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HEALTH EFFECTS OF OCCUPATIONAL EXPOSURE OF WELDERS TO CHROMIUM

CORE PROTOCOL

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I. INTRODUCTION

The Planning Meeting on Monitoring and Epidemiological Studies for Toxic Chemical Control (Copenhagen, 5-8 May 1982) proposed the Occupational Exposure of Welders to Chromium as one of a number of studies to be initiated to examine health risks posed by occupational and community exposures to chemicals, chromium being one of the substances selected by the Consultation in Baden. The planning meeting recommended *inter alia*, the development of a Model Protocol for Epidemiological Studies of Health Effects, and the development of a programme to provide central initiation and coordination of health studies in a number of European nations, with emphasis on exposure monitoring and epidemiology. Such a protocol was discussed in detail at a Planning Meeting On Health Effects of Occupational Exposure of Welders To Chromium (Copenhagen 4-6 May 1982), at which the present state of knowledge of welding fumes and the possible health effects due to the mixed exposure to metals, their oxides, and other active substances (e.g. ozone, NO_x, F, Mn, Be, Cr, Ni, etc.) found in welding fumes was discussed. It is agreed that welders, because of the uniformity of the occupation worldwide, represented a large heterogeneous homogenous population suitable for multinational studies. Exposure-dependent pulmonary effects such as siderosis and other pneumoconiosies, respiratory function changes and chronic respiratory disease could also be expected. Psychological and neurological changes, hepatotoxic and nephrotoxic effects, arthrosis, gastrointestinal problems, dermatitis and white fingers, are suitable health effects for additional follow-up studies.

Since increased lung cancer risks have been found in several studies of general welding populations, it is suggested that, on the basis of positive in vitro and in vivo studies of the genotoxicity of welding fumes and acute inhalation studies, fumes from the welding of stainless steel might be carcinogenic and affect lung function as well. These fumes are characterized by the presence of high concentration of Cr and Ni in different oxidation states and solubility fractions; several compounds of these two metals are, under certain circumstances, carcinogenic in man. Thus there is a selected group of stainless steel welders (10-15% of all welders) who are additionally exposed to high concentrations of various solubility fractions of Cr^+ and therefore at possibly added risk for respiratory tract cancer and chronic respiratory disease.

Data on lung cancer risk in chromium-associated occupations, other than chromate production, and Ni-associated occupations, other than Ni refining, are insufficient for the evaluation of the relative contribution to carcinogenic risk, especially in such a group of stainless steel welders with mixed exposures. It is therefore proposed to test the hypothesis that Cr is the primary causitive agent in welders' lung cancer by comparing the occurrence of delayed pulmonary effects and mortality in stainless steel welders with that in mild steel welders. The importance of this project is underlined by the possibility that future industrial exposure to high levels of Cr^+ of mixed solubility, is likely to be restricted to stainless steel welders: other industries such as primary chromate and chrome pigment producers (at least in the industrialized part of the world) are currently making concerned efforts to eliminate the exposure problem, while there is at present no simple technologically practical solution available to the welding industry.

Based on technical and medical discussions, a Revised Outline Model Protocol has been developed, and is intended for use as a guideline for optimal studies of the health effects of mixed exposures encountered by welders to be carried out in a number of countries under the central coordination of WHO/EURO. This protocol contains elements which are essential for historical prospective mortality and cancer incidence studies of welders, and suggestions for a number of extended and/or pilot studies, to be carried out where interest and facilities exist: these include biological monitoring, magnetopneumography, immunological surveillance and a search for mental health effects.

Detailed discussions are centered around techniques for epidemiology and exposure monitoring. The need for obtaining adequately large cohorts of stainless steel welders with at least 25 or more years of follow-up from first exposure must be stressed. Identification of a cohort consisting of all employees as of 1960, and including as many as possible of those employed before 1960 is ideal, provided that company records were adequate. Such cohorts would permit a separate analysis of the effect of exposure (based on some simple definition of degree) and of latency based on five year intervals from first exposure, and on the exclusion of an assumed latency time in the calculation of expected incidence. In order to attempt a characterization of (relative) lifetime exposure to fumes and/or their constituents, standardized exposure monitoring which resulted in individual, job, and workplace characterization is necessary.

There is a persistant need for central coordination of any planned projects. At present there are several European and one American round-robin studies of laboratory analysis of chromium in welding fumes, using not necessarily compatible variations of the same analytical techniques. Furthermore the need for exposure monitoring and workplace and lifetime exposure characterization (e.g. low, medium, high within agreed limits and definitions) must be stressed. Conflicting observations in cancer epidemiology, e.g. latency dependence with a lack of exposure dependence for welders, and exposure dependence in the chromate industry, may be due to poor exposure characterization.

It is expected that by careful use of mild steel welding - and non-welding cohorts as internal and external reference groups, the effects of welding, and especially the effects of welders' exposure to chromium can be established, provided that several countries participated in the study programme: minimum cohort size being of the order of 500 stainless steel welders occupied at least since 1960, with as many welders as possible from 1950, included in the study groups.

A major result of the proposed WHO/EURO programme is the possibility of localizing high risk to few if any welding processes permitting effective use of resources in reducing any risk so discovered. The welding industry occupies 2% of the work force, and comprises perhaps 2,000.000 welders in Europe (including USSR), of which an estimated 200,000 are exposed to chromium, and that number is large enough to support the importance of the study and the practical result would serve the interest of a large population.

CONCLUSIONS AND RECOMMENDATIONS OF THE 1982 PLANNING MEETING ON HEALTH EFFECTS OF OCCUPATIONAL EXPOSURE OF WELDERS TO CHROMIUM

Conclusions:

1. The conclusion and recommendation of the Planning Meeting on Monitoring and Epidemiology, Copenhangen, 5-8 May 1981 should be applied to special problems in studying health effects of occupational exposure of welders, especially to chromium.

2. The exposure of stainless steel welders to chromium in several oxidation states and solubility fractions at concentrations, which are high in relation to other welding processes, offers a good opportunity to assess the health effects of inhaled chromium in the welder population.

3. A number of priority problems in occupational exposure to welding fumes were identified and discussed and an outline proposal for monitoring and epidemiological studies was submitted for consideration by WHO.

4. The project aims to test the hypothesis that Cr^{+} is the primary causative agent for the higher incidence of lung cancer among welders by initiation of historical prospective epidemiological mortality and cancer incidence studies. Because of expected limitations in estimating previous exposure, it is suggested to extend the project to include follow-up studies on the currently and recently employed welding population.

5. International coordination of studies of the potentially toxic effects of Cr^{+} in welding fumes must be initiated. In order to avoid problems such as ethnological origins and intercountry variations in workplace organization, it is necessary to have much larger cohorts of workers under surveillance than can be found in one country.

6. Detailed proposals are presented for internationally coordinated pilot monitoring and epidemiological studies. The proposal illustrates the type of protocol required for the design of pilot studies. The problems described represent the immediate priority for internationally coordinated studies, but can easily be extended on national level to take advantage of local interest and facilities.

Recommendations:

A. The Link Between Monitoring and Epidemiology

1. A need exists for substantial improvement in the compatability of monitoring data and data produced or used by health information systems and epidemiological studies. The welders' environment is frequently monitored for controlling workplace pollution without registration of health status: it is therefore often difficult to estimate the previous exposure of welders if and when health problems appear. Regular contact is needed between groups performing the analytical control and the medical supervision.

B. Exposure Assessment

1. Methods of monitoring and evaluating exposure, which differ in various countries, should be brought into conformity. For epidemiological purposes it is necessary to use a reference method enabling results from different plants and countries to be compared directly.

2. Methods for monitoring present exposure can provide data for use in the retrospective studies: for theoretical and practical reasons certain modifications should be made, e.g. conformity of routine determination of the ration between total dust and respirable fraction in shop backgrounds.

3. Account must be taken of the substantial differences observed between laboratories in evaluating airborne concentrations of fumes and especially concentrations of various solubility fractions of Cr^{+}. A scheme should be developed for harmonizing the analytical methods and providing a basis for both retrospective and prospective epidemiology. The details of implementing the scheme should be the responsibility of a technical committee. The scheme should include research to solve the technical problems raised during this meeting.

   Data on national and international differences in the long-term variations of exposure to welding fumes are lacking. A protocol for estimation of life-time exposure for epidemiological studies should be developed, and the analysis of the differences between some (or all) of the work places selected for studies should be carried out. This would enable long-term sampling strategies to be assessed in terms of sampling frequency and cost.

4. Biological monitoring of chromium exposure by analyzing the chromium content in urine must be further developed. Laboratories must be stimulated to determine the most convenient sampling strategy (duration and frequency).

C. Development of Epidemiological Methodology

1. The effects of long-term exposure to complex occupational environments, such as welding fumes, appear to be subtle: it is therefore necessary to specifically develop sensitive tools to determine relevant health parameters.

D. Sampling, Analysis and Quality Assurance

1. Monitoring and epidemiological procedures for sampling, analysis, data handling and presentation should be standardized, especially with respect to the hexavalent chromium analysis.

2. The quality assurance procedures resulting from the pilot projects should be used, as necessary, as a basis for their more extensive development.

3. To implement the same protocol in several plants the main investigators of ongoing and joining researches in different countries have to meet as a technical committee to discuss the details of analytical and epidemiological methodologies.

Based on the above recommendations the following Model Outline Protocol and detailed study protocols are submitted for consideration by the 1982 Berlin Planning Meeting.

II. OUTLINE PROTOCOL
HEALTH EFFECTS OF OCCUPATIONAL EXPOSURE OF WELDERS TO CHROMIUM

1. Purpose

Increased lung cancer risks have been found in several studies of welders. Other respiratory diseases also appear to occur more frequently in welders than would be expected. Experimental studies suggest that fumes from stainless steel welding may be carcinogenic and may affect lung function. The purpose of this suggested study is to test the hypothesis that hexavalent chromium (Cr_6^+) is the primary causative agent. This will be accomplished by comparing the occurrence of delayed pulmonary effects and mortality in stainless steel welders with that in mild steel welders and in the general population. The effects of exposure to other metals, such as nickel, and gaseous components, such as NO_x and ozone, will also be considered.

2. Specific Objectives

2.1 Environmental Monitoring

To develop individual lifetime exposure scores for each of the two main types of fumes: those from stainless steel and those from mild steel welding.

2.2 Biological Monitoring

To assess current chromium and nickel exposures in welders by analyzing biological samples, such as blood and urine.

2.3 Cytogenetic Monitoring

To determine in pilot studies genotoxic effects in white blood cells from non-smoking welders exposed to different kinds of fumes.

2.4 Lung Function

To assess whether or not changes in lung function parameters in welders are associated with particular exposures.

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2.5 Chronic obstructive lung disease

To determine the prevalence of chronic obstructive lung disease in welders and its potential association with certain kinds of welding fumes.

2.6 Pneumoconiosis

To assess the origin and deposition of foreign material in the lung and its inter-individual variation.

2.7 Cancer

To determine whether or not the occurrence of lung cancer in stainless steel welders is more frequent than in other welders or in the general population.

2.8 Other Health Effects

To determine the role of welding in the psychological and neurological changes observed in welders as well as hepato and nephro-toxic effects and causing alteration in the immune system.

