton concluded that there is evidence of associations between decline in lung function and incidence of CBE and exposure to welding fumes. However, it was noted that these associations were mainly seen among current, and to a lesser extent, past smokers. Overall, there was no evidence to suggest that welders have at least a doubling of the risk of developing COPD. Hence COPD associated with welding was judged not to satisfy the criteria for prescription. However, not meeting the IIAC criteria for prescription does not necessarily demonstrate a lack of evidence for an association between welding and COPD.

Cases of CBE have been attributed to welding by doctors reporting within the THOR scheme. However, the total number of occupational CBE cases reported within this scheme is relatively small. Over the last 5 years (2004-2008) there were an estimated 75 cases of work-related COPD (CBE) on average per year. Previous analyses of CBE cases by occupation and causative agent show that some have been attributed to work as a welder or with welding fume based upon the opinion of the reporting doctors; of the CBE cases reported over the period 1989-2003, 16% were welders and 31% mentioned welding fume as the causative agent.

HSE's statisticians have analysed a number of population surveys on workers' perceptions of exposure to dusts, gases and fumes whilst at work, as well as undertaking an analysis of the distribution of COPD across occupations as determined in the Health Survey for England. The outcome of their initial analyses was 'that the findings provide some support for the view that work as "metal working operatives" and in "metal forming, welding etc trades" may be associated with an increased risk of COPD but that the findings are by no means conclusive' (WATCH/2009/2).
The WATCH Committee have been asked on a number of occasions to consider, and provide clarification on the available evidence for the position that COPD might or might not be caused by exposure to welding fume. WATCH recently considered this issue at the February 2009 meeting, and as part of their deliberations, members examined and considered the available evidence as outlined in the 4 preceding paragraphs above. WATCH's opinion was as follows:-

'The Chairman added his perspective that there is a vast body of literature on the health consequences of exposure to welding fumes. WATCH had not been asked to comprehensively review the scientific evidence underlying this issue because of the sheer size of the task'. However, WATCH deemed it appropriate that HSE adopt the position, 'that whilst current evidence is suggestive, it is not sufficient to establish a causal link between exposure to welding fume and COPD'.

Changes in Lung Function Parameters

The most pertinent document to-date with regard to exposure to welding fume and the potential to develop lung function parameter changes, is the HSL (2006) literature review. For this review, an earlier review paper by Antonini et al. (2003) was evaluated together with any relevant further studies obtained in the period immediately after (ie. 2003-2005). It is apparent from the HSL review, that although potential lung function parameter changes associated with exposure to welding fume have undergone widescale investigation, by and large, fairly ambiguous results have been obtained. This is mainly due to wide variations between the different studies in terms of the exposure setting under consideration, and the welding process employed.

Some of the earlier (pre-2003) reviewed studies indicate that transient effects on lung function parameters can manifest during exposure to welding fume, with a subsequent recovery of normal function during non-exposure. Up to a 4-fold reduction in lung function (not further specified) was measured among welders compared to controls in 1 study, and it was noted that 'long-term' (not further defined) stainless steel welders had 'more significant reductions in lung function towards the end of a shift than mild steel welders' in another study.

In the later (post-2003) reviewed studies (both cross-sectional with matched controls and longitudinal), associations between welding and impaired lung function parameters have been consistently reported. Such cross-shift reductions in lung function parameters were relatively small in magnitude [of the order of at least a 5% reduction in forced expiratory volume in 1 second (FEV_1)] and as already identified above, transient in nature. In one particular study, significant reductions in a range of lung function parameters ($FEV_{1,}$ $FEV_{1/}$FVC-forced vital capacity, and peak expiratory flow-PEF) were measured in welders with greater than 9 years of exposure compared to controls. Additionally, it was reported that 'stratification of results shows a dose-effect of years of welding on lung function' in non-smoking welders. It was concluded that this effect demonstrated 'an obstructive pattern of airways disease' but no further explanation for this conclusion was offered.

Overall, it is difficult to draw any firm conclusions regarding the interpretation of the described lung function decrements measured in welders since many of the reviewed studies were conducted on small study populations, and were limited by low statistical power. This equally applies when trying to make predictions regarding the long-term health significance of these lung function changes in welders. It is unclear as to whether or not they can be viewed as potential 'early markers' associated with the development of long-term respiratory disease, including occupational asthma.

Lung Cancer

Welding fume is currently classified as a Group 2B carcinogen (possibly carcinogenic to humans) under the International Agency for Research on Cancer (IARC) classification system.

