The health of welders / by A.T. Doig and L.N. Duguid.

FACTORY DEPARTMENT
MINISTRY OF LABOUR AND NATIONAL SERVICE

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LONDON: HIS MAJESTY'S STATIONERY OFFICE
1951

THREE SHILLINGS NET

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BY

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FOREWORD

In recent years there has been a great increase in welding and the process has undergone much development and modification. The possibility of ill health arising from this work has been considered in many quarters and H.M. Chief Inspector of Factories decided that an investigation into the matter should be made by members of his Department.

Dr. A. T. Doig undertook the main part of the work and Mr. L. N. Duguid collaborated with him in order to give guidance on technical matters of an engineering character. A survey of types of welding was carried out and this was followed by clinical examinations on a number of welders in different industries supplemented in many cases by special examinations such as radiological examination of the chest and blood examinations. In addition Dr. J. D. Fraser, Department of Ophthalmology, Glasgow University, was asked to undertake, under the guidance of Professor W. J. B. Riddell, a survey of certain welders to ascertain whether any chronic or permanent eye effects might be produced, and Dr. Ethel Browning, H.M. Medical Inspector of Factories, carried out a series of blood examinations. The reports of Dr. Fraser and Dr. Browning are included in the report which follows.

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THE HEALTH OF WELDERS

DESCRIPTION OF WELDING PROCESSES

(L. N. DUGUID)

Types of Welding

1. There is now a considerable variety of welding processes. Some of them, however, do not give rise to the evolution of any considerable quantity of fume or gas and it was not considered necessary to extend the enquiry into such kinds of welding as appeared to be neither harmful nor unpleasant. In the various kinds of resistance welding such as spot welding, projection welding, seam welding, butt welding and flash welding an electric current passes through the pieces of metal to be joined and they become hot by reason of the electrical resistance of the joint. While the metal is hot pressure is applied and a welded joint results. These processes are usually carried on without the use of fluxes or slags and there is no added metal. The metals are usually clean new material and the only possible source of fume seems to be any oil, grease or dirt left on the metal either accidentally or for economy by avoiding cleaning.

The remaining processes are fundamentally different. They are all included in the terms " autogenous welding " or " fusion welding " and produce fumes and gases. They consist of a local melting of the metals to be joined with or without adding molten metal from a " filler rod " or " electrode ". A pool of liquid metal is formed and quickly solidifies as the source of heat moves along the joint. Fusion welding includes Gas Welding, Metal Arc Welding, Carbon Arc Welding, Atomic Hydrogen Welding and Argonarc Welding.

2. Gas welding is mostly done by the well-known oxy-acetylene process. If metal has to be added to the joint it is supplied by a " filler-rod " which is melted into the pool of molten metal. The filler rod is generally, but not always, of similar composition to the metal being welded. Sometimes different metals are used for filler rods as for example in the repair of iron castings, a bronze rod may be used. These filler rods are never coated like electrodes. When welding mild steel no flux is used but with other metals a flux may be applied to the job or the filler rod or both immediately before welding. Other gases such as propane and hydrogen are sometimes used in place of acetylene where a lower temperature flame is sufficient. In the closely associated process of gas cutting an extra jet of oxygen is used to burn the heated metal so that the amount of metallic oxides produced must be relatively greater than in welding.

3. In metal arc welding the source of heat is an arc struck between the metals to be joined and an electrode. The parent metal melts and the electrode itself melts away and fills in the jointing space. Modern electrodes are nearly always coated and the coating also melts and performs very important functions. The electrode is commonly held in a holder which is manipulated in the welder's hand. Much metal arc welding is now, however, done by machine. In some cases the machine employs a coated electrode and as far as fumes are concerned the conditions are similar to those in hand welding. Some machine welding is, however, done by a process in which the arc is permanently submerged in a mass of powdered material which performs similar functions to those of the coating of the electrode in other processes and the emission of fumes is thereby suppressed. The use of machine welding is increasing. Machines will be found making welded joints on the decks of ships. Others will be found in factories welding boilers or other vessels. All these methods have the common factor that the electrode itself is carrying the current and is being melted away at the arc and depositing its own metal into the joint.

4. Carbon arc welding is in many respects similar to metal arc welding but the electrode carried in the holder is made of carbon instead of metal. The electrode is, therefore, not used for adding metal to the joint but simply for maintaining the arc to melt the metals to be joined. If it is necessary to add metal to the joint this is done with a filler rod as in gas welding. From the point of view of fume production carbon arc welding has much in common with gas welding. In both processes by manipulating the flame or arc the metal can be brought up to the necessary welding temperature without any excessive heating. In metal arc welding all the added metal and flux pass right through the arc and are therefore subjected to an extremely high temperature under conditions in which the metals present are very sensitive to oxidisation, although some of the metal may be volatilized without oxidation.

5. The Atomic Hydrogen process makes use of an electric arc but is essentially different from other electric welding processes. The arc is struck, not between an electrode and the job to be welded, but between two electrodes carried in the holder. A stream of hydrogen (or " cracked ammonia ") is blown into the arc. The result is a very high temperature flame which facilitates rapid working.

In the more recently developed Argonarc process, which is used particularly for non-ferrous metals, a stream of argon issues round the arc from a specially designed electrode holder. The electrode itself is a tungsten rod which is virtually non-consumable. Weld metal is added by means of a suitable uncoated filler rod without the use of fluxes.

Composition of Electrodes and Fluxes

6. In the early days of metal arc welding bare wire was used for the electrode particularly in other countries but nowadays wire with a covering of one kind or another is generally used. There are many kinds of electrodes. The object of an electrode designer is in the normal case to obtain a deposit of metal of similar properties to the parent metal being joined. It follows that many kinds of wire are used for making electrodes and the variety is increased by the different types of coating used. With the passage of time the coating compositions are tending to fall into certain classes with the different makes varying in detail, and, no doubt, with some variations in quality of material and method of manufacture.

Many of the terms used in describing electrodes simply refer to the manner in which the coating is applied to the wire in the course of manufacture, but at the same time afford some clue as to the materials which might be expected in the coatings.

" Dipped Electrodes " as the name implies are made by dipping the lengths of wire into a wet mixture of the coating material. A single dip produces a " wash coating " but the wire may be dipped several times to produce a " heavy coating ". The material used will probably be an arc stabilizer such as calcium carbonate or other carbonates and oxides.

A " wrapped electrode " has a coating such as blue asbestos in the form of a yarn wrapped spirally round the wire smoothed off with sodium silicate. This would give a " single coating "; but the wire may be coated with a paste before being wrapped, thus giving a " double coating ".

An " extruded electrode " has the coating in the form of a stiff paste applied to the wire under pressure in an extruding machine. If the paste goes directly on to the wire the electrode is described as " plain extruded ", but the paste may be applied to a wire which has already been " wrapped " giving a " wound extruded electrode ".

7. The main purposes of the coating on the electrodes are as follows :—

(i) Stabilization of the arc making the process more uniform and smooth running, thus facilitating control by the operator.

(ii) Production of a suitable flux for the minature melting furnace created by the arc and of a slag to cover the hot metal during solidification and further cooling.

(iii) To add to the weld metal certain alloying elements which might otherwise be deficient in the final composition.

(iv) To provide a " gas shield " round the arc to prevent the weld metal being contaminated by the nitrogen and oxygen of the air.

(v) To control the shape of the bead of weld metal deposited.

(vi) To control the depth of penetration of the weld.

It will be seen that in spite of its small scale there is quite a complex metallurgical operation going on between the electrode and the parent metal.

8. One of the simplest types of electrode coating contains a mixture of iron oxides and silicates. Among the forms of iron oxide used are the minerals, hæmatite (Fe_2O_3), magnetite or magnetic iron ore (Fe_3O_4) and micaceous iron ore, which is a form of hæmatite. The silicates used include kaolin (China clay, a hydrated aluminium silicate) ($H_4Al_2Si_2O_9$), potash felspar ($KAl\ Si_3O_8$) or soda felspar or lime bearing varieties of the latter; potash mica [$H_2KAl_3(SiO_4)_3$], talc ($H_2Mg_3Si_4O_{12}$), chrysotile or Canadian Asbestos ($H_4Mg_3Si_2O_3$). The natural blue asbestos mentioned previously is a compound [$NaFe(SiO_3)_2\ FeSiO_3$] which can replace the iron oxide-silicate mixtures and has been and still is very widely used.

The composition of the minerals mentioned may vary considerably and the formulæ which follow their names are quoted for the purpose of giving some indication of the elements which may be present in a typical sample.

An important step in the technique of welding was made when de-oxidising iron alloys were introduced into the electrode coatings. Among the alloys used are ferro-manganese, ferro-silicon, ferro-titanium, ferro-vanadium.

Another development which has greatly affected modern practice was the introduction of a large percentage of titanium dioxide (TiO_2) into the coating mixture. It is generally used in the form of the mineral rutile.

Most of the materials so far referred to form a mineral slag over the deposited metal. Some advantages are claimed for " gas shielded electrodes ". In this type, in addition to the normal constituents some form of cellulose is introduced into the coating. The cellulose decomposes and adds carbon monoxide and hydrogen to the sheath of gases and fumes which surrounds the arc and this provides further protection against contamination by atmospheric gases during the transference of metals from the electrode to the parent metal through the arc.

With the development of metal arc welding of stainless steels and some non-ferrous metals, fluorides were introduced into the coatings in order to take certain non-ferrous metallic oxides into the slag. The fluoride of calcium is mainly used.

Among other materials included in the coating are various forms of calcium carbonate and the carbonates of magnesium, manganese, sodium and potassium and various mineral oxides of manganese.

In gas welding, coated filler rods are not used except that some flux may be put on to the rod in the form of a paste immediately before welding as well as on the parent metal. For ordinary irons and steels no flux is used. For some non-ferrous metals a borax based flux is used, but for aluminium and magnesium the flux may consist of a mixture in various proportions of chlorides, fluorides and sometimes bromides, of lithium, potassium, sodium, barium or magnesium. Nearly all fluxes of secret composition are sold under trade names.

Composition of Fumes and Gases Evolved in Arc Welding

9. While most of the metal in the wire and coating of the electrode is deposited on to the parent metal in the form of weld metal or slag it is inevitable that some of it should escape in the form of a fume, that is fine particulate matter, or in the form of gas. It will be gathered from the variety of materials used in the manufacture of electrodes that the fume may be of very heterogeneous composition but at the same time the main constituents are, as would be expected, oxides of the various elements present. In welding plain steels the bulk of the fume will generally be ferric oxide, but other substantial constituents will be silicates and manganese dioxide with small quantities of many other oxides. In welding stainless steels there may in addition be substantial quantities of calcium fluoride and chromium oxide, and possibly a little oxide of nickel although a higher percentage of any nickel in the electrode finds its way into the weld than is the case with most metals.

The gases which may be evolved into the atmosphere in small quantities are hydrogen, carbon dioxide, carbon monoxide, nitrous fumes and ozone.

The quantity of fume produced in a given time depends upon the rate at which electrode metal and its coating are melted. Many sizes of electrodes are made and the nominal size is that of the wire or rod used. The bigger the electrode the larger is the current used and consequently the greater rate of melting and greater fume production.

The amount of fume a welder breathes in depends largely upon the rate of dispersal of the fumes and this, in turn, depends upon the environment, particularly the conditions of ventilation. In confined spaces the concentration of fume in the atmosphere will build up much more rapidly than in larger spaces.

Special Risks Due to Coatings on Parent Metal

10. In addition to the risks which are inherent in the welding processes, there are incidental risks due to the fact that the metal being welded is not always bare new metal of uniform composition. Metal which has been coated in one way or another often has to be flame-cut or welded and the coating is destroyed and contributes to the fume. The following are typical of the coatings referred to :—

(i) Zinc—on galvanized iron and steel.

(ii) Lead—in paint or on terne plates.