3. Background

3.1 Environmental Monitoring

Chronic exposures to welding fumes average about 4 mg/m^3, but short-term fume levels may exceed 100 mg/m^3. In addition to variations of total dust levels in the breathing zones of welders, the composition varies according to the type of work. Of particular concern are chromium- and nickel-containing fumes from stainless steel welding.

During manual metal arc and metal inert gas welding, high levels of Cr_6^+ and nickel as well as other pollutants common to other types of welding, such as ozone and nitrous gases, are detected in the fumes of stainless steel welding. The fume constituents vary in different welding processes, and the quantity of the airborne particles differs with variations of currents and voltages. However, the fume from each process can be characterised within relatively well-developed limits.

3.2 Biological Monitoring

Biological samples, i.e. blood and urine, are of some value in assessing current exposures to chromium and nickel at high levels. Welding fume is almost entirely respirable, with medium particles diameters ranging from 0.2 um to 2.0 um, the metal vapour is deposited in the lower respiratory tract. The more sparingly soluble particles may, however, only slowly be cleared from the alveoli of the lungs, thus giving rise to only small increases in metal levels of blood and urine. More easily soluble compounds of chromium and nickel tend to have a short half-life in the body and will be excreted relatively rapidly. Thus, biological monitoring results will probably vary according to the physicochemical characteristics of the welding fumes.

3.3 Cytogenetic Monitoring

Welding fumes contain several genotoxic compounds, such as chromium, nickel, ozone and nitrogen dioxide. Exposure to these substances may give rise to genotoxic effects which can be monitored in white blood cells from the exposed welder. The long-term significance of chromosome changes in white blood cells is, however, unclear at this time. Smoking causes genotoxic effects, and examination of non-smokers is, therefore, of particular relevance.

3.4 Lung Function

Chronic exposure to fumes eventually results in a detectable reversible deposition in the lungs. Several studies have shown that exposure to welding fumes may cause small airway disease and contribute to the development of chronic bronchitis and emphysema. Cross-sectional studies show significant excess incidence of pneumonia as compared to that of the general population. An unanswered question is, however: It is not known whether pulmonary disease is associated with most welding processes or only with particular kinds of fumes? Follow-up studies of respiratory function have demonstrated the workers' self-selection, a factor which must also be taken into consideration.

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3.5 Chronic Obstructive Lung Disease

Several cases of chronic obstructive lung disease have been described in welders. In vitro tests for fibrogenicity suggest that chromium is possibly responsible for fibrosis, but some other factors in addition to metal particles could be involved, e.g. NO_x, although there is no evidence at present for an excess risk of fibrosis in welders.

3.6 Pneumoconiosis

A large number of clinical studies have demonstrated the presence of opacities in radiographic analysis inferred to be due to the accumulation of welding fumes.

3.7 Cancer

Lung adenomas accompanied by cellular abnormalities were found in chromium exposed mice, and severe abnormalities, squamous dysplasia and atypical adenomatous hyperplasia were observed in the sputa of workers exposed to chromium. A number of epidemiological studies have shown an increased risk of lung cancer in welders. Shipyard welders have been exposed to asbestos, however, and the influence of welding fumes as such is not clear. In addition, smoking habits of welders may have contributed to an increased lung cancer incidence. Some types of welding fumes contain chromium and nickel, both known as human carcinogens, and stainless steel welders exposed to these metals may have an excess cancer risk compared to, for example, mild steel welders.

3.8 Other Health Effects

Nervous system, renal and liver effects were reported in epidemiological studies on welders, but the number of cases are not enough to determine which particular factors are responsible for the symptoms observed

4. Methods

4.1 Environmental Monitoring

Graviometric studies of total fume exposure should be based on personal samplers using either millipore or glass-fibre filters. A standard conditioning procedure is recommended whereby dessicated filters are weighed before exposure and reconditioned after exposure and before final weighing. Chemical analysis of fumes collected on filters shall be performed for iron, chromium and nickel. Each laboratory shall use its preferred method of analysis.

The recommended procedure is for water-soluble chromium to be determined in a standardized aqueous dissolution of 30 minutes of 95°C. The water-soluble chromium content is assumed to be exclusively in the form of ${Cr_6}^+$. Total chromium shall be analysed by the method of preference of each laboratory, provided that the analytical procedures have been demonstrated to be appropriate for use with welding fumes. This demonstration will be verified by an analysis performed in each laboratory of a uniform sample distributed among all laboratories. The sample shall consis of standard welding fume(s) with and without added ${Cr_6}^+$. Details of the analytical procedures should be exchanged among the participating laboratories. Total nickel content should be determined by the method of preference by each laboratory without differentiation of oxidation state.

Although not mandatory, the monitoring of breathing-zone levels of the gases, ozone and the oxides of nitrogen is recommended in those cases were continuous monitoring equipment is available. The documentation of standardized sampling methodology and standardized analytical methodology for each participating laboratory for the purpose of interlaboratory comparison is strongly recommended. Personal samplers shall be placed either in the breathing zone of the welding mask or on the lapel, and measurements shall be carried out over much of a daily workshift as possible (6-8 hours).

Characterizing workplaces by representative jobs (with personal samplers) and job sites (with stationary samplers and, if possible, cyclone separators) is also recommended. In addition, information concerning the type of technology and the nature of the welding consumables used is desirable. This information should take the form of a listing of processes and their applications including the type of material, type of workpiece and the nature of the job. Furthermore, the intensity of work should be determined by estimates of either arcing time per job shift, the number of electrodes consumed per unit time or the quantity of consumables purchased (kilogrammes of electrodes and wire per year). The size of each establishment should be determined by the number of current workers in each technology and the fraction of working time asigned to welding. If possible, information concerning past changes in buildings, category of activity and use and installation of ventilation should be obtained.

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To estimate the exposure a detailed lifetime occupational history should be obtained, with particular emphasis on welding methods, degree of exposure (low, medium or high), use of electrodes or rods, type of steel, use of primers and coatings, exposure circumstances (open air, shop or enclosed space) and possibilities of indirect ("bystander") exposure. A typical current exposure should be assessed in a representative group of subjects: total dust exposure over about six hours, its content of soluble and insoluble chromium and nickel, and averages of nitrogen dioxide and ozone. If indicated, other parameters could be added.

4.2 Biological Monitoring

Under certain circumstances of high exposure, individual exposure monitoring may appropriately be supplemented by a determination of chromium and nickel excretion in urine. These measurements should be performed as 6-hour samples before and after the workshift. They could be used to identify highly exposed individuals and their occupational circumstances.

4.3 Cytogenic Monitoring

Methods in routine use include examination for chromosome aberrations and assessment of sister chromatid exchanges in cultures lymphocytes. A blood sample for this purpose should be obtained by venipuncture.

4.4. Lung Function

Detailed lung function studies are necessary to assess the possible existence and extent of pulmonary disease. The lung function parameters should at least include FEV_1. Other lung function studies may be included such as FEV_{25-75}, closing time and CO diffusion capacity. These determinations can usually be performed at a pulmonary medicine laboratory at a central hospital. Although for jobsite measurements mobile equipment is preferable. Regular calibration of the equipment should be performed. In relation to the examination, detailed smoking history and past medical history should be obtained, and a distinction should be made with respect to lifetime exposure levels.

4.5 Chronic Obstruction Lung Disease

The degree of possible chronic obstructive lung disease should be assessed by suitable means.

4.6 Pneumoconiosis

The presence of pneumoconiosis above the grade one-zero should be demonstrated by standardized radiological techniques. For field studies, equipment from local hospitals or tuberculosis diagnosis centres could, perhaps, be utilized. The X-rays should be evaluated according to the ILO/UC criteria by an experienced panel of X-ray readers. If possible, a proportion of chest radiographs should be exchanges with other experienced readers. Magnetopneumography where possible could be carried out to assess the amount of iron (magnetite) deposited in the lungs.

4.7 Cancer

Single cases of lung cancer may occasionally be found on chest X-rays in cross-sectional studies. Retrospective mortality data must be analysed in respect to lifetime exposure.

For information on the incidence of precancerous changes, the cytological examination of sputum should be included in the medical surveillance of the workers. Smears are to be stained by the Papanicolaou technique and evaluated by pathologists. Lesions of cells from the upper respiratory tract and oral cavity must be classified, by internationally accepted criteria, into initial nonspecific stage (class II), intermediate specific stage (classes III-IV) and tumourous stage (classes IV-V).

4.8 Other Health Effects

Mortality and morbidity data for chronic diseases of liver and kidney amy be found in the retrospective study. In the follow-up study general clinical chemical analysis of the health status with special respect to the immunosystem is recommended. The changes in mental health can be tested by a single form of a standardized questionnaire.

5. Study Populations

The mortality studies should be carried out only in countries which can provide study populations of both stainless steel and mild steel welders. Latent periods for lung cancer in welders may be long (exceeding 20 years); therefore, study populations should include all welders entering employment from about 1950 onwards and remaining for at least one year. A population of stainless steel welders should include as many workers employed before 1960 as possible: preferably, at least 500 such workers. The mild steel welding population should have been recruited during the same time period but should be larger. A history of products and processes should be provided for each participating workplace. Grading of each worker's exposure level is recommended.

Using certified causes of death, the mortality experience of the study populations should be compared to national and/or local mortality experience. When available, incidence data from cancer registries should also be used. Mortality from all causes combined, all cancers combined, lung cancer and other respiratory diseases should be analysed separately using the classification of the International classification of diseases. All recently employed welders should be included in the follow-up studies of other health effects.

6. Data Evaluation

This study includes no control group in the traditional meaning of this term. Instead, welders exposed to chromium-containing fumes should be compared to welders not so exposed. For comparison between different study populations, man-years-at-risk and observed/expected death ratios should be calculated in terms of 5-year intervals after each worker's first exposure. For analysis of some causes of death (e.g. lung cancer), it is advisable to be able to exclude the first 15 or 20 years after first exposure from the calculation of expected and observed deaths. The study populations should be subdivided by length of exposure (e.g. 1-4, 5-9 and 10 or more years). Attributable risk (excess cases/man-years) should also be calculated to facilitate intercountry comparisons.

7. Significance of Study

The identification of high-risk occupations within the welding industry would offer important possibilities for efficient preventive efforts aimed at one particular hazardous process. If stainless steel welding causes more frequent pulmonary disease than does other kinds of welding, chromium could most probably be identified as the responsible factor. The significance of this study concerns both the growing welding industry and other settings with exposures to chromium.

8. Feasibility

Much essential information on welding exposures is available, within national and international welding institutes. Study cohorts can be identified with a reasonable effort. Medical expertise is needed to carry out X-ray and lung function evaluations. Monitoring determinations also necessitate participation by specialists. This multidisciplinary study will, therefore, need cooperation between welding institutes, hospitals and other centres where technology and specialists are available.

Mortality studies should be accompanied, where feasible, by workplace monitoring and clinical evaluations. However, studies of cohorts of stainless steel welders employed at early dates would be valuable without monitoring and clinical studies. Pilot studies (e.g. cytogenic monitoring and mental health effects) must always be accompanied by exposure monitoring.