As previously indicated, welding fumes from stainless steel and a number of other alloys, contain nickel compounds and chromium VI and III. Both soluble and insoluble nickel compounds are classified as Category 1 carcinogens according to Directive 67/548/EEC [equivalent to Category 1A carcinogens under the forthcoming new Regulation on Classification, Labelling and Packaging ("CLP Regulation"; 2009) which comes into force in December 2010]. Equally, chromium VI compounds are classified as Category 2 carcinogens under the current EU Classification and Labelling Scheme [equivalent to Category 1B carcinogens under the forthcoming "CLP Regulation"; 2009]. Additionally, both nickel compounds (soluble and insoluble) and chromium VI compounds are classified by IARC as Group 1 carcinogens (carcinogenic to humans).

HSE commissioned Imperial College London to produce an updated estimate of the current burden of cancer for Great Britain (GB) resulting from occupational exposure to carcinogenic agents or exposure circumstances (Rushton et al., 2008; HSE Research Report RR595, 2007). The primary measure of the burden of cancer used in this project is the attributable fraction i.e. the proportion of cases that would not have occurred in the absence of exposure; this is then used to estimate the attributable numbers. Estimates are made separately for each specific pairing of a cancer type and an occupational exposure known to produce cancer at this site, and by industry or occupation in which exposure occurs. Risk estimates are obtained from published literature. National data sources such as the CARcinogen EXposure database (CAREX), the UK Labour Force Survey (LFS) and Census of Employment, are used for estimating proportions of the GB population exposed. To take account of cancer latency a 'risk exposure period' (REP) is defined as the period during which exposure occurred that was relevant to the development of the cancer in a specific target year. For solid tumours such as lung cancer, a latency of at least 10 and at most 50 years is assumed. The proportion of the GB population exposed to the occupational carcinogens of concern over the REP is estimated as the ratio of the numbers ever exposed over the numbers ever of working age during the period, taking into account changes in numbers employed and adjusting for employment turnover.

For this Imperial College London study, estimates for cancer of the lung attributable to occupational exposure as a welder have been derived using mortality data for calendar year 2004. Occupation as a welder involves exposure to a variety of fumes and gases, many of which are carcinogenic to the lung. Ambroise et al. (2006) reviewed a total of 59 studies published between 1954–2004 that included shipyard, mild steel and stainless steel welders. Their overall combined relative risk of 1.26 [95% Confidence Interval (CI) 1.20–1.32] was used to calculate the attributable fraction of lung cancer from occupational exposure to welding fumes. For GB in 2004, there were 19,013 total deaths in men from lung cancer, and 13,328 deaths in women. The estimated attributable fraction for cancer of the lung associated with occupation as a welder in men is 0.7% (95% CI 0.6-0.9), and 0.01% (95% CI 0.008-0.012) in women, which equates to 139 attributable deaths of lung cancer in men and 13 attributable deaths of lung cancer in women, respectively.

Metal Fume Fever

Metal fume fever (MFF), reported as being 'the most frequently observed acute respiratory illness of welders' (Antonini, 2003), is a transient and self-limiting condition which usually occurs within 4-8 hours of exposure (Liss, 1995). It has been particularly associated with exposure to the fumes arising from welding galvanised metal such as galvanised steel. The responsible agents are thought to be metal oxides contained in the particulate fraction, with the most notable of these being zinc oxide. The reported signs and symptoms mirror those seen with flu, including, cough, fever, shivering and aches and pains. It is often referred to as 'Monday morning fever'. This is because although workers regularly exposed to welding fume can develop a 'tolerance', this is then lost whilst away from work for short time periods (2 days), with the condition recurring upon return to work. The underlying mechanism of effect for this condition is unknown, but an acute inflammatory response has been implicated. It is commonly considered that the occurrence of MFF is indicative of 'heavy' exposures to welding fume.

As part of the HSL (2006) literature review, a number of studies by El-Zein et al. were evaluated These papers looked at the possible association of welding fume-related MFF and respiratory symptoms in welders including apprentices, welding different metals and not exclusively galvanised steel. The likelihood of these workers developing occupational asthma was also investigated. Although a significant association between the occurrence of exposure-related respiratory symptoms and systemic effects indicative of MFF was demonstrated for welding fume, the data fell short of providing evidence for a causal link with occupational asthma. However, the authors did consider that the observed respiratory symptoms could be viewed as an early 'marker' for the subsequent development of occupational asthma.

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