(iii) Cadmium—in the form of paint or electro-plating.

(iv) Miscellaneous deposits such as scale on the water side and soot on the fire side of boiler plates.

A considerable amount of welding is done on new galvanised work in spite of the fact that the galvanizing is destroyed in the vicinity of the weld. Zinc oxide fume is given off. Still greater quantities of zinc fume are given off in demolition and repair work where galvanized metal has to be cut out by means of the oxy-acetylene burner as often happens in ship-repairing.

Plates coated with lead paint often have to be welded in the construction of ships. Terne plates which are coated with metallic lead are occasionally used in aeroplane and motor vehicle construction.

Cadmium may be present in paints and one case of cadmium poisoning resulting from welding, reported in this country, arose through filling up by welding, holes which had been wrongly drilled in a batch of cadmium plated articles.

Deposits on boiler plates or dirt on vehicles can give rise to offensive fumes when gas cutting is being done prior to repair or during repair by welding. This kind of work is often done in very confined spaces and exhaust draught should be provided to ensure that the welder has reasonably clean air to breath and work in.

REVIEW OF LITERATURE ON HEALTH HAZARDS OF WELDING

(A. T. Doig)

11. The literature on the health of welders has become voluminous in the last 15 years and the following is a brief summary of the present state of our knowledge regarding the harmful effects accruing from the process.

Effects on the Skin

12. Skin irritation may result from exposure to the ultra-violet and infra-red rays but would not appear to be very troublesome owing to the protection afforded by clothing, gloves and face shield. Occasionally temporary irritation may result if a welder wears a shirt having sleeves which do not meet his gloves, or an open neck, and sometimes a little pigmentation or desquamation may be seen on the ears or back of the neck resulting from exposure to the arc of a neighbour or reflection of rays from his own arc (as for instance when welding inside metal tubes). Welders may also be exposed to dirt with resulting blocking of the pores with oil, rust etc. from the plates being welded, but this seems likely to cause trouble mainly if insufficient attention is paid to personal cleanliness.

There are few references in the literature to dermatitis in welders. Slight burns are not uncommon and it has been alleged that these frequently become septic in spite of treatment (J. Am. Med. Ass. 1938). The scars of minor slag burns have been spoken of as an occupational stigma (Dreesen et al, 1947). Beinkter (1938) speaks of inflammatory pustules being common in aluminium welding, probably from tiny burns, and Tschauder (1942) says that furunculosis is commoner in electric arc and oxy-acetylene welders than in controls. McElroy & Svenson (1944) analysed the causes of disabling illness in a large group of shipyards in America and found a low incidence of dermatitis in welders. Molfino (1942) speaks of minor superficial burns from sparks causing real occupational stigmata on the uncovered skin, but only serious when affecting the eyes, and Reynard & Smith (1947) recently described the effects of minute foreign bodies embedded in the skin of spot welders derived from the sparks given off during that process.

It seems as though dermatitis is not a very severe or frequent occurrence amongst welders.

Effects on the Eyes

13. The radiation emitted from the arc may conveniently be divided into three categories.

1. Infra-red rays (8,000-13,000 A.U.) which are invisible and cause heating.

2. Visible light rays (3,500-8,000 A.U.) by which objects are seen. In high intensities these may cause painful effects.

3. Ultra-violet rays (below 3,500 A.U.) which are invisible and can give rise to painful effects.

14. Arc eyes is a well known condition, caused by the ultra violet rays, and consisting of pain and a feeling of grit in the eyes, photophobia and lachrymation which follows exposure of the unprotected eye to the rays from the arc. For short distances the exposure necessary is generally thought to be only a fraction of a second but recently some doubt has been cast on this belief by Kinsey, Cogan & Drinker (1943) who state " It is evident that the time of exposure required to produce symptoms is not consistent with the general idea of ' flash ' exposure and therefore the term appears to be a misnomer," and by Rieke (1943) who suggests that arc ' flash ' is the result of exposure over several minutes, or a cumulative injury similar to snow-blindness and sunburn.

The symptoms appear after a delay period of a few hours and seldom last longer than 24 hours, subsiding without any residual damage in by far the majority of cases. The main lesion appears to be a " conjunctivitis " or " keratoconjunctivitis " accompanied by some desquamation of the corneal epithelium (Occupation & Health, 1932). Kuhn (1944) describes the action of ultra-violet rays on the eyes as resulting in swelling of the cytoplasn of the corneal epithelium and an eosinophilic infiltration. In some cases a blinding sensation is said to last for several days during which the affected person is not able to fix or distinguish things and has the sensation of a black veil in front of the eyes, but it is generally understood that complete recovery without any permanent or chronic effects is the rule. Some writers, however, speak of keratitis and retinitis with permanent changes in the retina, [Hirschberg (1898), Crzellitzer (1906), Apfelbach (1914), Wurdeman (1936),] and Coutela (1939) quotes a case described by Terrien, of a worker blinded by the arc of a short circuit at about 30 cm from his eyes in whom bilateral optic atrophy resulted. This was attributed to infra-red rays. According to Parsons, (1926), only a few relatively innocuous ultra-violet rays reach the retina. On the other hand practically all the visible rays and many infra-red rays pass to the retina unimpeded and it is conceivable that pathological changes might be produced by the resultant heating effect. Parsons mentions some ophthalmoscopic signs found in the later stages of photo-retinitis after exposure to bright light and presumably due to infra-red rays. Definite evidence of damage *in welders* due to infra-red rays, however, appears to be lacking, and Themsche and Michel (1932) state that the quantity of infra-red rays from the arc is not considerable, and not at all comparable to that present near metallurgical or glass furnaces.

15. In regard to the question of possible effect on the eyes of infra-red rays in welding, I have, by courtesy of the British Standards Institution been able to see a letter from the Secretary of the American Standards Association to the Director of the British Standards Institution. This letter, dated May 3rd, 1945, states that Professor Phillip Drinker, Chief Health Consultant of the National Maritime Commission stated that he has not known of any troubles from infra-red rays in welding either by gas or by arc. It further quotes M. D. Kossoris, Chief, Industrial Hazards Division of the Bureau of Labour Statistics as saying, "A thorough check of nearly 100,000 injury reports sent to us by shipyards fails to reveal any information of injuries directly chargeable to the effects of infra-red radiation ".

16. Little prominence has been given to chronic effects or changes in the eye after continued exposure. Dreesen et al (1947) found that inflamed eyes ordinarily mild in degree, occurred only slightly more frequently in welders than in a control group. Granjon (1938) is one of those who believe that all eye symptoms are transient, but chronic electric ophthalmia with conjunctival hyperæmia in the palpebral fissure and asthenopia has been described (Natanson & Vinogorov, 1937). Toulant, quoted in Occupation and Health (1932) speaks of a diffuse scleritis which, according to Tacchini, may occur in oxy-acetylene welders after a few days. Ophthalmological examination showed a slight degree of injection of the papillary and retinal blood vessels. Pozzi (1938) quotes Natanson, Uhthoff, Silber, and Kandatsin & Tashiro as reporting more or less frequent complications such as detachment of the retina, annular scotoma for red and green, numerous cases of weakening of the visual acuity and chronic blepharitis, although he has not found any case in his own work or in the French literature. Feil (1946(b)) speaks of a slight weakness of vision in welders most obvious in the evenings after work.

Diminished corneal sensitivity has been described by Natanson & Vinogorov (1937), in 203 out of 290 eyes (Natanson, 1935). These writers found no diminution of visual actuity or change in the visual fields, but Pozzi (1938) says of arc flash " a persistent sign is reduction of visual acuity which, in certain cases, never recovers its previous state ". Depletion of the visual purple has been suggested (Kuhn & Wille, 1943) and Chautin (1934) describes delayed dark adaption which he attributes to reduced sensitivity of the visual cortical centres by exposure to ultra-violet rays and injurious gases, and to counteract the latter suggests special attention to ventilation and limitation of working hours. His findings were more marked in oxy-acetylene welders than in electric welders. Kuhn & Wille (1943) however say that there is no evidence of delayed dark adaptability among welders, but state that those receiving vitamin A showed improvement over controls. Waniek (1938) in an examination of 63 welders mentions only one with a pathological eye condition—a patient who, two years before was discovered to have a " Blendungsretinitis " and in whom prophylactic measures had prevented the condition progressing further. Gengoux (1946) in 165 electric welders, finds bilateral hyperæmia of the papillæ in 54 and unilateral hyperæmia in 11, and also venous congestion of the retina in 21 cases and hyperæmia of the central artery in 19. He suggests further enquiry regarding possible consequences of this congestion.

Rieke (1943) mentions that in cases of arc flash conjunctivitis, the slit lamp reveals some superficial epithelial devitalisation and minute œdematous blebs on and in the epithelium of the cornea which are quickly repaired within 12-18 hours of the onset of symptoms. He finds no evidence that this temporary injury to the corneal epithelium either permits ready bacterial invasion or contributes to permanent injury of the cornea even if frequently repeated.

Acute Effects

(a) GASSING

(i) *Nitric Oxides* :

17. Many cases of death resulting from acute respiratory disease (pneumonia, lung œdema, etc.) have been described following oxy-acetylene welding in enclosed spaces such as tanks and boilers, where ventilation was inadequate. These cases are usually due to the inhalation of oxides of nitrogen produced from the atmospheric gases by the heat of the oxy-acetylene flame, (Kienitz, 1939; Nordmann, 1937; Kœlbel, 1938; Duyster & Coppens, 1941; Mænicke, 1936; Reichsarbeitsblatt, 1943; Humperdinck, 1942 (a); Hatt, 1946). Kuster (1935) describes a similar

case, an acetylene welder who died 24 hours after working for ¾ hour in a closed boiler, the cause of death being pulmonary œdema, but he seems at a loss to decide the cause and suggests phosphine or gases arising from the shellac lining. He does not appear to have considered nitric oxides which seem the most likely cause. Felsch (1940) describes a case of pulmonary œdema after welding for 40 minutes inside a copper cooker. This is attributed to nitric oxides but we have the complication that copper fume may have contributed in whole or in part to the pulmonary irritation. Renander (1937) describes a similar case in a boy aged 15 years who was welding with the oxy-acetylene flame inside an aluminium cylinder. He considered that the illness, which ended with recovery, was due to acetylene of which there was said to be an excess present. The x-ray film showed patchy areas of consolidation which cleared in a few days and here again we have a similar clinical picture probably due to nitric oxides, but possibly in part to freshly formed aluminium oxide (which might produce metal fume fever just as zinc oxide does when inhaled in a freshly formed state). Ziemke (1933) gives a very full description of a man who died with acute pulmonary symptoms 4 days after being exposed to the fumes of oxy-acetylene flames in a confined space on board a ship. At post-mortem examination the lungs were found to be œdematous. Petechial hæmorrhages were found in the brain (especially the corpus callosum and medulla). He attributed the death to carbon monoxide although in the light of present knowledge it seems likely that nitric oxides were to blame. Schiotz (1942) describes 4 non-fatal cases which occurred after exposure to fumes from an oxy-acetylene welding torch in a narrow confined space on board ship. He advocates exhaust over the work or the wearing of helmets with a fresh air supply.

18. Lindquist (1944) reviews the literature, mentioning 75 cases. He describes 16 cases of his own of which four were fatal and gives post-mortem records and x-ray reproductions. He refers to a statement of Rimarski and Konochak that fatal concentrations of nitric oxides can be produced in 15 minutes with a large flame burning in a space of 20.7 c. metres, or in 20-30 minutes in a space 75 c. metres even if provided with a ventilator

The risk of gassing from nitric oxides is of course to be expected in operations other than welding involving the use of oxy-acetylene flames in ill-ventilated spaces, and, as examples, mention may be made of the alarming occurrences in shipyards described by Bridge (1934) (1938).