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MODEL PROTOCOL FOR HEALTH HISTORY

Dear Participant,

You are being asked to participate in a program, designed and coordinated by the World Health Organization, European Headquarters, together with a number of local national laboratories to study the possible effects of welding on health, and the specific effects of chromium, which is a constituant of stainless steel, and is a substance found in the fumes from the welding of stainless steel, but which is absent in the fumes of mild (non-alloyed) steel.

Please answer the questions to your best ability. Note that for some cases you are asked to place a check in the appropriate box:

1b What is the state of your health in the past 12 months?

a) Excellent .... [V]

b) Good .... [ ]

c) I must be careful .... [ ]

d) I have a problem, explain: ____________________

and for some answers you are asked to supply additional information (as in answer d) above). For some questions you are asked to write a number in the box or boxes:

3. How many days sick leave have you had from work in the past 12 months?

If you have been sick 12 days, write the number in the boxes .... [1][2]

These have been divided into how many periods of the following duration:

If you have had 4 periods of 2 day illness and 1 period of 4 days, indicate as follows:

1 day .... [ ]

2 days .... [4]

3 days .... [ ]

4 days .... [1]

5 days .... [ ]

More than 5 days .... [ ]

Name or Code Number ....

Employer ....

Date of first employment at present employer ....

1a Do you have any recurring problems with your health?

No ☐

Yes ☐ If yes explain: ____________________

____

1b What has been the state of your health the past 12 months?

Excellent .... ☐

Good .... ☐

I must be careful but my problems do not interfere with work .... ☐

I have problems which make working difficult; explain: ☐

____

2. Have you visited a doctor during the past 12 months?

No .... ☐

Yes ☐ If yes, indicate the number of visits, ☐

and what reason: ____________________

____

3. How many days sick leave have you had from work the past 12 months .... ☐☐

These have been divided into how many periods of the following duration (write the number of periods for each)

1 day .... ☐
2 days .... ☐
3 days .... ☐
4 days .... ☐
5 days .... ☐
more than 5 days .... ☐

4. If you have been on sick leave the past year, indicate the most common reasons (check several if appropriate)

Back problems (pain, slipped disc etc.) .... ☐
Colds/influenza .... ☐
Sinus infection .... ☐
Sore throat .... ☐
Bronchitis .... ☐
Pneumonia .... ☐
Other .... ☐

5. Have you ever had any of the following diseases:

Heart disease	- yes, started year 19______
	- no .... ☐
Asthma	- yes, started year 19______
	- no .... ☐
Bronchitis	- yes, started year 19______
	- no .... ☐
Emphysema	- yes, started year 19______
	- no .... ☐
Hay fever	- yes, started year 19______
	- no .... ☐
Infected sinuses	- yes, started year 19______
	- no .... ☐
Back pain	- yes, started year 19______
	- no .... ☐
Join-disease	- yes, started year 19______
	- no .... ☐
Exema	- yes, started year 19______
	- no .... ☐
Eye problems (except	- yes, started year 19______
welders eys)	- no .... ☐
Reduced hearing	- yes, started year 19______
	- no .... ☐
Stomach or intestinal	- yes, started year 19______
disease (ulcer?)	- no .... ☐
Other	- yes .... ☐

None of the above .... ☐

6. Do you regularly (more than once a week) take any form of medicine?

- No ☐
- Pain killers ☐
- Heart medicine ☐
- Blood pressure reducing medicine ☐
- Medicine to remove body water (divretics) ☐
- Asthma spray or pills ☐
- Cough medicine ☐
- Sleeping pills or tranquillizer ☐
- Ulcer medicine ☐
- Other ______________________ ☐

7. Have you had any form for medical treatment in the past 12 months?

- No ☐
- Physiotherapy ☐
- Hospital stay ☐
- Operation ☐
- Explain: ______________________

8. How often do you have a cold?

- Almost daily ☐
- Once a month ☐
- 4 times a year ☐
- Once a year ☐
- Almost never ☐

9. How often do you have a sore throat?

- Once a month or more .... ☐
- 4 times a year .... ☐
- Once a year .... ☐
- Almost never .... ☐

10. How often do you have inflamed sinuses?

- Once a month or more .... ☐
- 4 times a year .... ☐
- Once a year .... ☐
- Almost never .... ☐

11. How often are you hoarse, loose your voice, or have laryngitis?

- Daily (almost) .... ☐
- Once a month .... ☐
- 4 times a year .... ☐
- Almost never .... ☐

12. How often do you have headache?

- Almost daily .... ☐
- Several times a week .... ☐
- Several times a month .... ☐
- Almost never .... ☐

13. Are you often excessively tired after work?

Yes .... ☐
No .... ☐
Dont know .... ☐

14. How often have you had welders eye (arc eye, eye flash) in the past 12 months?

(Write number of incidents - if none write zero)........... ☐
If yes - have you been off work with it. (Write number of days - if none write zero) .... ☐

15. How often do you have itchy or painfull eyes?

Almost daily .... ☐
Once a month .... ☐
4 times a year .... ☐
Once a year .... ☐
Almost never .... ☐

16. Have you hade metal fume fever during the past year?

No .... ☐
Yes ☐ If yes write the number of times: ____________ ☐
If yes - write the welding processes used ______________
If yes - have you been off work with it. (Write number of days, - if none write zero): _______ ______________ ☐☐

17. Have you ever had attacks of white or dead finger where you have lost the feeling in them?

No .... ☐
Yes .... ☐
Dont know .... ☐
If yes - do these attacks come when you touch cold tools or when you are out in the cold?
Yes .... ☐
No .... ☐
Dont know .... ☐

18. Do you cough in the morning (including smokers cough)?

No .... ☐
Yes .... ☐

19. Do you usually cough during the day?

No .... ☐
Yes .... ☐
If yes - does it recurr during most of the day while at work?
No .... ☐
Yes .... ☐
Dont know .... ☐

20. Have you had daily cough for periods of as long as three months each year?

No .... ☐
Yes .... ☐

If yes - after how many years welding did you begin to have these periods? .... ☐

21. Do you usually bring up any phlegm from your chest first thing in the morning?

No .... ☐
Yes .... ☐

22. Have you within the past several years had a period where you have brought up phlegm from your chest in the morning on most days for a period of 3 months or more?

No .... ☐
Yes .... ☐

If yes, after how many years welding did you begin to have these periods? .... ☐

23. Have you ever coughed up blood?

No .... ☐
Yes (indicate which year _______) .... ☐

24. Are you troubled with shortness of breath?

Never .... ☐
When you climb two sets of stairs, or are hurrying on the level or walking up a slight hill — Yes .... ☐
— No .... ☐
When you walk with other people at an ordinary pace on the level — Yes .... ☐
— No .... ☐
When you walk at your own pace to the point where you have to stop for breath — Yes .... ☐
— No .... ☐
When washing or dressing — Yes .... ☐
— No .... ☐

25. Have you ever had attacks where you have had difficulty in breathing - with a wheezing or whisteling noise in your lungs?

No .... ☐
Yes .... ☐
If yes, has this happened while at work?
No .... ☐
Yes .... ☐
Dont know .... ☐

26. Have you ever with the past few years had pain or discomfort in your chest?

No .... ☐
Yes .... ☐
If yes, do you get it when you walk up hill or hurry?
No .... ☐
Yes .... ☐
Dont know .... ☐

27. Have you ever had exzema, rash, or other skin irritation?

No .... ☐
Yes .... ☐
If yes, do the problems disappear during weekends
or vacation?
No .... ☐
Yes .... ☐
Dont know .... ☐

28. Have you within the past few years had spells of vomiting, or diarrhea during or after working hours?

No .... ☐
Occassionally .... ☐
Frequently .... ☐

29. Do you ever have stomach pains?

No .... ☐
Yes occassionally .... ☐
Yes frequently .... ☐
If yes, do they occurr just after mealtime .... ☐
Disappear after meals .... ☐
Are independent of meals .... ☐

30. Do you feel stressed in your work?

No .... ☐
Yes .... ☐

31. Do you think you have a health problem associated with your work?

No .... ☐
Yes .... ☐

32. Have any members of your near family had lung cancer?

Yes .... ☐
No .... ☐
Dont know .... ☐
If yes, explain: ____

____

33. Where have you lived for most of your life?

In a rural area .... ☐
In a small town .... ☐
In a big city .... ☐
Near to a large factory .... ☐

MODEL PROTOCOL FOR ASSESSMENT OF LIFETIME WELDING EXPOSURE

34. Have you ever worked as a welder?

No ☐ If no go to question 53

Yes ☐ If yes please answer all the following questions.

35. Do you currently weld as part of your job?

Yes ☐ If yes go to question 38

No ☐ If no please answer the following:

36. When did you stop welding?

0-3 months ago .... ☐

4-12 months ago .... ☐

1-5 years ago .... ☐

More than 5 years ago .... ☐

37. Why did you stop welding? (check only one)

Transferred .... ☐

Became unemployed .... ☐

Sick leave .... ☐

Changed jobs because welding made me sick or feel uncomfortable .... ☐

Other; explain: ____

____

38. With what age did you first begin to weld? ____________

How many years have you been employed as a welder? ________

How many different employers have you had in this period? ____________

39. For how many years have you worked at other occupations, or been on sick leave?

If none - write zero: ______

40. In which industry are you currently employed as a welder?

- Shipbuilding ....
- Construction ....
- Chemical ....
- Transportation ....
- Food ....
- Pharmaceutical ....
- Job shop ....
- Other ....

41. Indicate the number of years you have worked in the following industries (if never write zero).

- Shipbuilding ....
- Construction ....
- Chemical ....
- Transportation ....
- Food ....
- Pharmaceutical ....
- Job shop ....
- Other ....

42. How many hours a week do you usually weld now?

- Less than 5 ....
- 5-10 ....
- 11-20 ....
- More than 20 ....

Is this typical for your lifetime average welding experience?

Yes .... ☐

No ☐ If no explain how many hours per week have you welded on the average? ____________________ ☐☐

43. Indicate the extent to which you have used the following welding techniques and materials - Write the number of years in each box. If never used write zero.

	A Stainless Steel	B Construction (mild) steel	C Aluminium	D Low Alloy Steel	E Other
1. Coated Electrode	☐	☐	☐	☐	☐
2. Inert Gas (MIG/MAG)	☐	☐	☐	☐	☐
3. Tungsten (TIG)	☐	☐	☐	☐	☐
4. Autogen (Gas)	☐	☐	☐	☐	☐

5. Other ____

Please write in the box the letter and number in the above scheme which corresponds to the combination used most frequently. ☐☐

44. For the combination used most frequently indicate the most common surface treatment of the base material:

- No surface treatment .... ☐
- Galvanized .... ☐
- Painted .... ☐
- Primed .... ☐
- Other .... ☐
- Dont know .... ☐

45. If the material was primed, what was the most frequent material used?

- Iron oxide (red) .... ☐
- Iron oxide (yellow) .... ☐
- Zinc (grey) .... ☐
- Titanium (white) .... ☐
- Titanium (blue) .... ☐
- Titanium (green) .... ☐
- Titanium (pink) .... ☐
- Other .... ☐
- Dont know .... ☐

46. If you use or have used manual coated electrodes, what type were they?

- Basic low hydrogen .... ☐
- Rutile .... ☐
- Basic-rutile .... ☐
- Cellulose .... ☐

47. Do you use or have you used a special process, such as bronze, copper, hard metal, nickel etc. on cast (black) iron etc.? If so, describe what and how often: ______________________

____

48. Have you ever welded on stainless steel?

No ☐ If no go to question 50

Yes ☐ If yes please answer the following:

What process do you use most?

