4. Summary of Data Reported and Evaluation

4.1 Exposure data

Welding has been an important industrial process since the early twentieth century and has become widespread since about 1940. A wide variety of welding techniques is used, although most welding is performed using electric arc processes — manual metal arc, metal inert gas and tungsten inert gas welding — all of which have been used for at least 40 years. Although most welding is on mild steel, about 5% is on stainless-steels; welding on stainless-steels can constitute more than 20% of welding in industrial economies. Welding of aluminium and other metals amounts to only a few per cent of the total.

The number of workers worldwide whose work involves some welding is estimated to be about three million.

Welders are exposed to a range of fumes and gases. Fume particles contain a wide variety of oxides and salts of metals and other compounds, which are produced mainly from electrodes, filler wire and flux materials. Fumes from the welding of stainless-steel and other alloys contain nickel compounds and chromium[VI] and [III]. Ozone is formed during most electric arc welding, and exposures can be high in comparison to the exposure limit, particularly during metal inert gas welding of aluminium. Oxides of nitrogen are found during manual metal arc welding and particularly during gas welding. Welders who weld painted mild steel can also be exposed to a range of organic compounds produced by pyrolysis. Welders, especially in shipyards, may also be exposed to asbestos dust.

4.2 Experimental carcinogenicity data

Particulates collected from stainless-steel welding fumes were tested by intratracheal instillation in hamsters and by intrabronchial implantation in rats. No treatment-related tumour was seen in rats, and single lung tumours were seen in groups of hamsters receiving manual metal arc stainless-steel welding fume. No study in which animals were exposed to welding fume by inhalation was available for evaluation.

4.3 Human carcinogenicity data

Two cohort studies of lung cancer mortality among persons in various occupations did not show significant increases in risk among welders. A total of three pleu-

ral mesotheliomas was reported from one of these studies. One large cohort study conducted in the UK showed an almost two-fold excess risk for lung cancer among shipyard welders, which was not confirmed when comparison was made with a local referent population. A moderately increased incidence of lung cancer was found in a large study of shipyard welders in Finland. Five studies conducted in the USA and Europe indicated an increased risk for lung cancer of about 30%.

A large European cohort study, including three cohorts reported previously, detected statistically significant increases in both the incidence of and mortality from lung cancer but demonstrated no consistent difference in cancer risk among stainless-steel welders as compared to mild-steel welders or to shipyard welders. In addition, five deaths were due to mesothelioma.

Of the 12 case-control studies on the association between lung cancer and exposure or employment as a welder, two detected no excess risk. Of the remaining ten, four showed a moderate excess, which was statistically significant in the largest study, conducted in the USA. The other six studies, of welders in various occupations, gave risk estimates exceeding a two-fold increase, which in four of the studies were statistically significant.

Four case-control studies conducted on bladder cancer — two in Canada, one in the USA and one in the Federal Republic of Germany — addressed the possible role of exposures during welding. Only one of the two from Canada reported a significantly increased risk.

Two case-control studies of leukaemia from the USA reported an elevated relative risk for myeloid leukaemia. No overall excess risk for either acute or all leukaemia was observed in a pooled analysis of data from several studies of welders.

Of the case-control studies of cancers at other sites, one on nasal cancer carried out in the Nordic countries, one on laryngeal cancer from Denmark and one on pancreatic cancer from Sweden reported elevated relative risks among welders.

4.4 Other relevant data

Welding fumes are retained in the lungs. Experimental studies have shown that sparingly soluble compounds may be released only slowly from the lungs. Elevated concentrations of chromium and nickel are seen in blood and urine, primarily in manual metal arc stainless-steel welders. Airway irritation and metal fume fever are the commonest acute effects of welding fumes. Studies of different groups of welders have documented an increased prevalence of pulmonary function abnormalities, in particular small airway disease, chronic bronchitis and slight abnormalities on chest X-rays, but only minimal indications of pulmonary fibrosis.

Reduced sperm quality has been reported in welders. Decreased fertility was seen in both male and female rats exposed to welding fumes; and the rate of fetal death was increased in pregnant female rats exposed to welding fumes.

One of three studies showed increased levels of sister chromatid exchange and chromosomal aberrations in peripheral blood lymphocytes of workers exposed during stainless-steel welding. The greater frequencies of sister chromatid exchanges were found in exposed workers who smoked.

In a single study, manual metal arc stainless-steel welding fumes injected intraperitoneally caused a mutagenic response in the mouse spot test. No increase in the frequency of sister chromatid exchange in peripheral blood lymphocytes or of chromosomal aberrations in lymphocytes or bone-marrow cells was observed in one study in rats after inhalation of stainless-steel or mild-steel welding fumes.

Both positive and negative results were obtained in tests for gene mutation in cultured mammalian cells exposed to stainless-steel welding fumes (manual metal arc). Stainless-steel welding fumes (manual metal arc and metal inert gas) induced transformation of mammalian cells *in vitro* in a single study. The frequencies of chromosomal aberrations and of sister chromatid exchange were increased in mammalian cells exposed *in vitro* to stainless-steel welding fumes (manual metal arc or metal inert gas). In a single study, mild-steel welding fumes (manual metal arc) increased the frequency of sister chromatid exchange but not of chromosomal aberrations in the same system. Fumes from the manual metal arc welding of mild steel or cast iron using a nickel electrode increased the frequency of sister chromatid exchange, but not of chromosomal aberrations, in mammalian cells *in vitro*.

Fumes from the manual metal arc or metal inert gas welding of stainless-steel and from manual metal arc welding of mild steel, but not the fumes from metal inert gas welding on mild steel or from mild steel welding on cast iron using a nickel electrode, were mutagenic to bacteria.

4.5 Evaluation[1]

There is *limited evidence* in humans for the carcinogenicity of welding fumes and gases.

There is *inadequate evidence* in experimental animals for the carcinogenicity of welding fumes.

Overall evaluation

Welding fumes *are possibly carcinogenic to humans* (Group 2B).

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[1]For definition of the italicized terms, see Preamble, pp. 33-37.