19. The operation of electric arc welding in confined spaces seems to carry very considerably less risk of nitric oxide gassing than oxy-acetylene welding, probably because such welding is almost invariably carried out with coated rods giving rise to a "shielded arc", (Dreesen et al, 1947). I have been able to find only one clear cut case of death from pulmonary œdema due to nitric oxides after electric welding, that of Adler Herzmark (1929). As far as I am aware no cases have occurred in this country. Another two probable cases have been reported. Wright Smith (1939) in Australia describes a fatality in an electric welder, one of four men who welded in a large enclosed tank, but an oxy-acetylene flame had been used by one of the men in the tank at the beginning of the operation. In America, Williman (1935) reports on a fatal case of pneumonia after electric welding in a galvanised tank but here zinc fumes must be regarded as playing at least a contributory part. (Metal fume fever may be accompanied by serious chest symptoms even in circumstances where the presence of nitric gases can be ruled out.)

20. The presence of nitric oxides in welding gases has been repeatedly demonstrated by analysis and their irritative action shown by animal experiment producing, according to the time and intensity of exposure, acute or chronic effects (v. Haam & Groom, 1941; Kinsey et al, 1943; Gardner & McCrum, 1942; Titus et al, 1935; Tollman et al, 1941; McQuiddy et al, 1938 a & b). Henderson and Haggard (1927) give 39 p.p.m. as the maximum allowable concentration of nitrogen dioxide but many observers including Harrold (1942) regard this as too low and consider that over 70 p.p.m. may be breathed for prolonged periods without harm. On the other hand the International Labour Office recommend that the permissible concentration should not exceed 25 p.p.m. for an 8 hour day. However, the amount of nitric oxides formed from the modern electric welding arc seems to be very small and Tebbens and Drinker (1941) as a result of experiments say that only in confined ill-ventilated spaces is it possible by welding to raise the concentration of nitrogen dioxide to even a few p.p.m. Von Haam & Groom (1941) in a large investigation concluded that the welding fumes and gases were of low toxicity and that at industrial concentrations their harmlessness was a fair assumption. Dreesen et al (1947) analysed 2,019 samples of air in shipyards (1,103 from the hull including double bottoms, tanks, forepeaks, etc.) and found that more than half the samples contained less than 5 p.p.m. of nitrogen oxides and more than four fifths contained less than 10 p.p.m. Only 1.8% of the samples contained 25 p.p.m. or more and only 0.2% more than 40 p.p.m., the highest value being 62 p.p.m. There seems to be no doubt that considerably less nitric gases are evolved with the coated rods such as are in almost universal use now, than with bare rods or the carbon arc (McCord et al, 1941; Harrold, 1942).

21. There is evidence that nitric oxides may be produced in harmful quantities from the carbon arc (Coltman, 1938; McQuiddy et al, 1938a, 1938b; Drinker & Snell, 1938), but I have no knowledge of mishaps attributed to the gases during carbon arc welding, an operation which is not very widely used at present.

(ii) *Carbon Monoxide*

22. Carbon monoxide may reach a toxic concentration during gas welding in confined and ill-ventilated spaces through incomplete combustion of acetylene (Britton & Walsh, 1940). The resulting symptoms might be influenced by some degree of oxygen lack. Some fatal cases have been attributed to carbon monoxide by observers on the Continent (Occupation & Health, 1932) but most of these are extremely doubtful and I think are more easily explained by nitric oxides. The following account (J. Am. Med. Ass. 1919) may be cited as an example. A man aged 34 years died on the fourth day after acetylene welding inside a large boiler. Post mortem examination was negative including blood spectroscopy for carbon monoxide. In spite of this the cause of death was attributed to carbon monoxide, the rapid disappearance of the gas from the blood being given as the reason for negative spectroscopic findings. Since commencing welding the man had complained of nausea and loss of appetite which were attributed to chronic carbon monoxide poisoning. Even more doubtful cases were described by Holtzmann (1928) and Ziemke (1933).

23. In regard to electric welding there would appear to be general agreement with one exception (Ræva & Karacharoff, 1936) that the risk of gassing from carbon monoxide is absent. Small amounts of carbon monoxide may possibly be formed when the rod coverings contain

carbonaceous material, but the concentrations of this gas never appear to rise near to the toxic level.

24. There is however an extrinsic source from which carbon monoxide fumes may be generated in some amounts to prove dangerous. This is paint or varnish containing bituminous or other form of carbonaceous substances which may cover the work. Schwartz (1929) describes circumstances involving the death of four men from this cause, several other men being partially overcome during attempts at rescue.

(iii) *Ozone*

25. Ozone is an intensely irritant gas with a delayed action like phosgene and nitric oxides. It is formed in very small quantities by the electric arc but is said by Britton & Walsh (1940) to dissociate rapidly into oxygen a few inches away from the arc. These observers quote several authorities for the conclusion that it does not offer a serious problem in welding, but mention that Druskin & Krasinskaja (1934) report that ozone may be present in amounts sufficient to be irritating. Flury (1939) on the other hand believes that ozone is of greater importance than nitric oxides in causing acute pulmonary effects.

(iv) *Other Gases*

26. Britton & Walsh (1940) and other writers mention the possibility of trouble arising from impurities in the acetylene such as arsenic, phosphine, phosphoric anhydride, hydrogen cyanide, acrolein, etc., but there would appear to be little definite evidence of actual cases of poisoning from these substances. Arsenic may also be present in the oxy-hydrogen flame, derived from impurities of the materials used for making hydrogen (Occupation & Health, 1932). As regards carbon dioxide there seems general agreement that this may be formed in only small amounts and never reaches dangerous levels. Britton & Walsh, however, make the interesting observation that its presence may, in ill-ventilated spaces, be sufficient to stimulate and deepen the respirations and so cause greater absorption of other gases present.

27. Fluorine, as fluorides, mainly of calcium, may occur in the coatings of some welding rods, as, for example those used in welding stainless steel or aluminium. Sander (1939) states that much of the fluorine comes off in the fume as silicon tetrafluoride and that such fume is more irritating than that from ordinary rods, but that no severe reactions have been met. He adds, however, that the U.S. Navy discourages the use of rods containing fluorides. Britton & Walsh (1940) do not comment on any health effect from fluorine, and while some articles in 1939 (de Balsac & Leroy; Molfino) suggested the possibility of injury to health, I am not aware of any reports of actual cases.

28. The possibility of anoxæmia resulting from depletion of the oxygen of the air by the welding arc has been raised. Viles & Silverman (1945b) deal with this point and show that even under the most extreme conditions of confined space work the oxygen consumption by the arc is low, and that heat production and nitric oxide concentration would limit the welder's exposure before the atmosphere would become deficient in oxygen.

29. In electric welding, apart from nitric oxides, and possibly carbon monoxide from volatilised carbonaceous covering material, no gases would appear to be evolved in important amounts.

(b) METAL FUME FEVER

30. This is one of the commonest specific diseases attributable to welding, and most welders who have worked on galvanized metal in poorly ventilated conditions can describe the symptoms which are, typically, the onset, after a delay period of a few hours, of shivering, pains in the limbs, headaches, tightness in the chest and pyrexia, then a fall in temperature accompanied by sweating. The worker is only comparatively rarely absent from work next day although he may experience nausea, chest pains and lassitude on the day following the attack.

Serious complications are unusual although the irritation to the respiratory system may sometimes be severe enough to be followed by pulmonary œdema and pneumonia as in the case described by Williman (1935) already mentioned. Quinn (1944) reports six cases of metal fume fever following welding of galvanized metal in confined spaces on board a cruiser. Two of these developed pulmonary œdema.

The subject of metal fume fever is known to be resistant to the causative fumes for a time following the attack and Drinker and his co-workers (Sturgis et al, 1927; Drinker et al, 1927a) have correlated this resistance with a leucocytosis which develops along with the fever but which persists for some twelve hours after the body temperature has returned to normal. They showed that exposure to high concentrations of fume during the period of persistance of the leucocytosis was successfully resisted.

31. Metal fume fever has long been known to occur in other industries particularly where zinc fume (zinc oxide) may be inhaled, such as brass founding. While zinc fume from welding galvanized metal, brass, etc., is the commonest cause of the condition in welders, fumes from other metals can produce the same symptoms, for example, antimony, cadmium, chrome, cobalt, copper, magnesium, manganese, mercury, nickel, silver, tin, etc. Welders working with any of these metals or their alloys might conceivably under certain conditions suffer from metal fume fever. Cases have even been reported from iron fume (Holstein, 1930; Schiotz, 1947) and from fine dust as well as fume, for example Friberg (1947) & Schiotz (1947) in regard to copper dust, Lindaas (1947) in regard to iron dust. Schiotz suggests that the condition should be termed "metal fever" rather than "metal fume fever". The condition is considered by the majority of investigators to be due to a protein reaction, following injury to the cells lining the respiratory tract by the inhaled metal fume. Kuh and his fellow workers (Kuh et al, 1946) however, suggest that it is caused by the absorption of bacterial endotoxins liberated in the lungs as the result of the killing of the micro organisms of the lower respiratory tract. They say the immunity is due to sterilisation and that it is lost when this area is again invaded by organisms from the upper respiratory tract. The theory is interesting but no proof is presented.

There are many references in the literature to metal fume fever amongst welders, and summaries and lists of references can be found in articles by Kœlsch (1923) who appears to have been first in propounding the theory of cell destruction and protein reaction as the cause, Britton and Walsh (1940) Drinker et al (1927b, 1927c), Sessions (1944) and others.

(c) OTHER ACUTE AND SUB-ACUTE EFFECTS

(i) *Discomfort*

32. Mention might here be made of the discomfort experienced by welders. This may be regarded as falling into three main categories —due to fumes, to excessive temperature, and to uncomfortable posture.

Other sources of irritation would include the multiple tiny burns from sparks especially when welding vertical or overhead seams. The fumes in enclosed spaces may cause acute irritative phenomena of the throat but these appear to be transitory reactions leaving no residual impairment (Sander, 1944). High temperatures may be met in welding in ill-ventilated compartments and Deutschmeister is quoted (Drinker, 1944) as finding temperatures reaching 30°C. during welding in a boiler. The amount of heat produced in thermal units is discussed by Viles & Silverman (1945b). I have not, however, seen any reports of welders being overcome by the heat, or suffering from heat cramps.

Apart from those who work at benches, it is suggested (Drinker, 1944) that welders spend about 75% of their working shift in a bent position. The work frequently necessitates particularly awkward working postures such as lying on the side and working in cramped positions on a large cold metal surface.

33. In regard to selection of workers for training as arc welders, interesting comments on the clinical and psychological qualities considered desirable are made by Themsche (1933), Oakley (1933) and Laugier, Kowarski & Weinberg (1937), and in regard to young persons the U.S. Children's Bureau (1943) lays down certain advisory standards regarding conditions of their employment.

(ii) *Catarrhal Infections; Pneumonia*

34. The reports regarding the incidence of colds, catarrh, bronchitis and pneumonia in welders are to some extent conflicting. Westhofen (1934) in a study of illness in 146 welders speaks of a high incidence of colds and lung inflammation and Tschauder (1942) in an analysis of the disorders of 300 electric arc welders, 230 gas welders and 1,000 metal workers finds throat affections, influenza, influenzal pneumonia, bronchial catarrh and pleurisy, muscular rheumatism and pulmonary tuberculosis highest in electric welders. Von Haam & Groom (1941) state that insurance statistics support a high incidence of pulmonary disease in welders despite discrepancies in the literature. Schœth (1933) too found that sickness rates for 119 welders and their mates were much higher than those relating to 11,000 other industrial workers, especially in regard to respiratory illness. He thought that, as welders work in winter in high draughty shops without much physical activity, and seated on cold metal, chills may be entirely responsible for the higher rates there being no evidence that fumes were the cause. More recently Waniek & Roosen (1944) found that the incidence of respiratory diseases in electric welders was higher than in autogenous welders, metal workers and foundry workers. Dreesen et al (1947) found inflammation of the nasal mucous membrane slightly more frequently in welders than non-welders but were not inclined to attach much significance to this. Pharyngitis was also found more frequently amongst welders in whom it tended to be more severe. Kœlsch (1941) referring to his examinations of 40 electric welders speaks of the high incidence of bronchitis.