Electrodes .... ☐
MIG/MAG solid wire .... ☐
Powder filled wire .... ☐
TIG .... ☐
Other .... ☐

On what type of material?

Thin plate (under 1 mm) .... ☐
Plates 1-3 mm .... ☐
Thick plates .... ☐

49. When was the last time you welded stainless steel this year?

1-5 years ago .... ☐
More than 5 years ago .... ☐

50. What type of protective devices do you use (indicate the number of years in use)?

Booth .... ☐
Respirator .... ☐
Flow bench .... ☐
Point extraction .... ☐
General only .... ☐
None .... ☐
Outdoors .... ☐

51. Have you worked in small enclosed spaces?

Never .... ☐
Occassionally .... ☐
Usually .... ☐

52. Please indicate in each box the approximate number of years you have welded stainless steel, for each process indicated, in each of the ten year periods shown:

		A TIG	B MIG	C MMA
1.	1940-1950	☐	☐	☐
2.	1951-1960	☐	☐	☐
3.	1961-1970	☐	☐	☐
4.	1971-1980	☐	☐	☐
5.	1981-	☐	☐	☐

FLAME CUTTING AND BURNING

53. Have you ever worked with flame cutting/burning?

No ☐ If no go to question 60

Yes ☐ If yes please answer the following:

54. Do you currently work with flame cutting?

Yes .... ☐
No .... ☐
If no, when did you stop flame cutting?
0-3 months ago .... ☐
4-12 months ago .... ☐
1-5 years ago .... ☐
More than 5 years ago .... ☐
How many years have you worked with flame cutting? .... ☐

55. How many hours a week do you use a flame cutter?

Less than 5 hours .... ☐
6-10 hours .... ☐
11-20 hours .... ☐
More than 20 hours .... ☐

56. What is your mos. usual way of cutting?

Stationary cutter .... ☐
Hand cutting .... ☐
Other: ______________________________

57. The material most often worked on has had the following surface treatment:

None .... ☐
Painted .... ☐
Primed .... ☐
Other ______________________________________

If primed, the most typical type of primer has been:

Red .... ☐
Yellow .... ☐
Grey .... ☐
White .... ☐
Blue .... ☐
Green .... ☐
Pink .... ☐
Other ______________________________________

58. Has local ventilation been in use at your cutting station?

No .... ☐
Yes .... ☐
First introduced in year 19___

59. Have you used a mask?

Never .... ☐
Occassionally .... ☐
Frequently .... ☐
Always .... ☐

PLASMA CUTTING

60. Have you ever operated a plasma cutting machine or worked with a plasma cutter?

No ☐ If no go to question 67
Yes ☐ If yes please answer the following:

61. Do you currently plasma cut?

Yes .... ☐
No ☐ If no, when did you stop?
0-3 months ago .... ☐
4-12 months ago .... ☐
1-5 years ago .... ☐
More than 5 years ago .... ☐

62. How many years have you worked with plasma cutting?

Less than 5 years .... ☐
5-10 years .... ☐
11-20 years .... ☐

63. What material do you usually use?

Mild steel .... ☐
Stainless steel .... ☐
Aluminium .... ☐

64. Have you ever plasma cut stainless steel?

No .... ☐
Yes ☐ If yes, how many hours per week: ____________ ☐☐
How many weeks per year: ____________ ☐☐
How many years: ____________ ☐☐

65. How many hours per week do you work with plasma cutting?

Less than 5 hours .... ☐
5-10 hours .... ☐
10-20 hours .... ☐
More than 20 hours .... ☐

66. What type of protection do you use?

None .... ☐
Mask .... ☐
Table .... ☐

GOUGING (air-arc)

67. Have you ever worked with gouging?

No ☐ If no go to question 71
Yes ☐ If yes please answer the following:

68. Do you work as a gouger at present?

Yes .... ☐
No .... ☐

69. How many years have you worked as a gouger alltogether?

Less than 5 years .... ☐
5-10 years .... ☐
11-20 years .... ☐
More than 20 years .... ☐

70. How many hours per week have you gouged?

- Less than 5 hours .... ☐
- 5-10 hours .... ☐
- 11-20 hours .... ☐
- More than 20 hours .... ☐

GRINDING/POLISHING

71. Have you ever worked as a polisher/grinder?

No ☐ If no go to question 77

Yes ☐ If yes please answer the following:

72. How many years have you worked grinding/polishing?

Less than 5 years .... ☐
5-10 years .... ☐
10-20 years .... ☐
More than 20 years .... ☐

73. How many hours have you typically ground/polished?

Less than 5 hours .... ☐
5-10 hours .... ☐
11-20 hours .... ☐
More than 20 hours .... ☐

74. Have you mostly done:

Dry grinding .... ☐
Wet grinding .... ☐
Polishing .... ☐

75. What material have you most frequently used:

Construction (mild) steel .... ☐
Stainless steel .... ☐
Other alloy .... ☐
Aluminium .... ☐
Other .... ☐

76. When was the last time you ground/polished stainless steel?

- This month .... ☐
- 1 year ago .... ☐
- More than 1-5 years ago .... ☐
- More than 5 years ago .... ☐

CUTTING OIL/FLUIDS

77. Have you ever worked with cutting fluids?

No ☐ If no go to question 81

Yes ☐ If yes please answer the following:

78. How many years have you worked with cutting fluids?

Less than 5 years .... ☐
6-10 years .... ☐
11-20 years .... ☐
More than 20 years .... ☐

79. How many hours per week do you use cutting fluids or are you exposed to cutting fluids?

Less than 5 hours .... ☐
6-10 hours .... ☐
11-20 hours .... ☐
More than 20 hours .... ☐

80. What type of fluids have you most frequently used?

Mineral oil .... ☐
Water based .... ☐
Synthetic .... ☐
Other ______________________________
Dont know .... ☐

OTHER EXPOSURES

81. Have you ever been exposed to quartz sand in a casting hall?

No ☐ If no go to question 84

Yes ☐ If yes please answer the following:

82. How many years have you worked with quartz sand?

Less than 5 years .... ☐
6-10 years .... ☐
11-20 years .... ☐
More than 20 years .... ☐

83. How many hours per week have you usually worked with sand?

Less than 5 hours .... ☐
6-10 hours .... ☐
11-20 hours .... ☐
More than 20 hours .... ☐

84. Have you ever worked with asbestos (insullation, etc.)?

No ☐ If no go to question 89

Yes ☐ If yes please answer the following:

85. How many years have you worked directly with asbestos:

Less than 5 years .... ☐
5-10 years .... ☐
11-20 years .... ☐
More than 20 years .... ☐

86. How many hours per week have you worked with asbestos?

Less than 5 hours .... ☐
6-10 hours .... ☐
11-20 hours .... ☐
More than 20 hours .... ☐

87. Have you ever had indirect asbestos exposure (e.g near spraying in a shipyard)?

No ☐
Yes ☐ If yes explain: ______________________________

____

88. Have you ever used asbestos cloth or gloves?

Yes .... ☐
No .... ☐

89. Have you ever worked with other dusty materials (cement, granite, demolition, glas fibre, etc.)?

No ☐ If no go to question 92
Yes ☐ If yes answer the following questions:

What type? ____

90. How many years exposure?

Less than 5 years .... ☐
6-10 years .... ☐
11-20 years .... ☐
More than 20 years .... ☐

91. How many hours per week have you been exposed to the above?

- Less than 5 hours .... ☐
- 6-10 hours .... ☐
- 11-20 hours .... ☐
- More than 20 hours .... ☐

92. During your working career have you frequently been exposed to the following conditions (several times each week or more)?

- Noise (so that you could not talk in a normal voice)....... ☐
- Cold, drafts .... ☐
- Vibrations from hand tools .... ☐
- High temperatures .... ☐
- Difficult/uncomfortable positions .... ☐
- Heavy loads to lift or carry .... ☐
- Fumes from welding, cutting, gouging .... ☐
- Fumes from paint, laquer, varnish, etc. .... ☐
- Glas fibre .... ☐
- Plastic fumes .... ☐
- Fumes from, solvents (tricloroethylene, carbon tetra chloride etc.. ☐
- Soldering fumes (brazing) .... ☐
- Other ______________________________

- None of the above .... ☐

Appendix 1

GUIDE TO RETROSPECTIVE CANCER INCIDENCE/MORTALITY STUDY

The need has been stressed for establishing the largest possible cohort size (exposed and controls) to enable the possible detection of an enhanced incidence rate of respiratory tract cancer among stainless steel welders compared to non-stainless welders, and of the combined welding populations compared to non welding controls.

The data obtained by the single published survey (Sjögren 1980) can be considered as probably representative of the real situation, as it agrees to within a factor of two in relative risk ratio predicted from an independent risk calculation (Stern 1981) in this study a cohort of 243 welders was assembled who satisfied the criteria that

1) they were principally occupied with welding of stainless steel.
2) had a minimum of 5 years exposure to fumes during the period 1950-1965.
3) mortality was followed through 1977 (min. 17 years, max. 27 years from onset).

The average length of exposure was 11 years (2735 welders years).
The average estimated Cr(VI) exposure was at 270 ug/m^3.
The total Cr(VI) exposure was 3.4 $mg/m^3 \cdot$years.
3 cases observed.
0.68 cases expected.
Risk ratio 4.4 $p<0.03$ not smoking adjusted.
$p<0.05$ smoking adjusted.
Background incident rate 18/100,000 (rural Sweden).

It can be seen that a study of this size can barely sustain statistical analysis. A cohort size of at least 500 men or 5000 man years would permit a much more reliable test of the hypothesis of the effects of chromium exposure.

It should be recognized that welders, in general, can be consideres as possibly exposed to three carcinogens: chromium, asbestos, cigarette smoke. It is therefore strongly recommended that the design of epidemiological studies should reflect the severe limitations of not identifying separate cohorts, and care should be taken to screen individuals into several groups with distinct sets of limited exposures. It is suggested that mixed exposures of asbestos and chromium be avoided. This entails a separate study of chromium and non chromium exposed welders, divided into smokers and non-smokersn for whom there is strong evidence for the absence of asbestos exposurel Similarly, a separate study of asbestos and non-asbestos exposure among non-chromium exposed welders, separated into smokers and non smokers might be considered.

Appendix 2

ASSESSMENT OF RISK OF LUNG CANCER FOR WELDERS

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ABSTRACT

Certain welding fumes contain significant amounts of Cr, Mn and Ni, and trace amounts of As and Pb, metals which exhibit mutagenicity in one or more in vitro bioassay, and several of which are strongly suspected human carcinogens, albeit in unknown forms. It might therefore be expected that welders suffer an excess risk of respiratory tract cancer because of their occupation. A survey of the world literature has disclosed 19 epidemiological studies of cancer incidence among welders, 16 of which yield a total of 586 cases of lung cancer observed, based on approximately 600,000 man years at risk: a risk ratio of less than unity was excluded within 95% confidence limits for 5 of these studies: A risk ratio of 1.3 was not excluded in any study. Although there may be many possible origins to the excess risk, if welders of stainless steels suffer an "Equivalent Lung Cancer Risk" to that of chromate workers because of their equivalent Cr(VI) exposure, then a resulting threefold risk ratio for the 10% of all welders engaged in stainless steel welding would account for the total overincidence experienced by the entire occupational group.

INTRODUCTION

Technological developments in metallurgy and in construction techniques over the past four decades have been accompanied by a similar increase in the use of welding in all branches of industry, especially shipbuilding, transportation, (petro)chemical, and building construction, leading to a current welding populations of between 0.5-2% of the work force in most industrialized countries (Stern, 1981a). A significant fraction of welders form stable, local cohorts with average occupational experience of the order of 17 years (Coggio, 1979; Gobbato et al., 1979; Attfield and Ross, 1978; Mehl, 1976), and are exposed to eight hour average fume concentrations of the order of 2-10 mg/m^3 (Stern, 1981a; Ulfvarson, 1981), although there are extremely wide variations in individual exposures depending on the welding technology used, the nature of the base materials, job type, and individual occupational status.

Although it is impossible to predict in advance the details of an individual welders' exposure, laboratory experiments have demonstrated that one can predict the approximate composition of welding fumes characteristic for a given combination of process, consumable (e.g. wire or electrode), and work piece. In addition to the photo-oxident gases NO, NO_2 and O_3, significant concentrations of Al, Na, Mg, F, Si, K, Ca, Ti, Mn, Cr, Fe, Ni and trace amounts of Cd, Zn, As, Mo, and Pb can be found in certain fumes (Stern 1981a; Mayer et al., 1980).

The approximately twenty major welding technologies, when applied to ten major classes of materials, provide the possibility of 5-10,000 different working environments. Fortunately two major technologies, manual metal arc welding (MMA) using stick electrodes, and Metal Inert Gas (MIG) welding (using continuous wire) applied to Mild Steel (MS), Stainless Steel (SS) and Aluminum (Al), yield combinations which are practiced by of the order of 70% of the welding population. In order of complexity, the resulting exposures are: MIG/Al; Aluminum oxide, ozone: MIG/MS; Ferric oxide, silicon, copper, and NO and NO_2: MIG/SS; oxides of iron, manganese, silicon, copper, nitrogen plus nickel, chromium and ozone: MMA/MS; same as MIG/MS plus sodium, potassium, molybdenum, fluorine, titanium calcium, aluminum: MMA/SS; same as MMA/MS plus chromium, nickel, vanadium. Examples of average, eight-hour workplace exposures for typical applications are given in Table I (Stern, 1981a; Ulfvarson, 1981): 80% of each occupational subgroup is exposed to average values within a factor of three of these values.

While the acute effects of inhalation toxicity of various welding fume components (e.g. O_3, NO_2, Cr(VI), Mn, Cd) have been reported and recently reviewed (Stern, 1981b; Newhouse and Murray, 1981), effects of chronic exposure have received less attention and are apparently difficult to document, especially because of confounding effects due to population dynamics, and the masking of welding related health problems by tobacco use (Loeb, 1979; Oxhöj et al., 1978). On the other hand, the presence of Ni and Cr in high concentrations in certain welding fumes, and the ubiquitous presence of traces of As, Pb, and occasionally Cr(VI) and benzopyrene in the general welding workshop background environment, and significant concentrations of pyrolytic decomposition products from organic primers and of asbestos in the working environment of shipyard welders, raises the serious question as to whether or not welders are exposed to excess risk from respiratory tract cancer because of their occupation.

Epidemiology Of (Lung) Cancer Among Welders

A search of the world literature has revealed 19 epidemiological studies of cancer incidence among welding populations. Of these, 15 report more than 3 cases of lung cancer, and 16 of these collectively report a total of 586 cases, based on approximately 600,000 man years of observation: A risk ratio of less than unity was excluded within 95% confidence limits for 5 of these studies, and none of the studies exclude a risk ratio of 1.3:1 within 95% confidence limits. Their details are listed in Table II.

Table I

Average Fume Concentration Of Important Toxic Substances For Typical Welding Processes[$]

PROCESS	Fraction of Welders (%)	Ozone	NO_2 +NO	Total Fume	Fe_3O_4	Cr/Cr(VI)	Ni	As	Cu	Pb	Mn	Organic Gases
		---- ppm ----		---------- ug/m^3 ----------								
MIG/Al	3 2	0.08	0.5	10,000	800	8/4[+]	-	-	-	-	-	-
MIG/MS	12 3	-	0.5	8,000	5,000	-	1.5	1.5	40	3	1,000	-
MMA/MS	36 5	-	0.3	5,000	2,000	0.5/0.5	-	2.5	-	-	-	15
MMA/MS*	24 5	-	0.3	10,000	4,000	1.0/0.5	-	5.0	-	-	-	300
MIG/SS	2 1	0.02	0.5	2,500	1,250	250/100	125	.25	-	-	-	-
MMA/SS	10 5	-	0.5	5,000	500	200/150	50	-	-	-	-	-

\+ Cr alloy/Wire 300 ug/m^3
* Shipyards/primed plates
$ Adapted from Stern (1981b), Ulfvarson (1981).

Table II

Author	Study Type	Cohort Description	Period	Material	Reference Population	Observed	Expected	Risk Ratio (95% CL)	p	Comments
1. Beaumont & Weiss 1980 1981	Historical prospective study of lung cancer	Seattle (western) Washington State. Union welders engaged in ship-building, field construction. No direct asbestos exposure.	Incidence during 1950–1976	3,247 welders, 43,670 welder years	US white males, age adjusted ≈ local males: 38/100,000	53	40.5	1.32(0.95–1.67) All welders* 1.69(1.13–2.24) >20 years latency Risk Ratio vs. Latency: 0.7 (0.3–1.5) <20 years 1.4 (0.9–2.0) 20–30 years 2.2 (1.42–3.8) 30–40 years 5 (1.1–20) >40 years	<0.06 ns. <0.001 ns. ns. <0.05 <0.05	* RR = 1.28 (0.89–1.84) using local non-welders as reference population. Attributable risk = 24 34/100,000 p <0.05. SMR pneumonia: 1.67 p <0.05. Burners have same risks as welders. No mesothelioma cases. Raw lung cancer mortality rate: 121/100,000.
2. Milham 1976	Proportional mortality study of trachial, bronchial and lung cancer.	Washington State welders and flame cutters.	Deaths during 1950–1971	3–4,000 welders, 1376 welder deaths, approx. 80,000 welder years.	US age adjusted.	67	49	1.37 (1.2–1.7)	<0.05	PMR for chronic bronchitis and emphysema = 5.37 p <0.05, bladder cancer: 1.62 ns.
3. Menck & Henderson 1976	Crossectional study of lung cancer.	Los Angeles County 1/50th sample.	Deaths (d) during 1968–1970 and incidence(i) during 1972–1973	15,300 welders, approx. 45,000 welder years.	Age specific, smoking adjusted, local population.	21 (d) 27 (i)	34 (d+i)	1.37 (1.03–1.76)	<0.05	
4. Breslow 1954	Case-control study of lung cancer incidence.	California State welders and sheet metal workers doing welding with more than 5 years employment.	cases during 1949–1952	493 cases, 493 controls, approx. 5,000 welder years.	Non-cancer patients, same hospital.	Cases 14	Controls 2	Odds Ratio 7	<0.01	
5. Office of Pop., Censuses & Surveys 1978	Retrospective mortality study of lung cancer.	English and Welsh welders and burners.	Deaths during 1968–1969	128,000 welders, approx. 256,000 welder years.	Age adjusted general population.	246	192	PMR 127 SMR 151 (1.3–1.8) SMR 116 Adjusted for 22% overincidence of smoking.	<0.01 <0.01 <0.01	SMR for pneumonia 1970–1972 = 1.44 p <0.01. Raw lung cancer mortality rate: 96/100,000.
6. Redmond 1980	Historical prospective study of lung cancer mortality.	Pennsylvania welders employed in 7 Allegheny steel companies before 1953.	Deaths during 1953–1975	646 welders, approx. 16,000 welder years.	US popul./ all employees in same industry.	14	9.3	1.51 Vs. US population 1.13 Vs. all employees in steel industry.	0.07 ns. 0.07 ns.	Raw lung cancer mortality rate: 87/100,000.

Author	Study Type	Cohort Description	Period	Material	Reference Population	Observed	Expected	Risk Ratio (95% CL)	p	Comments
7. Polednak 1981	Long term follow up study of lung cancer mortality.	Oak Ridge, Tenn. welders of mild, low alloy, and nickel plated steels.	Deaths during 1943-1973	1059 welders, 23,674 welder years.	US white males.	17 5 7 10	11.4 2.66 5.65 6.12	1.50 (.87-2.40) All welders* 1.88 <20 weeks Ni exposure** 1.24 All Ni exposed 1.75 Unexposed	ns. ns. ns. ns.	Exposure subgroups *,**: Total Cr(VI): <1 mg/m^3 year; Ni: 5 mg/m^3 year. Raw lung cancer rate: 72/100,000. (NOTE: Relatively low cumulative exposures to Ni and Cr(VI)).
8. Putoni et al. 1979	Historical prospective study of trachial, bronchial and lung cancer.	Genoa shipyard welders.	Mortality during 1960-1975	Electric welders (78 men, 1723 man years), and autogene (gas) welders (136 men 2106 man years).	Local male hospital employees.	3 4 7	1.18 1.89 3.07	2.54 Electric welders 2.12 Autogene welders 2.5 All welders	ns. ns. <0.08 ns.	Overall mortality risk ratio for welders: 1.89 p <0.005. Total cancer risk ratio for welders: 1.80 p <0.025. Bladder cancer risk ratio for welders 5.88 p <0.25. All risk ratios slightly lower if general Genoa population used as reference. Raw lung cancer mortality rate: 183/100,000.
9. Gottlieb 1980	Case control study of lung cancer	Lousiana petroleum industry welders, resident in 19 oil producing parishes.	Mortality 1960-1975	Total study: 2803 cases, 346,041 popul. during 15 years, approx. 12,000 welder years.	Non-lung cancer welder deaths: control (age & tobacco use adjusted).	Cases 8 5 3	Controls 2 1 1	Odds Ratio 4 All welders 1.89 Under 60 years of age 0.93 Over 60 years of age	<0.09 ns. ns. ns.	Raw lung cancer mortality rate: 54/100,000. These belong to a group of 69 cases in occupations with odds ratio: 2.33 (1.42-3.85) p <0.05.
10. Dunn & Weir 1968	Historical prospective study of lung cancer	California union welders and burners age 35-64.	Mortality during 1954-1962 (follow up of Breslow, 1954).	81,339 welder years.	Total study popul. (68,153 union members, 482,658 man years, 368 lung cancer deaths).	49	46.5	1.05 (0.8-1.3)	ns.	No exposure- or latency-incidence correlation. Raw lung cancer mortality rate: 60/100,000.
11. Ott et al. 1976	Historical prospective study of total cancer and lung cancer mortality	Midland Michigan chemical workers employed as welders during 1950-1954.	Mortality during 1954-1972	220 welders, 4,500 welder years	US popul.	12 2	7.4 2	1.62 All cancer sites 1.0 Lung cancer	ns. ns.	SMR for mortality for welders 119 ns: US population, 1.0; entire cohort of chemical workers: 0.81 ns.
12. Petersen 1980	Proportional mortality study of lung cancer	California welders.	Mortality in 1959-1961	863 welder deaths	200,000 total deaths in California	27	27	.99 (0.61-1.4)	ns.	