35. On the other hand, Britton & Walsh (1940) found no excess of disability frequency rates in a study of 286 welders. Sander (1939) says that a previous susceptibility to colds has disappeared in many cases after starting welding. Gardner & McCrum (1942) found no increase in the incidence of pneumonia in several hundred workers exposed for five years or more to iron dust of a nature similar to that given off in welding fume (magnetic iron oxide in the form of sesquioxide). What would

appear to be very reliable evidence is given by Collen and his colleagues (1944) in a striking analysis of the incidence of pneumonia in 90,000 workers in the Kaiser Richmond Shipyards. He found a pneumonia frequency rate of 9.5 per thousand workers and that there was no indication that this was heavier in special occupations including welding (15,533 welders). In a later article Collen (1947) brings his analysis up to date (2794 consecutive cases of pneumonia in shipyard workers) and confirms his earlier findings saying that the annual incidence, death rates, and case fatality rates for welders were similar to all other shipyard workers, and that the cases were similar in severity, required the same number of days for treatment and showed no difference in the incidence of complications.

Chronic and Systemic Effects

(a) GENERAL HEALTH

36. Divergent views have been expressed as to the effects of welding on the general health. On the one hand complaints of ill-health in certain groups of welders notably those who work in very confined spaces or with special alloys are not uncommon. The main symptoms described include nausea, lassitude, sleepiness, upper respiratory and chest catarrh, headaches, etc. Molfino (1942) for instance, mentions these symptoms and others but says that it is not easy to find definitely and regularly occurring clinical pictures. Some authors give most prominence to the gastro-intestinal symptoms (Tallenberg, 1937; Waniek, 1938; de Laet & Wiser, 1939; Humperdinck, 1938; Rosing, 1941; Kny, 1942) and others to the respiratory troubles (Gramer, 1942; Westhofen, 1934; Tschauder, 1942; Jones & Lockhart, 1944; Pozzi, 1938; v. Haam & Groom, 1941). The evidence will be examined in more detail below but it must be remarked that many workers with considerable experience have failed to find evidence that welding contributes to impaired health. Lipkovitsch (1934) after observation of 123 welders says that the health of welders compares favourably with that of men in other trades. Britton & Walsh (1940) in a group of about 1,000 welders found no one disease entity outstanding and the disability frequency rate of welders was not in excess. They found that the diseases occurring in the welders did not differ from those occurring in a general group of workers and that special clinical syndromes in welders reported by others were not observed. Cranch & Vosburgh (1942) in their survey of 1943 state that there is no reliable evidence to show that welders have poorer health or accident records than others in the same environment, or that they show any characteristic type of illness and Ross & Drinker (1945) scorn the imaginary ailments due to welding fumes. Carter (1939) also reviewing the literature on welding hazards says that the most important source of risk to welders is exposure to the radiations from the arc (which of course have only local effects). Gengoux (1946) after examining 165 electric welders concluded that their general health was satisfactory but suggested further enquiry in regard to the incidence of peptic ulcer, and effects on the blood and the eyes.

(b) RESPIRATORY TRACT

37. Attention was first called to the occurence of x-ray changes in the lungs of electric arc welders in 1936 by Doig & McLaughlin, who found that of 16 electric welders employed for periods ranging from 6 to 16 years six showed a fine nodulation of the lung fields. They found few abnormal signs on clinical examination and emphasized that the x-ray appearances were found in men who were apparently in good health. They made further investigation of upwards of 100 welders in the following year but

delayed publication in the hope of obtaining an opportunity, which so far has not presented itself, for post mortem and histological investigation. Confirmation of the x-ray changes has been reported by many workers and the majority stress that the condition is not associated with disability.

38. Enzer & Sander (1938) found that 5 out of 26 welders of low carbon steel showed nodular shadows on the x-ray film " simulating a modified type of silicosis ". Most of these men had worked with bare electrodes with frequent work in enclosed spaces. There were no symptoms and blood counts were normal. In this article which is illustrated by excellent photomicrographs they describe the post-mortem appearances of one of their cases who showed x-ray changes and who died of pneumonia following fracture of the spine.

> Apart from lobar pneumonia in the left lung, both lungs showed a finely distributed black pigmentation throughout and there was no tuberculosis. On histological examination the lymph glands showed irregularly distributed pigment almost all of which was within large macrophages. In the lungs there was much amorphous pigment mainly in periarterial, but also in peribronchial lymphatic channels and in the alveolar septa. No fibrosis was found either in the glands or in the lung tissue; the blood vessels were not obliterated even where the pigment was most dense, and the walls were not thickened. Chemical analyses of two samples of the lungs showed 0.096 and 0.089 mg. of silica per 100 g. No quantitative analysis for iron was made but both in sections of the lungs and glands and in the residue left after microincineration the Prussian blue reaction for iron was obtained.

Enzer & Sander conclude that the radiographic appearances were caused by the deposition of iron oxide in the lungs resulting from inhalation of the welding fume, and point out the apparently inert nature of the pigment and the absence of functional impairment. The fact that this account, published in 1938, is the only one of a post-mortem examination, with histological study of the lungs of a welder who showed the characteristic radiographic changes during life is further evidence of the at least relative harmlessness of the condition.*

39. Sander (1944) stated that his incidence of films showing nodular shadows was 5% out of 500 workers, there being little confined work in the district. He reviewed in detail five cases watched since 1939, showing that with continued exposure there was a tendency for the shadows to increase but that symptoms referable to the condition remained absent. Britton & Walsh (1940) found 24 out of 286 welders with mottling of the x-ray films but in five of these the mottling was ascribed to causes other than occupation. This gives a rate of 6.6% for the remaining 19 men. They also found that the changes were not accompanied by disability. Kœlsch (1941) in 40 men using uncoated eletrodes found 3 with changes similar to first or second stage silicosis and in addition one with marked nodulation.

40. Gramer (1942) found 16 out of 100 welders radiologically examined showed slight variations from the normal. Although these resembled silicosis the author considered that they should be regarded only as " bronchopneumonic irritation ". Many of these had symptoms (cough 45% sputum 55%) but signs of bronchitis were present in less than 10%. Humperdinck (1942) describes one case in a 34 year old welder who had been using uncoated rods for 10 years. He found no cases amongst

* McLaughlin (1950) has now described the post mortem findings in a welder in a steel fettling shop who was exposed to silica dust from the castings being cleaned. He died of nephritis and cardiac failure but early silicosis was present along with siderosis.

welders using coated rods. The man he described was investigated in hospital, found to be in good general health and without symptoms and the author states that no question of compensation arises. Groh (1944) found the extraordinary incidence of 59 cases out of 83 showing fine nodulation in the x-ray films. The men were engaged welding jeep frames and gun mountings in a large workshop the various operations being separated by canvas screens 15′ apart. The average period at welding for those with slight nodulation was 8.5 years and more extensive nodulation 9.2 years compared with 6.7 years for those with normal lungs. He also found no disability and stated that arc welders siderosis was not a hazard to the health of the workman, but a menace to his mental stability if not interpreted correctly by the physician. Lanza (1945) states that welder's siderosis is a condition characterised by the deposition of iron pigment in the lymphatics of the lungs without proliferation of fibrous tissue, with no tendency to progressive change after exposure has ceased or to predispose to tuberculosis, symptomless and of little if any clinical significance.

41. There are few dissentients from this view that the x-ray changes are not associated with pulmonary fibrosis and impaired working efficiency. Killick (1938) made a small investigation on respiratory efficiency in a group of 11 electric welders. Five men who showed fine mottling of the x-ray film gave on the whole rather poorer performances than the other six. Jones & Lockhart (1944) mention the x-ray changes due to iron oxide and say that these exist without symptoms but also state that the fumes apart from acute effects, may lead to chronic bronchitis, pulmonary fibrosis, asthmatic wheezing, and eventually emphysema. We find it difficult to correlate these apparently opposing views. Brailsford (1938) paints a most alarming picture of electric welding saying that of a series examined in 1936 most showed some degree of (pulmonary) fibrosis with pleural adhesions and emphysema, and that the fibrosis not only leads to early death of the worker but may be preceded by six or more years of distressing dyspnœa. He cited no illustrative cases, post-mortem results, or other confirmatory evidence, and as has been shown, his findings are considerably at variance with those of other workers.

42. One of the most important studies on the physiological response of welders to exercise and other tests was carried out by Enzer, Simonson, & Evans (1945). Fifteen welders showing x-ray changes, along with a group of 10 foundry workers with silicosis were compared with a group of normal men in comparable age groups. The silicosis group showed significant depression of vital capacity, maximum pulmonary ventilation, relative pulmonary reserve and endurance in dynamic and static work, but no statistically significant difference was found between the normal group and the siderosis group (welders) in any function.

43. The above review relates to findings in electric arc welders. It would seem that pulmonary changes in oxy-acetylene welders are not nearly so commonly met with and there would appear to prevail an opinion in some quarters that they do not occur. Rosing (1941) for instance says that iron oxide is not found radiographically in the lungs of such workers. McLaughlin & Doig (unpublished results) found one definite and four suspicious cases in 13 oxy-acetylene welders who had never engaged in electric welding. The average exposure for the whole group was 13.6 years (highest 32 years lowest 2 years). The definite case, a man aged 58, had 27 years experience and the four suspicious cases an average of 17.25 years (highest 32 years lowest 6 years). The same workers found another definite

case showing x-ray changes of the inhalation type in a man aged 32, who had been an oxy-acetylene welder for 12 years and an electric welder for only six months. Waniek (1944) in 113 oxy-acetylene welders found 4 with exposures of 15 to 28 years, with x-ray shadows suggestive of pneumoconiosis. The blood picture, sedimentation rate, complement fixation tests for tuberculosis and respiratory function tests were all negative. None of the affected men showed any clinical signs of respiratory dysfunction and only two had a cough, and Waniek concludes that the findings did not warrant recognition as disability justifying compensation.

44. The question of predisposition to chronic pulmonary infection such as tuberculosis has not unnaturally received a good deal of attention. Pozzi (1938) postulates a clinical syndrome in welders with tuberculosis as a terminal complication but he does not present examples. Apart from this there would appear to be general agreement that neither the work of welding nor the occurrence of x-ray changes is associated with an increased predisposition to tuberculosis or a liability to the reactivation of old lesions. (Britton & Walsh, 1940; Fleischer et al, 1944; Groh, 1944; Jones & Lockhart, 1944). The last authors, however, state that persons with arrested tuberculosis may rapidly develop hæmoptyses when exposed to concentrated welding fumes such as occur in enclosed spaces. They cite six cases all of whom recovered after cessation of exposure and none of whom developed any spread of the tuberculosis process. Sander also (1944) describes the case of a man aged 43 who, after electric welding for 11 years, developed a tuberculous infiltration. The progress of this lesion was carefully watched and after definitely spreading for a time it began to retract during the second year, and 5 years after it was discovered it appeared to be well arrested and represented on the x-ray film only by a string-like opacity. This spontaneous arrest took place while the man continued to work at welding. Dreesen et al (1947) actually found tuberculosis more prevalent in their control group than in welders but consider that possibly selective factors were in operation, making it likely that persons who knew they had tuberculosis would choose a shipyard occupation other than welding.

In regard to the influence on tuberculosis already present careful experiments by Gardner & McCrum (1942) have shown that exposure to arc welding emanations is incapable of causing reactivation and spread of tuberculosis from pre-existing foci. They state that their animal experiments " offer striking evidence of the fallacy of the popular belief that pulmonary irritation per se is likely to favour the development of tuberculosis ". They find that free silica invariably does so, however.