Author	Study Type	Cohort Description	Period	Material	Reference Population	Observed	Expected	Risk Ratio (95% CL)	p	Comments
13. Blot et al. 1980	Case control study of lung cancer	Welders and burners employed in shipyards in coastal (tidewater) Virginia before 1950.	Deaths in Virginia hospitals in 1976	336 cases, 361 controls, (112 cases, 95 controls shipyard workers) approx. 12,000 welder years	Non-lung cancer shipyard welders. Age adjusted local lung cancer mortality rate: 82/100,000.	Cases 11	Controls 9	1.25	ns.	Risk ratio for shipyard vs. non shipyard employment: 1.7 (1.2-2.4) p <0.05.
14. Decoufle et al. 1978	Case control study of lung cancer	Welders and flame cutters in New York State	Hospital admissions 1956-1965 (Buffalo, N.Y.)	394 cases and controls among welders, non welders ever employed.	Non-lung cancer admissions among welders in same hospital.	Cases 11	Controls 107	0.85 (0.5-1.5). Non-cancer controls: 27/211 welders/non-welders ever employed.	ns.	
						9	73	0.92 (0.5-1.5). Non-cancer controls: 16/120 welders/non-welders >5 years employed.	ns.	
15. Blot et al. 1978	Case control study of lung cancer	Welders in Georgia shipyards (more than 6 months employment).	Mortality during 1970-1976	458 cases, 533 controls, appr. 12,000 welder years	Non-cancer shipyard welder deaths (local lung cancer mortality = 130% US aver.)	11	20	0.7 (0.01-1.09) Vs. all shipyard employees.	ns.	Risk ratio for shipyard vs. non shipyard employment: 1.5 p <0.01 (tobacco use adjusted).
								1.05 (0.01-1.64) Vs. non shipyard workers.	ns.	
16. Sjögren 1980	Historical prospective study of lung cancer mortality	Stainless steel welders with at least 5 years employment during 1950-1965 in Sweden	Mortality followed through 1977	243 welders, 2735 welder years	Local male Swedish popul.: Age adjusted lung cancer mortality rate: 18/100,000	3	0.68	4.4 Not smoking adjusted 4.4 Smoking adjusted	<0.03 <0.05	Cumulative Cr(VI) exposure: 3.4 mg/m^3 x years. Especially designed study to determine risk of Cr(VI) exposure for welders of stainless steel. Raw lung cancer mortality rate: 110/100,000 cases/man year.
17. Howe et al. 1977	A Canadian study of bladder cancer which shows welders at significantly increased risk ratio, strongly dependent on tobacco use.									
18. Sheers & Cole 1980	Historical prospective study of mesothelioma	Portsmith England shipyard welders employed in 1966	Mortality during period 1966-1978	7500 man years	Non-asbestos exposed local population	6	1.2	5	<0.001	Naval shipyard welders engaged in repair, refitting etc. on warships have a high bystander exposure to asbestos, with a raw mesothelioma mortality rate of 80/100,000.
19. McLaughlin 1982	Case control study of renal cell & renal pelvis cancer	Welders, ever employed, in Minneapolis - St.Paul, Metropolitan area.	Death certificates (next of Kin interview) and incidence (direct interview) 1974-1979	413 cases, 751 controls: males	Non-renal-cancer deaths and hospital admissions (males)	5	13	1.1 (0.4-3.1) (147/407 cases/controls) direct interview.	ns.	
						8	12	1.5 (0.6-3.6) (166/344 cases/controls) next of Kin.	ns.	

Although it would appear that welders are at some excess risk for lung cancer because of their occupation, a number of additional comments should be made after examination of the studies listed above. It should be noted that a large number of shipyard welders are included in the total population. Since there is strong evidence that any type of employment in shipyards raises the risk of cancer (studies 8, 13, 15, 18) and of a variety of pneumoconioses (Selikoff et al., 1980; Coggio, 1979; Gobbato et al., 1979) above that of the local population, the excess risk among many shipyard welder cohorts probably contains a significant contribution from their employment in shipyards, and is not necessarily do to their activity as welders: these shipyard welders are at lower risk than are members of a number of other shipyard trades. Note that crude lung cancer mortality rates among the welding populations range from 183/100,000 (study 8) to 54/100,000 (study 9) so that details of age distribution, tobacco use, and other factors, among the welders and choice of reference population will significantly effect the relative results in each case.

Process Dependent High Risk Hot Spot for Welders

After excluding effects for shipyard employment and smoking (most of the studies described have been corrected for smoking prevalence) there still appears to be a small but irreducable excess risk for lung cancer for general welding populations. One may therefore consider the possibility of overthrowing the negative hypothesis that this excess risk is not due to any specific (combination of) component(s) in welding fumes, but is a result of the general lung burden of metallic oxide dusts and co-exposure to the photo-oxidant gases (e.g. welding fumes <u>per se</u>). This could be accomplished by establishing the existence of a sufficiently high risk for a well defined but limited cohort of welders, exposed to known (or strongly suspected) carcinogens absent from the working environment of the general welding population.

Although most metallic ions are mutagenic in at least one short term <u>in vitro</u> bioassay (Hansen and Stern, 1982; Sunderman, 1980; Flessel, 1979;

Table III

ESTIMATED CUMULATIVE EXPOSURES TO Cr(VI) IN VARIOUS INDUSTRIES[+]

Industry	Average cohort experience (years)	Average Total Airborne Cr(VI) Concentration ug/m^3 Low Exposure	High Exposure	Average Cumulative Exposure to Cr(VI) $ug/m^3 \cdot$ years Low	High
Stainless Steel Welding	17	50	400	850	6,800
Chromate Production	20	100	500	2,000	10,000
Chrome Plating:					
Old Plants	5	50	1,000	250	5,000
New Plants	5	5	25	25	125
Ferrochrome	20	10	140	200	2,800
Chrome Pigment	15	60	600	900	9,000
Tanning* (as Cr(III) only, except for 2 bath processes)	(10)	10*	50*	(100)*	(500)*

[+] After Stern 1982a.

DiPaolo and Casto, 1979; Sirover and Loeb, 1976) only inorganic compounds of Ni, Cr, As, Cd, and Be are suspected or demonstrated human carcinogens (IARC, 1980, 1976), and of these, only Cr and Ni appear in significant concentrations in the welding environment, and then only in the fumes from welding of stainless steel, or Ni-plated mild steel. An extensive series of investigations has demonstrated that both Ni (Niebuhr et al., 1980; Sunderman and Stern, 1982; Hansen and Stern, 1982) and Cr(VI) (Maxild et al., 1979; Hedenstedt et al., 1978; Koshi, 1979; Knudsen, 1980; Knudsen and Stern, 1980; White et al., 1980; Stern et al., 1982a; Petersen et al., 1982; Stern et al., 1982b) from welding fumes are biologically active both in vitro and in vivo and do not exhibit properties (in the test systems used) which differ from those of Ni and Cr from non welding sources (e.g. the metal salts). One can therefore conclude that there is at present no evidence to support a premise that exposures to Ni and/or Cr in welding fumes present risks which are different from those due to exposures which result in equivalent dose in the non-welding industries.

Equivalent Risk for Welders Exposure to Cr(VI)

It is convenient to briefly introduce the concept of Risk Equivalence (Stern 1982b) which states that in the absence of direct epidemiological evidence for human risk (or adequate in vivo bioassay data), equivalent exposures to active substances should be assumed to result in equivalent risk. This premise permits the assessment of risk in situations where actual risk is unmeasured or unmeasurable. For the case of stainless steel welders, the concept can be used to estimate the excess risk of lung cancer due to occupational exposure to Ni and Cr(VI) based on those equivalent exposures in the chromate and nickel industries where the risk is well known.

A recent survey of occupational exposures to chromium (Stern, 1982a) has revealed that average (crossectional) cumulative-exposures to Cr(VI) (in (mg/m^3) (years)) for high and (low) exposure groups in various industries are quite similar, e.g.: Stainless steel welders: 6.8 (0.9); Chromate production workers: 10 (2.0); Chrome platers: 5.0 (0.25); Ferrochrome workers: 9.0 (0.9). The details are shown in Table III. Analysis of the literature (IARC, 1980) shows that an approximately (logarithmic) average exposure of 3 2 (mg/m^3) (years) to Cr(VI) results in approximately an (logarithmic) average absolute lung cancer mortality rate of (500 250/ 100,000 cases/man year: (approximately a risk ratio of 6:1 assuming a background raw mortality rate of 80/100,000).

From Table I it can be seen that an average stainless steel welding cohort with 20 years experience has a cumulative exposure to Cr(VI) of the order of 3 (mg/m^3) (years) (highly exposed individuals, or those with more than the average length of exposure have average values approximately 1.5–2 times this number). Thus stainless steel welders have, if their exposure to Cr(VI) results in a risk equivalent to that of the chromium industry in general, an occupational lung cancer risk ratio significantly greater than unity, which is, on the average, of sufficient magnitude to account for the entire overincidence observed for the general welding population. The observation of Sjögren (1980) supports this hypothesis. The risk arising from exposure to Ni appears to be negligible compared to that due to Cr(VI) (Stern, 1981a).

Summary and Conclusions

Welders, as a well defined occupational group appear to exhibit an excess risk for lung cancer approximately 30% above that of the non-welding population, which cannot be completely accounted for by tobacco use or bystander exposure (primarily to asbestos in shipyards). If, as it would appear, the biological activity of Cr(VI) in welding fumes is not different from that of Cr(VI) as found in other industries, then since stainless steel welders have exposures to a respirable aerosol containing various solubilities of Cr(VI) which are equivalent to the average cumulative Cr(VI) exposure in the general chromate-producing and -utilization industry, they should be expected to have an equivalent risk for lung cancer. Since the average excess risk ratio in the chromate industry lies between 2.5:1 and 10:1, the stainless steel welding population which comprises of the order of 10% of the welding work force, could be responsible for a significant fraction of the overall excess risk observed. Verification of this hypothesis can only be accomplished by epidemiological studies specifically designed for this purpose, where special attention is paid to the definition and selection of sufficiently exposed cohorts (e.g. 3(mg/m^3) years Cr(VI)) having adequate latency time (e.g. 20 years) and appropriate reference populations (e.g. non-shipyard welders of mild steel).

The demonstration of such an internal "high risk" hot spot in the welding industry would strongly emphasize the need for risk modelling and lifetime exposure monitoring in studies of other industries with hetorogeneous and mixed exposures. Many epidemiological studies may give non-significant results only because the "at risk" cohorts are not well defined, and are diluted by the presence of large number of unexposed individuals.

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Appendix 3

MODEL PROTOCOL FOR DETERMINATION OF CHROMIUM IN URINE AND BLOOD

Collection of air and urine samples

Air and urine samples should be collected during one work week. Urine samples should be taken from every subject at 07:00, 11:00, and 16:00 every day of the week, plus the previous Friday at 16:00 and the following Monday at 07:00. Air samples should be collected each morning and afternoon on Monday through Friday, for between 3-4 hours each period. Control subjects should have air samples measured on Tuesday and Thursday only. Blood samples should be collected on Monday at 07:00 and Tuesday at 07:00 and 16:00.

Welding fume samples should be collected using preweighed cellulose ester membrane filters (millipore or equivalent) mounted in cassettes having a cover with several small holes, used together with a personal sampling pump.

The cassette holder shall be placed in the welders breathing zone, inside the face mask. Each pump-filter combination should be calibrated against a flow meter before and after the sampling period. Flow rates of between 1.5 - 3 l/m are acceptable. Total fume concentrations should be determined by direct weighing. Analysis should be made routinely for chromium, iron, nickel, fluorine. Chromium analysis shall be made following the standard protocol accompanying this document.

Urine samples should be collected in polyethylene bottles which have been allowed to stand overnight in a 10% Deconex solution, then rinsed several times with a final rinse of distilled water.

Before collection, subjects should remove work clothing and wash their hands to prevent possible contamination. Before the last sample of the day, subject should take a shower. A early morning sample, taken after waking up, should be collected at home. A first sample at the workplace should be taken as indicated.

Venous blood samples of 5 ml should be drawn into carefully washed heparinized tubes.

Analysis

Urin samples should first be measured for specific gravity and an aliquot removed for creatinine measurement, preferably by the Jaffe reaction.

Urine and blood chromium are preferably measured using electrothermal AAS, with a 0.5 + 4.5 ml dillution of the samples and 20 ul samples used for analysis.

The method should be calibrated using aqueous calibration standards of 2, 5, 10 and 20 ug/l chromium as potassium chromate prepared daily from a stock solution. The absence of dilution effect should be demonstrated.

The reliability of the method should be checked using a number of urine samples spiked with 20 ug/l and 100 ug/l chromium. The precision should also be verified by analysis of a number of duplicate samples. A detection limit of 2 ug/l Cr or less should be verified.

Data for individual welders, and the group of welders for each welding process, which enables a determination of the correlation of urinary chromium concentration increase during the work shift with airborne chromium for individual welders and processes, should be collected and analysed following Tola, S.; Kilpiø, M.; Virtamo and Haapa, K., Scand. j. work, environment & Health 3: 192-202 (1977).

Appendix 4

PROPOSED MODEL PROTOCOL FOR STUDIES OF EYE ABNORMALITIES IN WELDERS

It is proposed that the lens of the eys can be used as a dosimeter for non-ionizing radiation from the welding arc, and that lifetime welding exposure can to some degree be estimated from the degree of radiation induced opacity. This hypothesis is based on the observation of a statistically significant overprevalence of sclerosis, opalesence, cortico-nuclear opacity, anterior capsular lens opacity, and posterior capsular lens opacity among welders compared to non-welding cohorts, independent of the use of eyeglasses, and/or age. (L. Ambrosi, et al. Eye Findings In Arc Welders, La medicina del lavoro (Milan) 1983, in press).

It is proposed to preform a routine examination of the anterior segment of the eye using a slit lamp (Topocon 51-SD or equivalent) with a camera attached. The pupils should be dilated (tropamyde 1%) and a photograph obtained of each eye under suitable condition.

It is proposed to attempt to correlate a model grading scheme (of the degree of opacity) with lifetime exposure as determined from the appropriate welding experience protocol

Appendix 5

PROPOSED MODEL PROTOCOL FOR STUDIES OF WELDING FUME CONTENT OF THE THORAX USING MAGNETOPNEUMOGRAPHY

Recent evidence has been presented which verifies that the amount of welding fume retained in the thorax, and determined by remanent magnetic field measurements (PMG) (magnetopneumography) correlates with lifetime welding exposure. This finding suggests that PMG can be used to determine lifetime exposure in welders, and hence is a useful technique for sorting individuals into cohorts of various degrees of exposure for testing different hypothesis with respect to the health effects of welding: i.e. the establishment of dose/response relationships.

Although the number of instruments currently available for clinical study is small, there is strong indication that a larger number will soon be available. If this is indeed the case during the coming years, it would be of great use if PMG screening could be performed on welders who participate in any of the epidemiological/clinical studies developed within the WHO/EURO program.

Because there are a number of different instrument designs available or under development (remanent field measurements using Helmholz coils, pancake coils, local magnetization, surface demagnetization, and susceptibility measurements using symmetrical and unsymmetrical arrangements) it is necessary that results are comparable through the use of appropriate phantom samples which can be exchanges for intercalibration. Such samples can be prepared using mixtures of form and magnetite powder, having volumes of between 1-6 l, with total magnetite concentrations of 50-500 mg/l.

Appendix 6

PROPOSED STANDARD METHOD FOR DETERMINATION OF TOTAL HEXAVALENT CHROMIUM IN WELDING FUMES (After NIOSH)

(Note: it is observed that in all cases tudies for welding fume, only chromium in the oxidation state +6 is water soluble, while all other oxidations states of chromium are insoluble in aqueous solutions. Thus, a determination of the chromium ion concentration by a non-selective technique (i.e. AAS) in aqueous solution is equivalent to a determination of the water soluble Cr+6 concentration in the fume, the total concentration of Cr not withstanding. The fraction of Cr(+6) in welding fumes of all processes which is not water soluble in a standard 30 min. room temperature agitation has never been found to exceed 0.5% and is typically of the order of 0.2%. For most purposes, it is sufficient to determine only the water soluble Cr (e.g. Cr(+6) content of MMA fumes. Total Cr(+6) content of MMA or MIG fumes must be determined by a complex technique, which specifically avoids the acidificacion step of the normal DPC technique, which, in the case of welding fumes, has been shown to lead to a reduction (occasionally to zero) of the measured Cr(+6) content).

1. Synopsis

This method expands the diphenylcarbazide method (Refs. 11.1, 11.2) from acid- or water-soluble to total hexavalent chromium (Cr(VI)).

A known volume of air is drawn through a polyvinyl chloride (PVC) filter. The filter is extracted with hot, 3% sodium carbonate - 2% sodium hydroxide solution to dissolve all Cr(VI) and to protect it from reduction to trivalent chromium. The extract is acidified with sulfuric acid and analyzed by diphenylcarbazide colorimetry at 540 nm.

2. Working Range, Sensitivity, and Detection Limit

2.1 The working range is 0.5 to 10 µg Cr(VI)/m^3 in a 600-L air sample. This corresponds to 0.3 to 6 µg Cr(VI)/sample, dissolved in 25 mL. The samples may be diluted for larger amounts of Cr(VI). For smaller amounts, larger air samples must be taken.

2.2 The sensitivity (0.0044 Absorbance) and detection limit are approximately 0.05 µg Cr(VI)/m^3 for a 600-L air sample, using a final volume of 25 mL and a 5-cm optical cell.

3. Interferences

3.1 Iron (III) and vanadium (V) give yellow diphenylcarbazide complexes, with color intensities equal to 0.04 µg Cr(VI) given by 200 µg Fe (III) or 4 µg V (V). The vanadium complex is unstable, and samples containing vanadium in less than a 10-fold excess by weight over Cr(VI) may be determined accurately by allowing the solution to stand for 10 minutes after addition of the diphenylcarbazide. For samples containing large amounts of iron or vanadium, these elements are removed from the sample by extraction at pH 4 with 8-quinolinol in chloroform (Ref. 11.4).

3.2 Mercury (I or II) reacts slowly with diphenylcarbazide to give a violet-blue precipitate. Addition of sodium chloride before color development eliminates this interference (Ref. 11.4).

3.3 Nitrates cause fading of the color; this can be eliminated by buffering to pH 2 with sodium dihydrogen phosphate (Ref. 11.5).

3.4 Chromium (III), when present at 100 µg/sample, has no effect on the determination of 0.5 µg Cr(VI).

4. Precision and Accuracy

4.1 The precision of the analytical method, using PVC filters spiked with 0.3, 0.6, and 1.2 µg Cr(VI) as potassium dichromate solution, was 3.4%, 2.0%, and 3.2% relative standard deviation (RSD), respectively.

4.2 A collection efficiency of 0.945 was determined for 100 $\mu g/m^3$ Cr(VI) as chromic acid mist using 5-um pore size PVC filters (Ref. 11.2).

4.3 Recoveries of Cr(VI) determined by adding weighed amounts of the pure compounds to PVC filters and extracting were (mean % recovery ± standard deviation): barium chromate ($BaCrO_4$), 99.8 ± 4.6; calcium chromate ($CaCrO_4$), 99.5 ± 7.3; lead chromate ($PbCrO_4$), 98.5 ± 2.6; and potassium dichromate ($K_2Cr_2O_7$), 95.1 ± 2.9.

5. Advantages and Disadvantages

5.1 The method is simple, rapid, and is specific for Cr(VI) in the presence of Cr(III) or other reducing substances such as iron.

5.2 The method prevents loss of hexavalent chromium by maintaining alkaline conditions during extraction of the samples.

5.3 Water-insoluble and water-soluble hexavalent chromium compounds are soluble in the alkaline extraction medium used.

6. Apparatus

6.1 The apparratus for the collection of the personal air samples is:

6.1.1 Filter holder, 3-piece cassette, polystyrene, 37-mm diameter.

6.1.2 Shrinkable cellulose band.

6.1.3 Polyvinyl chloride (PVC) filter, 5.0-µm pore size, 37-mm diameter, supported by a backup pad. (NOTE: Cellulose ester filters are unacceptable because they may react with Cr(VI). Gelan VM-1 or equivalent are acceptable).

6.1.4 Personal sampling pump, calibrated in line with a representative filter to an accuracy of ± 5% at the recommended flow rate (1.5 to 2.5 L/min.).

6.1.5 Thermometer

6.1.6 Manometer

6.1.7 Stopwatch

6.1.8 Bottles, glass, screw cap (30-mL scintillation vials are adequate).

6.1.9 Tweezers, polypropylene or polytetrafluoroethylene.

6.2 Spectrophotometer, for use at 540 nm with 5-cm cells.

6.3 Cuvettes, matched, 5-cm path length.

6.4 Filtration apparatus, vacuum, with PVC filter, 5-µm pore size.

6.5 Beakers, borosilicate, 50-mL, with watch glass covers.

6.6 Volumetric flasks, 25-mL, and 1-L.

6.7 Hot plate, 120-140°C.

6.8 Micropipettes, 20-µL and other convenient sizes.

7. Reagents

All reagents should be analytical reagent grade, and "distilled" water means double-distilled or deionized.

7.1 Sulfuric acid, H_2SO_4, concentrated (98%).

7.2 Sulfuric acid, 6 N. Add 167.0 mL concentrated sulfuric acid (7.1) slowly to distilled water in a 1-L volumetric flask and dilute to the mark with distilled water.

7.3 Sulfuric acid, 0.2 N. Add 5.5 mL of concentrated sulfuric acid (7.1) to distilled water in a 1-L volumetric flask and dilute to the mark with distilled water.