45. An interesting though unusual illness in an electric welder aged 30 of 7 years experience was described by Nayer (1942). The amount of enclosed work done is not stated but the man was employed on shipbuilding construction and so may have had to work in ill-ventilated conditions. He suffered from ulceration of the right main bronchus and the author gives a full description of the clinical and bronchoscopic findings. The condition was attributed to exposure to welding fumes. No other similar cases have been reported, but some of the animals exposed to high concentrations of fumes in the experiments of v. Haam & Groom suffered from necrosis of the trachea in addition to acute infections and œdema of the lungs.

46. In regard to the dust produced by welding with three different types of rods Von Haam & Groom (1941) separated this by means of a thermal precipitator and circulated it, without gases and fumes in an animal cage. They say of this " the essential inertness of the dust could be proven by us

repeatedly by the finding of large deposits of brownish iron pigment in the lungs without any reaction whatever". (In connection with manganese pneumonitis it is to be noted that the dust in their experiments had a manganese content of 6.43 to 10.56%.) Harrold, Meek & McCord (1940) found no fibrotic changes or other pathology of a permanent nature in animals exposed to welding fumes. The same authors in another study (McCord, Harrold, Meek, 1941) showed that the iron pigment of welding fumes could undergo elimination from the lungs provided adequate lymphatic drainage existed.

Further evidence of the inertness of iron dust is given by the experiments of Næslund (1938, 1940), Harding (1945), Harding et al (1947)*, Titus, Warren & Drinker (1935), Miller & Sayers (1934), and Cappell (1930), while confirmatory clinical studies in man include the investigations of McLaughlin and his co-workers (1945) and of Barrie & Harding (1947) on silver finishers. Otto with his case of "ochre lung" (1939, a case of acute siderosis described by Bentzen (1933), a study of siderosis in iron grinders and turners by Buckell et al (1946), etc.

47. To summarise it may be said that the existence of a pneumoconiosis demonstrable radiologically in welders has been proved. The results of clinical examination and respiratory function tests and animal experiments do not indicate that this is associated with pulmonary fibrotic changes or disability, nor is there any increased liability to tuberculosis.

(c) GASTRO-INTESTINAL TRACT

48. As has been shown there exists amongst observers a high degree of agreement regarding the existence of a non-disabling and symptomless pneumoconiosis in welders, but opinion regarding interference with the function of the gastro-intestinal tract is divided. There exist several references in the literature to gastro-intestinal troubles, most of them of a subjective nature and many rather vague. References to specific affections are few. Humperdinck (1938) mentions that amongst 40 electric welders working in a poorly ventilated factory, complaints of stomach ache were especially common. Rosing (1941) found that absenteeism due to digestive troubles was three times greater in electric welders than in other workers at the Krupps steel works. Classifying by subjective symptoms he found 64 out of 410 electric welders (15.6%) suffering from severe gastro-intestinal disturbance (i.e. receiving hospital or ambulatory treatment) and 89 (21.7%) with slight disturbance, (never, or rarely, involving absenteeism). In 64 gas welders 6.25% were classed as having severe gastro-intestinal symptoms and 4.75% as slight. Like Humperdinck he tentatively suggests the inhalation of small amounts of manganese in the fume as the cause. De Læt & Wiser (1939) also note a predominance of gastro-intestinal symptoms with 11 complaints of dyspepsia in 14 welders. Thirteen were x-rayed and only one was considered to be normal, 7 were classed as having peri-duodenitis and 5 with peri-gastritis. They found two men had had treatment for ulceration (one medical and the other surgical—gastro-enterostomy) attributed by the sufferers to their occupation and on radiological and clinical evidence they presumed ulceration in a further 3 cases. Kny (1942) whose article is referred to late under "liver" (p.24) and Molfino (1942) also refer to dyspeptic symptoms including anorexia, bulimia, pain and nausea.

* Harding (1948) has reported a very small amount of fibrosis in one of his silver finishers, demonstrable only microscopically. He did not consider that it could have caused any disability and suggested that the subject may have been "unduly sensitive to the presence of inhaled iron oxide which is commonly inert"

49. The majority of writers including Britton & Walsh (1940), Lipkovitsch (1934), Cranch & Vosburgh (1942), Ross & Drinker (1945) however do not appear to have been impressed with the suggestion that welders suffer from dyspepsia to a greater extent than other workers. Tschauder (1942) carried out a statistical analysis on health disorders in 300 electric welders, 230 gas welders and 1,000 controls. The only essential difference in regard to gastro-intestinal disorders was in the incidence of chronic gastro-intestinal catarrh which was highest in gas welders.

The evidence regarding the effect of welding on the gastro-intestinal tract may be said to be equivocal.

50. Ferguson (1946) makes the interesting observation that disabled persons (mainly discharged from the forces) suffering from gastro-intestinal troubles did not do well when trained as welders. In a review 3 to 6 months after resettlement he found that a higher proportion of such persons trained as welders had given up the work than in those trained for other jobs. The same was true though to a less extent, of persons suffering from respiratory ailments, and it became the practice to advise against the training of dyspeptics and chest sufferers as welders. He had previously shown (1945) that as a rule gastric and duodenal ulcer patients did not do well at work involving much stooping.

(d) THE LIVER

51. Attention was first directed to the question of liver damage in welders by Tallenberg in 1937. He states that the effect of the absorption of heavy metals generally is to produce liver dysfunction. He investigated the liver function of 80 welders, 41 of whom used oxy-acetylene torch, 29 the electric arc, and 10 who used both methods. Blood cholesterin examinations were normal, leucopenia was absent, urobilingogen in the urine was found in only three cases, but 10 out of 63 men showed a deviation from normal of urinary porphyrin (7 with a small increase, 3 with a large increase). There were 12 positive Takata reactions in 70 examinations and galactose tests in 80 cases showed an excretion of over 3 gr. in 14 and over 2 gr. in 17. These disturbances were found equally in electric and oxy-acetylene welders. Apparently no observations were made on a control series of workers.

52. Waniek (1938) working from the same laboratory, reports confirmation of these results, re-examining 40 of Tallenberg's welders and adding 23 new cases. He submits graphs showing increasing proportions of workers exhibiting evidence of liver damage (based on galactose excretion) with increased length of service in welding. Nineteen of the 63 men examined showed disturbance of carbohydrate metabolism. Eleven of these who exhibited only a slight rise in the galactose excretion complained of loss of appetite, nausea, feeling of discomfort, depression, malaise, dislike of work and sleepiness, symptoms which he says are described by G. Bergman in his " Funktidnellen Pathologie " as characteristic of " latent liver trouble ". The remaining 8 patients with more marked disturbance of carbohydrate metabolism showed a different condition and detailed case notes of each are given. To summarise, he found diffuse enlargement of the thyroid, exophthalmos, slight tremor, active reflexes, pulse rate at upper limit of normality or slightly above, and slight lymphocytosis with symptoms of psychical variability, irritability, nervousness, large or small decreases of weight not remedied by additions to diet, sometimes diarrhœa, excessive perspiration and falling out of the hair. These symptoms and signs he attributes to hyperthyroidism.

53. In 1941 Waniek again described his findings and cited an illustrated case in detail. The man suffered from irritability, nervousness, sweating, headaches, sickness, loss of hair and loss of weight. On examination he was found to be thin, pale, rather pigmented, with a fine tremor and pronounced dermographism. Basal metabolism was increased and liver dysfunction was indicated by galactose tolerance test. This man was not a welder. He was a crane driver in a large welding shop for only 10 months, and one is inclined to think that the symptoms have been attributed to welding fumes on very slight evidence indeed.

54. Kny (1942) confirms the findings of Tallenberg and Waniek describing under the term " welder's disease " symptoms of anorexia, bulimia, spasmodic gastric pain, nausea, lassitude, nervous irritability, restlessness, excessive sweating, palpitation, falling out of the hair, insomnia and giddiness and occasionally decreased libido. The symptoms appear to be most severe and frequent in welders longest employed and in those employed in the " Arcatom " process in which wolfram electrodes are used. Evidence of liver dysfunction was provided by liver function tests which showed in some cases galactosuria, urobilinogenuria, porphyrinuria, positive Takata Ara reaction and adrenalin sensitivity. No relation was found between liver dysfunction and basal metabolism, and the blood picture was normal. Gramer (1942) found an increase of urobilinogen in the urine in 8.3% of 455 electric welders and de Laet & Wiser (1939) theoretically implicate the liver on the basis of their blood findings. Britton & Walsh say that clinical transient jaundice may arise, quoting an unpublished communication from G. A. Abbott relating to acetylene welders. This is attributed to phosphine which may be present in small amounts as an impurity of acetylene, and which is very toxic. J. Adler Herzmark (1939) describes chronic hepatic lesions in a worker engaged in zinc metallisation inside a large but ill-ventilated tank, which supervened on acute effects similar to gassing. The exact cause was not definitely established but phosphine, hydrogen sulphide, carbon monoxide and perhaps zinc were all considered under suspicion.

55. v. Haam & Groom (1941) produced liver damage in their experimental animals exposed to electric arc fumes of much higher concentration than met with in industry but as has been stated they were not impressed with the toxicity of welding products and assume the harmlessness of the fumes at industrial concentrations. McQuiddy et al (1938a) noted fatty changes in the livers of guinea pigs exposed to undiluted carbon arc fumes but these were associated with inflammatory changes in the respiratory tracts. The continental observers stress the toxity of heavy metals on the liver and attribute the changes they describe to the metallic products of the fumes. Tallenberg's animal experiments, however, were negative (1937). It is also interesting to note that Cappell (1930) found that, with intravenous injection of colloidal iron no ill-effects followed massive accumulation of iron in the liver cells.

(e) ENDOCRINE SYSTEM

56. Waniek's findings in regard to symptoms of hyperthyroidism have been described above (under Liver). As far as I know there is no confirmation of thyroid dysfunction by any other observers.

The question of the effect on the parathyroids has only once been raised in my knowledge. In connection with an electric welder aged 43 with chronic tetany it was asked in the J. Am. Med. Ass. (1945) whether the rays given off from the arc could have produced the effect. The answer very fully given stated that this would not be possible from the rays. The possi-

bility from other causes, e.g., unknown effects of electric fields in the neighbourhood of the arc, unknown effects of substances inhaled from the fume, e.g. fluorine, lead, could not be disproved but was unlikely, so that the emphasis was on the probability of coincidence

57. Many writers have dealt with the question of decreased libido and impotence and the matter seems to have caused unrest amoungst welders on the Continent, according to Gramer (1942) by the publication, by firms manufacturing leaded protective garments, of literature suggesting the danger from gamma rays in welding. It seems to have been proved definitely that no rays of wave length shorter than those included in the ultra violet group are produced by the arc (le Compte, 1940) so that the possibility of danger from this source is eliminated. Whether or not there are changes in the sex organs due to other causes has not been definitely established, but there does not seem any evidence of this; and Waniek (1938) and Sessions (1944) find no supporting evidence.

(f) CARDIO-VASCULAR SYSTEM

58. Dreesen et al (1947) found that arterio-sclerotic hypertensive disease was about three times more prevalent in their non-welding control group than in the welders, probably because of selection of jobs by such persons, welders requiring to exercise agility and indulge in comparatively strenuous activity on shipways. Electrocardiographic records on 35 welders and 23 non-welders showed no differences.

59. Blood pressure readings in welders were slightly lower than in the control group. This was most marked in the first year of employment as a welder. They suggest that it may be due to the nitrogen oxides which on absorption give rise to sodium nitrite in the body.

(g) HÆMOPOIETIC SYSTEM

60. There have been no marked or constant blood changes noticed in welders. Methæmoglobin considered due to nitrous fumes has been found in animal experiments and in welders (McCord et al, 1941; McQuiddy et al, 1938a; Harrold, 1942). McCord, Harrold & Meek found average values of 2.5% in humans (no value over 3%) even after exposures to as little as 13 p.p.m. In animal experiments v. Haam & Groom (1941) found no effect on the red cells or hæmoglobin but a characteristic response of the white cells—an initial drop in the count followed by a rise often exceeding the normal. McQuiddy and his co-workers (McQuiddy et al, 1938a; Tollmann et al 1941) also found an increased polymorphic leucocyte count without uniform changes in the red cells and hæmoglobin in animals exposed to carbon arc fumes. They attribute this to pulmonary irritation. They also found increased non-protein nitrogen in the blood. Fleming (1945) found an elevation in the blood platelet count in dogs in which exposure to nitric gases was sufficient to cause pulmonary irritation, and also in a human case in which pulmonary œdema developed. Dreesen et al (1947) found hæmoglobin values almost identical in welders and in the control group. Stippled cell counts and measurements of cell volume were also similar and smears showed an absence of nucleated cells. Blood sedimentation rates showed only minor differences with the exception of those exposed to zinc fumes who had somewhat increased rates. Differential white cell counts were practically normal, with a very slight increase in the number of young polymorphs in welders, possibly associated with the slight upper respiratory symptom complex (slight pharyngitis and inflammation of the nasal mucous membrane). No record is given by these observers of total white cell counts.

In arc welders Lipkovitsch (1934) quoted by Titus et al (1935), and Kny (1942) have found a normal blood picture but polycythæmia and leucocytosis have been found (Gramer, 1942; de Laet & Wiser 1939). Gengoux (1946) found a high monocyte count in electric arc welders, but this was not related to length of service.

61. Occasional cases of disease of the hæmopoietic system have been described by different writers, some of whom have attributed them to welding. Such cases are probably of little significance, for with welding such a widespread and common occupation as it is, the paucity of such reports, and the fact that they relate to a variety of blood diseases and not to any one type suggest that they occur in no higher proportion in welders than in the general population. Pierquin et al (1942) talk of "welders' hæmopathies", and describe a fatal case of leukæmia in a welder aged 39 with 11 years experience, and a fellow worker of his who suffered from bleeding gums and showed polycythæmia and an abnormal differential count. Hodgkin's Disease has been associated with the occupation by Ledoux (1937) and Chavigny (1937), the latter stating that the occupation might be regarded medicolegally as causative. Nickum (1934) reports a case of aplastic anæmia in a welder and suggests a doubtful causal relationship.

(h) NERVOUS SYSTEM

62. The literature contains few references to effects on the central or peripheral nervous system, and Feil (1946b) says that disturbances of these systems are no more frequent in welders than in other persons. Gerbis (1928) reported facial palsy in acetylene welders in 1938, ascribing it to impurities in the acetylene. There has been no confirmatory evidence of this. Humperdinck (1938) describes the results of examinations of 40 electric welders in a poorly ventilated factory. In addition to other symptoms including stomachache and loss of weight he found increased irritability to mechanical stimuli, increased sensitivity to autonomic stimuli and occasional positive Romberg's sign. Although there was 15 to 23% manganese in the electrode coverings he did not find any definite symptoms of manganese poisoning. De Laet & Wiser (1939) mention subjective phenomena such as sleepiness, headache, nervousness.

(j) RHEUMATISM

63. There is little evidence of excessive incidence of this type of illness in electric or oxy-acetylene welders. Tschauder (1942) seems to be the only writer who reports an increase, saying that rheumatism is prominent in electric welders as compared with acetylene welders and non-welding controls. Gramer (1942) analysing symptoms of 455 welders found that rheumatism showed the lowest incidence.

Specific Intoxications

64. Apart from cases of gassing, metal fume fever, etc., already discussed certain specific intoxications may arise in welding, chiefly from breathing fumes containing poisons derived from the metal or electrodes, or their coverings.

(a) LEAD

65. Lead poisoning is probably the best known of the specific risks. As has been shown in the Annual Reports of H.M. Chief Inspector of Factories 1921-39 and 1945-48, the burning and welding of lead painted metal carried the highest risk of lead poisoning of any trade. The subject has been very

fully dealt with in the general literature (Occupation & Health, 1932; Tabershaw et al, 1942; Brown, 1926; Ferguson, A. E. & T., 1934; Sessions, 1934, etc.), and will not be further dealt with here. In recent years the risk from welding or cutting lead alloy steel has become apparent (Halley & Dudley, 1940; Halley, 1941).

(b) MANGANESE

66. Manganese poisoning is rare in welders but has occurred when alloy steel containing manganese is welded in confined spaces. Two such cases are known to the Department one of which was reported by Bridge in 1943. The frequently quoted cases described by Beinkter (1932) are not particularly convincing.

(c) MERCURY

67. A case of acute mercury poisoning due to 15 minutes exposure to fume during the brazing of a patch on a small copper cylinder the inside of which had been contaminated with volatilised mercury, is known to the Department. The exposure to fume resulted a few hours later in a sharp attack of metal fume fever which was followed by undoubted symptoms of mercury poisoning.

(d) CADMIUM

68. Exposure to fumes containing cadmium have resulted in the typical symptoms of industrial cadmium poisoning, consisting of severe irritation of the respiratory tract tending to be followed by pneumonia, pulmonary œdema and bronchitis. The symptoms are like those of metal fume fever but tend to be more marked and prolonged with a greater tendency for serious complications to arise. Two cases in welders working with electrodes containing 1/50 ounce in each rod are described in the Annual Report of H.M. Chief Inspector of Factories for 1931. Prodan (1942) mentions welding of cadmium alloys as having a high degree of risk of cadmium poisoning.

(e) SILICA AND ASBESTOS

69(a). The rod coatings usually contain silicates, of which asbestos is one form, and although free silica is almost always absent in any but very small amounts, there has been speculation as to whether welding gives rise to any risk of silicosis or asbestosis. Doig & McLaughlin discussed this point in their first paper in 1936. Certainly some fume analyses have shown relatively high amounts of silica. Case & Castrop (1940) found 8-15%, von Haam & Groom 1.4-15.9%, Drinker & Nelson (1944) 10-30%, and Dreesen et al (1947), in an average of 1,765 samples, found the silica content approximately 8%. Most of it however exists in the combined state and Tebbens & Drinker (1941) showed by chemical tests and x-ray diffraction that free quartz was absent. Animal experiments regarding the possibility of toxicity of the dust by inhalation and intraperitoneal injection have been negative (McCord et al (1941); v. Haam & Groom (1941)). On theoretical grounds too the existence of free silica in the fume seems most unlikely. Free silica begins to vapourise about 1,750°C. and boils at atmospheric pressure at 2,230°C. At this and the higher temperatures of the welding arc there would be no tendency for silicates to decompose; rather the reverse and for any free silica that might be present to combine with oxides also present in the coating to form silicates, or with metal to form silicides.

So far as is known there have been no reports in the literature of cases of silicosis or asbestosis due to welding and it is generally agreed that there is no practical threat of development of these diseases from the fume. Welding near a source of silica would naturally constitute a possible hazard and in most fettling shops in steel foundries one or more welders may be employed.

The air of such places is known to contain free silica arising from the castings being cleaned and so in such places a risk of "modified silicosis" may be said to exist. McLaughlin (1950) reports the finding of early nodular silicosis along with siderosis in a carbon arc welder employed for 34½ years in the fettling shop of a steel foundry.

(f) BERYLLIUM

69(b). So far there has been only one report, that of Aub & Grier (1949), of an association between welding and beryllium poisoning. Two men, employed cutting beryllium sheets on an abrasive wheel and welding them with the electric arc in an atmosphere of helium, developed pneumonitis, attributed to the beryllium. There was no adequate dust or fume removal. Many beryllium alloys have very valuable properties and are being increasingly used in industry, for example beryllium copper and beryllium steel. It is possible, therefore, that the manufacture of articles of beryllium and its alloys may give rise to an important risk to the health of welders. It seems certain that the welding and burning of such metals should be performed only when adequate means have been provided for removing the fumes produced.

(g) IRRITATING FUMES

70. Fumes arising from the welding of certain alloys or metals coated with paint or other coverings frequently give rise to irritation of the upper respiratory tract. The noxious agents may be the fumes arising from painted or varnished surfaces, or from oil on the surface (acrolein); fluorides and even occasionally bromide from the rod coverings or fluxes, and chromium, vanadium, and other substances from the electrodes themselves or parent metal. So far as I can ascertain no specific case of poisoning due to these substances has occurred, the irritation being temporary and generally rapidly passing off.

71. Impurities in acetylene have been blamed for cases of illness on the Continent and elsewhere. These include arsine and phosphine and in a case described by Adler Herzmark (1939) there would appear to be considerable evidence that these substances, which were found to be present on analysis, precipitated the illness of a man who suffered from an acute hepatitis. This man, a welder, was not however welding at the time, but was using an oxy-acetylene torch in metallising, with zinc ribbon, the inside of a tank. In addition to containing arsine and phosphorous compounds, impure acetylene may contain sulphur and tellurium. Acetylene itself has been implicated, or carbon monoxide from its incomplete combustion, but as most of the cases described have suffered from acute pulmonary symptoms it seems to me more likely that they have been due to nitric oxides.

Ionisation

72. Ryazanoff (1936) made a number of estimations of the amount of ionisation in the atmosphere surrounding the arc during electric welding at three factories in Leningrad. He found the concentration of ions to be 10 to 15 times more than the normal. The number of negative ions (which he says have a favourable influence on the organism according to F. Dessauer) were found to exceed the positive ones. Tschjevsky (1939) also showed a very high degree of ionisation in the air at one metre from the arc. He mentions the work of Yaglou et al at Harvard in showing that such high ion concentrations had effect on metabolism, blood pressure, and pulse rate and who held it to be responsible for physiological changes.

The effects of breathing and living in a highly ionised atmosphere are insufficiently known at present. There is obviously a large field for research. However, the more recent literature on the health of welders has not shown that observers tend to attribute any important ill-effects to ionisation in welders, nor have any reports of ill-effects in other occupations exposing workmen to the effects of strong electrical fields been noted.

73. In this review of the literature an attempt has been made to deal with all the major and usual health hazards of welding for it is practically impossible to cover all the risks. From time to time owing to varying conditions of work, various hazards will be met with not here mentioned. Who for instance would expect to meet with carbon tetrachloride poisoning in a welder? Such a case is described by Corcoran et al (1943), an acute attack following the welding of a petrol tank into which carbon tetrachloride was sprayed from time to time to prevent explosion. Less obvious risks arise on occasion. With new developments the complexity of the process will increase as new materials, some no doubt with toxic potentialities, are used, and it is essential that persons in charge of welding processes shall constantly be on the alert to appreciate possible hazards and instal necessary safety measures.

CLINICAL INVESTIGATION

(A. T. Doig)

Material Under Review

74. The group examined consisted of 249 persons, all males. Of these 245 were welders and two had previously been welders, one being at the time of the investigation a storeman and the other an electrician's mate. The remaining two persons were welding shop foremen who had been exposed to the fumes in the welding shops for many years but had never themselves performed welding. The results of the examination of these foremen are dealt with in a separate paragraph, so that the following analysis relates to 247 men, i.e. the 245 welders and the 2 men who were previously welders.

In general the only attempt at selection was on account of welding experience, it being considered more valuable to concentrate mainly on welders who had several years experience rather than those with only one or two years. Certain men were selected because they had performed a considerable amount of enclosed work, others because they had considerable experience of some special type of welding, for instance of high manganese steel. At one factory a number of men were specially chosen for examination because 10 years previously they had been examined and x-rayed by myself and Dr. McLaughlin and it was felt that their re-examination would be of interest. No men were selected either because they were thought to have good health or bad health. The usual method was to have a list prepared of all welders in the factory with over 6 years experience and to examine a number of them, either in alphabetical progression or in descending order of their experience. When the number of welders with this experience was insufficient at any factory the numbers were made up with men with less experience and a sprinkling of men with short experience, 1-3 years were included mainly to hear their opinions on the work and on their health after a short experience.