7.4 Sodium carbonate, Na_2CO_3, anhydrous.

7.5 Sodium hydroxide, NaOH.

7.6 Potassium chromate, K_2CrO_4, or potassium dichromate, $K_2Cr_2O_7$.

7.7 Filter extraction solution. Dissolve 20.0 g of sodium hydroxide and 30.0 g of sodium carbonate in distilled water in a 1-L volumetric flask and dilute to the mark with distilled water. Store the solution in a tightly capped polyethylene bottle and prepare it fresh monthly.

7.8 Diphenylcarbazide. Dissolve 0.50 g of sym-diphenylcarbazide in a mixture of 100 mL of acetone and 100 mL of distilled water. Store in an opaque bottle in the refrigerator. The solution is stable for up to 1 month.

7.9 Cr(VI) stock standard (1000 ug/mL). Dissolve 3.735 g potassium chromate or 2.829 g potassium dichromate in distilled water and dilute to the mark in a 1-L volumetric flask. Store in a polyethylene bottle, and prepare it fresh every 6 months.

7.10 Cr(VI) working standard (10 μg/mL). Dilute 1 mL of the Cr(VI) stock standard to 100 mL with distilled water. Prepare the solution fresh daily.

8. Procedure

8.1 Cleaning of equipment. Glassware, including screw-cap bottles, should be washed in hot water with detergent and rinsed with, in order, tap water, dilute (5%) nitric acid, and distilled water. Under no circumstances should chromic acid cleaning solution be used.

8.2 Collection and shipping of samples.

8.2.1 Assemble the PVC filter and the backup pad inthe cassette filter holder and press together firmly to insure that a seal is made around the edge of the filter. Apply a shrinkable cellulose band around the assembled cassette.

8.2.2 Remove the cassette plugs and attach the cassette to the personal sampling pump by means of flexible tubing. Clip the cassette face down to the worker's lapel. The sampled air should not pass through any hose or tubing before entering the cassette.

8.2.3 Take the sample at an accurately known flow rate in the range 1.5 to 2.5 L/min. A sample size of 600 L is recommended. Check the pump during operation to assure proper functioning. Record the sampling the sampling time, flow rate, and pressure.

8.2.4 Remove the PVC filter from the cassette within 1 hour of completion of sampling and place it in a screw-cap bottle. Handle the filter only with plastic tweezers. Discard the backup pad.

8.2.5 With each batch of 10 samples or less, submit a blank filter from the same batch used for sampling.

8.3 Analysis of Samples.

8.3.1 Remove the PVC filter from the bottle, place it in a 50-mL beaker, and add 5.0 mL of filter extraction solution (7.7). Cover the beaker with a watch glass and heat it near the boiling point on a hot plate, with occasional swirling, for 30 to 45 min. Do not allow the solution to evaporate to dryness, because hexavalent chromium may be lost due to reaction with the PVC filter. An indication that hexavalent chromium has been lost in this manner is a brown-colored PVC filter.

8.3.2 Cool the solution and transfer it quantitatively, with distilled water rinses, to a 25-mL volumetric flask, keeping the total volume about 20 mL. (NOTE: If the solution is cloudy, it should be filtered first through a PVC filter in a vacuum filtration apparatus (6.4), using distilled water rinses).

8.3.3 Add 1.90 mL of 6 N sulfuric acid to the volumetric flask and swirl to mix. CAUTION: carbon dioxide will be evolved, causing increased pressure in the flask. Let the solution sit for several minutes, until vigorous gas evolution ceases, and then dilute to the mark with distilled water.

8.3.4 Add 0.5 mL of diphenylcarbazide solution (7.8) and invert several times to mix thoroughly. Then pour aout about one-half of the contents of the flask, stopper the flask, and shake it vigorously several times, removing the stopper each time to relieve pressure. (NOTE: This step releases excess carbon dioxide, which would otherwise cause high and erratic readings).

8.3.5 Transfer the solution to a 5-cm cell and read the absorbance at 540 nm. Zero the spectrophotometer with a reagent blank. Intensely colored solutions may be diluted with 0.2 N sulfuric acid and the resulting absorbance multiplied by the appropriate dilution factor.

9. Calibration and Standardization.

9.1 To 25-mL volumetric flasks, add 20, 40, 60, 80, and 100-μL volumes of Cr(VI) working standard (7.10) and dilute to the mark with 0.20 N sulfuric acid (7.3) to produce solutions containing 0.2, 0.4, 0.6, 0.8, and 1.0 μg Cr(VI). Add 0.5 mL diphenylcarbazide solution (7.8), mix, and read the absorbance of each solution in a 5-cm cell at 540 nm.

9.2 Draw a calibration curve by plotting the absorbance of the standards vs. amount of Cr(VI), in micrograms/25 mL.

10. Calculations.

10.1 Subtract the absorbance of the sample blank from the absorbance of each sample.

10.2 From the calibration curve (9.2) determine the micrograms of Cr(VI) in each sample.

10.3 Express the concentration of Cr(VI) in the air sample as

$$C = \frac{W}{V}$$

where: C = concentration of Cr(VI), $\mu g/m^3$

W = weight of Cr(VI) in the sample, μg

V = volume of air sampled, m^3

NOTE: For personal sampling pumps with rotameters, the air volume should be corrected

$$V_{corr} = Q \times t \sqrt{\frac{P_1 T_2}{P_2 T_1}}$$

where:

Q = sample flow rate, L/min

t = sampling time, min

P_1 = pressure (mm Hg) of atmosphere when pump was calibrated

P_2 = pressure (mm Hg) of atmosphere sampled

T_1 = temperature (K) of atmosphere when pump was calibrated

T_2 = temperature (K) of atmosphere sampled

11. References

11.1 Chromic Acid Mist in Air, P&CAM 169, NIOSH Manual of Analytical Methods, 2nd ed., Vol. 1, U.S. Dept. of Health, Education, and Welfare Publ. (NIOSH) 77-157-A.

11.2 Chromic Acid and Chromates, S317, NIOSH Manual of Analytical Methods, 2nd ed., Vol. 3, U.S. Dept. of Health, Education, and Welfare Publ. (NIOSH) 77-157-C.

11.3 Criteria for a Recommended Standard. Occupational Exposure to Chromium (VI), U.S. Dept. of Health, Education, and Welfare Publ. (NIOSH) 76-129.

11.4 Sandell, E.B., Colorimetric Determination of Traces of Metals, 3rd ed., Interscience Publishers, pp. 392-397 (1959).

11.5 Tentative Test Method for Chromium in Workplace Atmospheres (colorimetric Method), Amer. Soc. for Testing and Materials Method D 3586-77T, ASTM (Philadelphia), 1978.

11.6 Thomsen, E. and Stern, R.M., A Simple Analytical Technique for the Determination of Hexavalent Chromium in Welding Fumes and Other Complex Matrices, The Danish Welding Institute Report No. 79-01, Scand. j. work, environment & health, 5: 386-403 (1979).

From: NIOSH Chromate Iron/Hexavalent Chromium Analysis Proceedure
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Appendix 7

PARTIAL LISTING OF CURRENT RESEARCH ON THE HEALTH EFFECTS OF WELDING

A. International Organizations

1) International Institute of Welding
   Commission VIII: Chairman Gideon Gerhardson, SAF, Stockholm.
   Major interests: Chemical analysis, health effects, risk management and risk assessment.

2) European Council for Cooperation in Welding.
   Compilation of health related research among welding institutes in the countries of the common marketl Coordination of collection strategies.

3) Health and safety directorate EEC/European Coal and Steel Union, Luxembourg.
   International projects on welding: risk assessment carcinogenicity, etc. (TNO, Holland; DVS, Germany; SVC, Denmark)

B. National Organizations (European)

1) Danish Welding Institute (and other Danish Laboratories), R.M. Stern project leader.
   Risk assessment and management.
   Mutagenicity of metals, in vitro studies.
   Cr(VI) analysis.
   Reference standard welding aerosols.
   Particle size distributions.
   Analysis of stainless steel industry in Denmark.
   Magnetopneumography.

2) National board of worker protection, Solna Sweden, Ulf Ulfvarson project leader.
Analysis of welding industry in Sweden.
Analysis of welding fumes in the workplace.

3) German Welding Institute, Døsseldorf, H. Sossenheimer.
Humanization of the work place of welders: national project involving collection, analysis of welding fumes, study of fume formation. Clinical and epidemiological studies.

4) British Welding Institute, Abbingdon, Cambridgeshire.
Frank Coe, Director of project.
Study of welding fumes in industry. Study of health effects of welding.

5) Institute of Occupational Health, Helsingfors, Finland.
P.-L. Kalliomøki and others.
In vivo studies of welding fume toxicity. Epidemiology of welders of stainless steel. Magnetopneumography.

6) Institut de Soudure, Paris (Beaufis, project leader).
Chemical analysis of welding fumes.

7) TNO, Holland.
In vitro and in vivo studies of toxicology and genotoxicology of welding fumes.

In addition, a number of other countries have active programs of research on welding and health effects: USSR (Kiev), Italy (Trieste), Norway (Oslo), among others.

C. Outside Europe

1) Japanz Origin of welding fumes (Kope Steel Laboratories).

2) USA: Nature of the welding environment, effects of Cr and Ni in welding fumes, epidemiology of stainless steel welders (American Welding Society, Miami).

3) Australia: Nature of the welding environment (Australian Welding Society).

Appendix 8

CENTRAL REFERENCE LABORATORY FOR ANALYSIS OF WELDING FUMES

It is proposed to identify a single laboratory as a reference laboratory for the production and analysis of welding fumes.

The Danish Welding Institute currently produces a range of surrogate standard welding fumes, which are thought to be representative of approximately 70-80% of occupational exposures. Samples of these fumes are available.

A system of cascade impactor sampling and analysis for small quantities of fume has been developed. A service for the chemical analysis of weighed millipore filters containing known amount of welding fume is offered at a very low cost, utilizing a proton induced x-ray fluorescense analysis system (PIXE) operated at the Bohr Institute by the national meterological laboratory (Price 100-200 DKr per analysis, for all elements heavier than No. 14, depending on sample quality, number, and detection threshold required). Chromium (VI) analysis following Appendix 6 is also offered.

Appendix 9

CENTRAL REFERENCE INSTITUTE FOR CLINICAL AND EPIDEMIOLOGICAL STUDIES

It is proposed that an institute be selected to act as a reference center for clinical and epidemiological studies. Such a center will provide the necessary coordination and harmonization of the respective national projects, and will ensure maximum inter-comparability of the results of various protocols, which, out of necessity, will have certain elements of national character which will not be identical in all cases.

Appendix 10

PULMONARY FUNCTION PROTOCOL

The effects of long term inhalation of welding fumes are known to be, for the most part, subtle. It is the current impression that field measurements of respiratory function will not provide significant information on welders reaction to fume inhalation, since most effects will be limited to the small airways and gas exchange region. It is recommended that a complete battery of clinical respiratory function tests be carried out. Such a battery should be composed of:

1) Total lung capacity
2) Vital capacity
3) Residual volume
4) FEV_1
5) PEF
6) MEF_{50}
7) Closing volume (%)
8) Closing capacity (%)
9) Wash out volume
10) VTG
11) Diffusion capacity (transfer factor)
12) Slope (of closing volume)

Detailed protocols for a number of these tests are described in the core protocol "Health Significance Of Formaldehyde In The Indoor Environment" presented in the present consultancy.