75. The examinations were conducted in private, the managements concerned co-operating in providing suitable facilities. The object of the enquiry and the confidential nature of the results of the examination were explained to each man, and with the exception of one man suffering from hyperthyroidism their acquiescence in undergoing the examination was readily obtained. The

result of each examination was recorded on a form drawn up for the purpose, a copy of which is given below :—

EXAMINATION SHEET—WELDERS No.....

1. Occupation Duration

2. Factory Industry

Name of employee Age

Address

Date Panel Dr.

---

3. Occupation 1. History

Summary EW /OAW /CAW /

2. *Protection* Goggles Screens

Overalls Gloves Boots

3. *Ventilation of* usual work

4. *Other*

---

4. *Health History*

1. Family

2. Past : Before Welding
While Welding

3. Present :

Influence of work

---

5. *Examination*

1. General Condition

2. Skin : Previous
Present

3. Eyes : Previous
Present

4. Throat : Previous Teeth
Present

5. Nose : Catarrh
6. Lungs : Symptoms
   Examination
7. Heart :

   P.R.
8. Abdomen : Symptoms
   Examination
9. Muscular
10. Nervous
11. Other.

    B.P.

    E.T.

The results of special examinations such as x-ray examinations of the chests, or blood examinations, were entered on the back of the form.

Age and Welding Experience

76. The average age of the group is 34 years; highest - 62, lowest - 17. The age distribution is shown in Table I.

TABLE I

AGE DISTRIBUTION – ALL WELDERS

Under 20	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	Over 60
2	40	47	55	44	24	15	11	5	4

The average length of welding experience of these men was 12.7 years (highest 37 years, lowest 1 year). Table II shows the distribution according to welding experience. It will be seen that 155 (62.8%) had over 10 years experience, and 235 (95.1%) over 5 years experience.

TABLE II

WELDING EXPERIENCE – ALL WELDERS

Under 5	5-9	10-14	15-19	20-24	25-29	30-34	Over 35 years
12	80	77	38	19	11	9	1

77. In this report the welders are divided into three classes for separate consideration, electric welders, gas welders (mainly oxy-acetylene welders) and a group who have done both types of welding called mixed welders. Quite a number of men have been engaged in both electric and gas welding but in many cases one of these jobs has predominated to such an extent that the other assumes a minor importance, and for classification purposes can be neglected. Accordingly the purely arbitrary proportion of 7 to 1 has been adopted for classification purposes ; i.e. a welder has been included in the electric, or gas

class if he has performed more than $\frac{7}{8}$ths of his total work in one or other of these classes of work. If less than $\frac{7}{8}$ths has been performed as an electric welder or gas welder he is classed in the mixed group. According to this classification there were 183 electric welders, 39 gas welders and 25 mixed welders.

78. The electric welders comprise a younger age group with shorter welding experience than the gas welders. The average age of electric welders is 32.1 years (highest 62, lowest 17) and the average welding experience 11.4 years (highest 37, lowest 1). The age distribution and welding experience in 5 year periods are shown in Tables III and IV.

TABLE III

AGE DISTRIBUTION – ELECTRIC WELDERS

Under 20	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	Over 60
2	35	39	45	34	12	8	5	1	2

TABLE IV

WELDING EXPERIENCE – ELECTRIC WELDERS

Under 5	5-9	10-14	15-19	20-24	25-29	30-34	Over 35
8	71	64	23	9	5	2	1

79. The 39 gas welders include a number of men who were wholly or partially employed as burners. The main technical difference between gas welding and burning is that in gas burning use is made of an additional jet of oxygen, hence a greater production of iron oxide might be anticipated. There are no indications in the literature of any great difference as regards health hazards between gas welders and burners and in this report no differentiation is made. For record purposes however, the group contains 26 men who were principally or solely engaged in gas welding, 10 who were principally or solely engaged in gas burning, and 3 who were substantially engaged in both processes.

The average age of the gas welders is 40.3 years (highest 62, lowest 26) and their average welding experience is 17.8 years (highest 34, lowest 2). This information is analysed in Tables V and VI.

TABLE V

AGE DISTRIBUTION – GAS WELDERS

Under 20	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	Over 60
—	4	5	5	5	6	6	3	4	1

TABLE VI

WELDING EXPERIENCE – GAS WELDERS

Under 5	5-9	10-14	15-19	20-24	25-29	30-34	Over 35
4	3	7	6	9	5	5	—

80. The 25 mixed welders have an average age of 37 years (highest 61, lowest 23) and an average welding experience of 14.5 years (highest 32, lowest 5). This group has performed rather more electric welding than gas welding in the proportion of 9.4 years to 5.1 years. Their age distribution is shown in Table VII.

TABLE VII

AGE DISTRIBUTION – MIXED WELDERS

Under 20	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	Over 60
—	1	2	5	7	6	—	3	—	1

Type of Work Performed

81. In order to make the group as representative as possible, welders were examined in different factories engaged in different industries and situated in different parts of the country. Altogether examinations took place at 16 firms, and Table VIII shows the classification of the firms concerned according to industry, and also gives the number of men examined in each group and their average age and welding experience.

TABLE VIII

INDUSTRIES – AGE AND EMPLOYMENT

Industry	No. of Factories	No. of Welders Examined	Average Age (Years)	Average welding experience (Years)
Light Engineering	1	10	35.3	11.3
Structural Engineering	2	18	30.7	8.9
Mfr. of Steel Tubes	1	30	38.4	15.1
Heavy Engineering	1	17	43.7	16.6
Boiler and Tank Makers ...	2	18	39.1	13.3
Boiler Makers and Engineering ...	2	50	35.1	14.2
Locomotive Building and Repair	2	20	38.6	15.8
Shipbuilding	5	84	29.4	10.2

Table VIIIA shows the number of electric, gas and mixed welders examined in each industry.

TABLE VIIIA

INDUSTRIES – TYPE OF WELDING

Industry	Electric Welding	Gas Welding	Mixed	Total
Light Engineering	10	—	—	10
Structural Engineering	15	—	3	18
Steel Tube Manufacture	12	15	3	30
Heavy Engineering	14	1	2	17
Boilers and Tanks	12	2	4	18
Boilers and Engineering	37	9	4	50
Loco Building and Repair	11	4	5	20
Shipbuilding	72	8	4	84

Metals Welded

82. The analysis of the work performed by the 247 welders presents some difficulty owing to the variety of work done and to the intermingling of special work for short periods. All the men have worked on uncoated mild steel for some part of their welding career, and for the majority this type of work has greatly predominated so that other work, such as the welding of aluminium, brass, or coated steel has often been in the nature of special work done in short periods of an hour or two or a day or two at a time. Even in the case of workers with a good memory, and memory is unreliable for remote events, it is no easy matter to assess accurately the proportion of time a man has spent on various jobs. In dealing with a group a rough idea is the best that can be obtained. Subject to these considerations Table IX is presented to show the approximate proportion of welders who are estimated to have spent 95% or more of their time on uncoated mild steel work and over 5% on other types of work.

TABLE IX

TYPE OF WORK – METALS WELDED

	Electric Welding	Gas Welding	Mixed	Total
Uncoated Mild Steel: 95% or more	115	30	22	167
Nickel Chrome Stainless High Tensile } Steels: more than 5% ...	18	—	—	18
Cast Iron: more than 5%	—	1	—	1
Galvanized Metal: more than 5%	15	1	—	16
Painted Metal: more than 5%	27	1	—	28
Brass: more than 5%	5	2	—	7
Armour Steel: more than 5%	1	—	1	2
High Manganese Steel (12 - 14% manganese): more than 5% ...	12	1	1	14

It will be noticed that the totals obtained by adding the numbers in each column do not agree with the total number of welders in each group; for instance there are 183 electric welders, yet the total in Table IX is 193. The explanation is that some welders have performed more than 5% of more than one type of special work and so are included in the table in two or more groups; others who have performed less than 95% of uncoated mild steel welding have not performed 5% of work at any of the special types and so are not included in the table at all.

83. A further analysis of the work performed, by estimating the number of welders who have performed 25% or more of their work on coated steel or special alloys, is shown on Table X.

TABLE X

TYPE OF WORK

	Electric Welding	Gas Welding	Mixed	Total
Nickel Chrome Steel, Stainless Steel, High Tensile Steel } 25% or more	5(1)	—	—	5(1)
Galvanized metal: 25% or more	3(?1)	—	—	3(?1)
Painted Metal: 25% or more	6	3	—	9
Cast Iron: 25% or more	—	1(1)	—	1(1)
mour Steel: 25% or more	1	—	1	2
gh Manganese Steel (12 - 14% Mn): 25% or more	11(10)	1(1)	1(1)	13(12)

The figures in brackets relate to the number of welders estimated to have performed over 50% of their work in the category shown. It will be seen that 12 out of the 13 high manganese steel welders are so classified. Some of these men have worked on high manganese steel for over 90% of their time for years. Similar though less intensive histories are given by welders who have worked with galvanized metal,—some of whom had been practically full time on this kind of work for periods of 1 to 3 years, yet their overall experience was more than 25% in only 3 cases. The figure 15 (Table IX) relating to welders with 5% or more experience in galvanized work seems low and it is probable that the true number should be much higher.

Carbon Arc and Bare Rod Electric Arc Welding

84. Carbon arc welding had been performed by 26 men, but four had had less than 6 months experience. The average ages and duration of employment of the remaining 22 men are shown in Table XI.

TABLE XI

CARBON ARC WELDERS : AVERAGE AGE & DURATION OF EMPLOYMENT

	Highest	Lowest	Average
22 *Carbon Arc Welders*			
Age	62 years	18 years	42.4 years
Total Welding Experience	34 years	8 years	18.5 years
Carbon Arc Welding Experience ...	20 years	½ year	5.5 years

Electric welding using uncovered electrodes had been performed by 29 men but 4 of them had used them for less than 6 months. Table XII shows the average age and duration of employment of the remaining men in this group.

TABLE XII

BARE ROD WELDING: AGES & DURATION OF EMPLOYMENT

	Highest	Lowest	Average
25 *Welders*			
Age	62 years	27 years	43.9 years
Total Welding Experience	34 years	5 years	18.3 years
Bare Wire Welding Experience ...	18 years	½ year	5.3 years

It will be seen that both the carbon arc welders and the bare rod welders have considerably higher total welding experience, and age average than the whole group examined. These types of welding are being displaced by the method of using covered rods and consequently it is mainly in the older group that they are found now. It is also to be noted that 13 of the 22 carbon arc welders and 15 of the 25 bare wire welders were employed at the same factory, a firm engaged in heavy engineering in which a large amount of high manganese steel (12-14%) was welded. The welding of this type of steel in this factory is to a large extent carried out with bare rods.

Work in Confined Spaces

85. The amount of work done in enclosed and ill-ventilated spaces is important but it is difficult to assess. Detailed occupational histories regarding this aspect are often complicated, dealing with intermittent spells on different types of work, and the accounts given by the welders are often incomplete and vague owing to blunting of the memory. Further, there is no clear cut definition of what is confined work, for the work varies from completely open work done in the open air or on the floor of a large shop, through degrees of partially enclosed work to work that can be called totally enclosed. Welding inside open tubes, gun mountings, prefabrication of ships' parts, etc., are examples of partially enclosed work, and work inside tanks, boilers, boom defence buoys, and the cofferdams, chain lockers, bilge tanks, asdic compartment, and double bottoms of ships, offer examples of work that is often totally enclosed.

The cases have been classified according to whether they have performed "no significant amount", "small amount", or "substantial amount" of enclosed work. As an arbitrary index of what is a "substantial" amount the figure of 100 representing work for a year in enclosed spaces has been taken, e.g. a man who has performed 50% of his work for 2 years, or 25% of his work for 4 years in enclosed spaces would be included. "Small amounts" of enclosed work relates to intermittent or regular work in totally enclosed spaces in which the index figure arrived at by multiplying the years

of service by the percentage of enclosed work is less than 100, e.g. 5% enclosed work for 10 years; or to work which is only partially enclosed. It will be agreed that personal judgment has to be relied on to a considerable extent in this classification.

Of the 247 welders, 120 have performed substantial amounts, and 45 have performed small amounts, of enclosed work. The figures are further analysed in the following table, those in brackets relating to workers in shipyards.

TABLE XIII

ENCLOSED WORK

	Electric Welding	Gas Welding	Mixed	Total
No significant amount	52(1)	22	9	83
Small amount	25	10(2)	9	44
Substantial amount	106(72)	7(6)	7(3)	120

It will be seen that, except for 1 electric welder and 2 gas welders, all the shipyard welders have performed substantial amounts of enclosed work.

Medical Examinations

(a) OCCUPATIONAL HISTORY

86. Of the 247 men, 121 had done no work other than welding since attaining the age of 18 years, 102 had done other work of a non-dusty nature, and the remaining 24 had performed dusty work.

TABLE XIV

OCCUPATIONAL HISTORY

	Electric Welding	Gas Welding	Mixed	Total
No other work after 18 years of age ...	95	17	9	121
Other non-dusty work	74	17	11	102
Dusty work	14	5	5	24

Details of the cases who had performed dusty work are as follows :—

TABLE XV

Previous Dusty Occupations

Electric Welders

Case	Age	Welding Experience	Previous Dusty Work
5	37	10	Fettler 5 years (Iron foundry)
42	34	12	Coal miner 3 years
43	39	17	Steel Works moulder 5 years
78	42	5	Steel melting and rolling 15 years
125	62	37	Grinder 2 years
126	54	26	Wet grinder (sandstone) 8 years
127	52	16	Fettling shop labourer 10 years (mostly outside) in steel foundry
131	43	8	Fettling shop labourer 2 years (steel foundry) Wet grinder (sandstone) 2 years
132	61	10	Steel fettler 25 years (hand tools)
134	42	11	Steel fettler 15 years (hand tools)
140	38	13	Coal miner 4 years ; grinding shop labourer 5 years
151	49	25	Coal miner 10 years
161	33	8	Steel grinder 2 years
167	30	7	Coal miner 6 years

Gas Welders

Case	Age	Welding Experience	Previous Dusty Work
10	59	30	Ironstone miner 14 years
47	62	27	Stone-cutter 9 years
51	57	20	Coal miner 2 years
156	56	20	Blacksmith 18 years

Mixed Welders

Case	Age	Welding Experience*	Previous Dusty Work
60	42	17(12/5)	Labourer, metal works 8 years
73	39	8(5/3)	Iron moulder 3 ; coal miner 4 years
115	42	15(8/7)	Coal miner 6 years
141	43	5(3/2)	Coal miner 9 years
165	34	15(12/3)	Iron moulder 3 years

* Figures in brackets relate to years spent in electric and gas welding, e.g. 12/5 means electric welding 12 years, gas welding 5 years.

(b) FAMILY HISTORY

87. This was taken in detail in 104 cases. It did not appear to warrant continuance nor is it considered of sufficient importance for analysis.

(c) PAST HISTORY

88. The following information relates only to illnesses that occurred after the worker had commenced work as a welder. Childhood illnesses and illnesses suffered in previous occupations are omitted.

TABLE XVI

ILLNESSES DURING WELDING EXPERIENCE

	Electric Welding	Gas Welding	Mixed	Total
No serious illnesses or operations ...	104	24	17	145
*Operations**				
Hernia	5	—	—	5
Appendicitis	11	—	—	11
Gastric (Duod.) Ulcer	1	2	—	3
Tonsillectomy	5	1	—	6
Respiratory				
Bronchitis	9	2	1	12
Pneumonia	7+?1	1	2	10+?1
Pleurisy	7+?1	1	?1	8+?2
Tuberculosis	1	—	—	1
Gastric				
Gastritis, Indigestion‡	10	1	4	15
Gast. or Duod. Ulcer	7	1	1	9
Rheumatic				
Acute Rheumatic Fever	3	1	—	4
Chronic Arthritis	2	3	—	5
Myalgia, Neuritis	12	1	—	13
Other				
Kidney	5+?1	—	—	5+?1
High Blood Pressure	1	—	—	1
Cardiac	—	2	1	3
Erysipelas	—	—	1	1
Thyroid	1	1	—	2
Tonsillitis	1	1	—	2
Nervous Disability	1	—	—	1
Cholecystitis	1	—	—	1
Nitric Oxide Gassing	—	1	—	1
	201+?3†	43†	24+?1†	258+?4†

* Excluding operations on nose, foot, hæmorrhoids.

‡ Excluding persons having only one single isolated attack.

† These totals are larger than the number of men examined because some individuals gave a history of two or more illnesses.

This table does not appear to present information of an unduly high incidence of illness, 145 out of a total of 247 having had no serious illness or operation over an average period of 11.6 years. With the possible exception of respiratory ailments, it does not seem that the incidence in any one class is higher than that would be expected in any similar group of workmen.

89. The incidence of chest ailments is considered to be especially reliable as far as the workers themselves can recollect, because each man was asked specifically whether he had suffered from pneumonia or pleurisy or bronchitis. The group represents 34 persons of whom there is some doubt about three.†† Two persons appear twice in the group of respiratory ailments, case 103 (age 46 with 24 years experience) having had pleurisy 6 years previously and bronchitis and influenza three years previously, and case 186 (age 22 with 7 years experience) having had three attacks of pleurisy since he started welding, at ages 16, 18, and 22, also occasional attacks of bronchitis.

Of the 12 bronchitis cases six had had only one attack necessitating loss of time varying from one week to six weeks; one had had bronchitis on two occasions with one week off work each time, and the other five had had several attacks.

There did not appear to be any relationship between the time of onset of pneumonia or pleurisy in relation to the amount of welding experience as shown in the following table which includes the suspected and doubtful cases.

TABLE XVII

Pneumonia & Pleurisy Onset

	1st Year	2nd to 5th Year	6th to 10th Year	After 10 Years
Pleurisy	—	3	1	6
Pneumonia ...	3	1*	3†	4

In this table the case marked * was one in which the pneumonia complicated an accident which involved a fractured spine, and one of the cases in the group marked † had had pneumonia previously in childhood. In four cases, two in the pleurisy group and two in the pneumonia group there was more than one attack, and the cases are classified as at the date of the first attack only. These four cases all occurred in shipyard workers.

†† Case 118, aged 31 with 10 years welding experience could not recollect whether his single attack of pneumonia 10 years ago took place before or after he had begun to weld; Case 60, aged 42 with 17 years experience, was off work for 3½ weeks five years previously with suspected pleurisy, and case 189, aged 22 with 7 years experience was off work for 2 weeks four years ago with " pains in the back and all over his body ", which he also thought was due to pleurisy.

90. In this small series the shipyard workers have a higher ratio of pleurisy and pneumonia. In Table XVIII each attack of pneumonia and pleurisy is recorded. This was impossible in regard to bronchitis. The attack rate in shipyard workers is seen to be appreciably higher than in non-shipyard workers.

TABLE XVIII

RESPIRATORY DISEASES: INCIDENCE IN SHIPYARD WORKERS

	84 Shipyard Welders		163 Non-Shipyard Welders	
	Cases	Attacks	Cases	Attacks
Bronchitis	3 (3.6%)	—	9 (5.5%)	—
Pleurisy	5 (5.9%)	8 (9.5%)	5 (3.1%)	5 (3.1%)
Pneumonia	5 (5.9%)	7 (8.3%)	6 (3.7%)	6 (3.7%)
Total	13 (15.5%)	15 (17.9%)	20 (12.3%)	11 (6.8%)

A similar analysis in relation to the performance of enclosed work is made in Table XIX, and a higher rate is found in workers who have performed a substantial amount of enclosed work.

TABLE XIX

RESPIRATORY DISEASES: RELATION TO ENCLOSED WORK

	Substantially Enclosed Work 120 Workers		Non-Enclosed Work 83 Workers	
	Cases	Attacks	Cases	Attacks
Bronchitis	9 (7.5%)	—	1 (1.2%)	—
Pleurisy	5 (4.2%)	8 (6.7%)	4 (4.8%)	4 (4.8%)
Pneumonia	7 (5.8%)	9 (7.5%)	3 (3.6%)	3 (3.6%)
Total	21 (17.5%)	17 (14.2%)	8 (9.7%)	7 (8.4%)

The evidence from these few cases would therefore seem to suggest that persons exposed for substantial periods to a high concentration of welding fumes have an increased risk of developing respiratory diseases. Some of the workers have attributed their illness to the fumes and some support is given to this view in at least three cases—Case 169 who developed pneumonia after electric welding for one week in an enclosed tank, Case 186 who spends 66% of his time at enclosed work in shipyards, and who had the first of three attacks of pleurisy soon after commencing welding, and case 208 who has had two attacks of pneumonia, the first following a spell of seven weeks almost continuous enclosed work.

91. In the rheumatism group on the other hand, eight (6.2%) of the workers have performed a substantial amount of enclosed work and nine (10.8%) have performed no significant amount of this work. The slightly greater incidence in the latter group is possibly explained by the fact that the average age in this group is much higher than that of the group doing a substantial amount of enclosed work (44.9 years as compared with 33.6 years) so that a greater incidence of rheumatic complaints would be expected. When the electric welders alone are considered the proportion is about equal.

The group of 24 men who have suffered from gastric trouble are not separately analysed here, but are considered with others having slight gastro-intestinal symptoms in paragraphs 129 and 130.

(d) PRESENT HEALTH

92. The following table shows the answers to enquiries regarding the health of the men at the time of examination.

TABLE XX
PRESENT HEALTH

	Electric Welding	Gas Welding	Mixed	Total
Good	147	35	20	202
Fairly Good	35	3	5	43 (17%)
Not Good	1	1	—	2

The men who described their health as " not good " were cases 7 and 109. Case 7, aged 50, an electric welder for 16 years, had suffered from rheumatism for many years, and three years previously had been in hospital with high blood pressure and heart trouble. He also suffered from neuralgia of the face and had a limp from hip joint disease in childhood. Case 109, aged 46, an oxy-acetylene welder for 23 years complained of feeling run down attributing this partly to hours of work, to fumes from the electric welders working in the same shop, and to the proximity of a muffle furnace. Case 7 had performed only a small amount of enclosed work and case 109 no significant amount.

Of the 43 men who said their health was only fairly good, 19, all electric welders, had performed substantial amounts of enclosed work. Thus 100 of 119 men who performed substantial amounts of enclosed work regarded their general health as good or excellent. That there is no undue proportion of shipyard welders in the " fairly good " class is shown by the fact that only 13, all electric welders, are included in this category. This means that 71 of the 84 shipyard welders stated that their general health was good.

Taking the group of 45 men whose health was stated to be fairly good or not good it is found that their average age is 38 years and their average welding experience 14.8 years. (E.W. 35.9 and 13.7 years : G.W. 54.7 and 26.7 years: Mixed 39.6 and 13.4 years.) As might have been expected these ages are rather higher than those given for the whole groups (Paras. 78-80) and as the average length of welding experience is also proportionally increased I cannot attribute the apparent lowering of general health to the work. (This would have been a reasonable deduction had the unhealthier group had longer welding experience without increase in the average age.)

(e) INFLUENCE OF WELDING ON HEALTH

93. It may be of interest to analyse the answers received to the question " Do you consider that welding has any bad effect on your health?". The answers were given with hesitation in many instances, usually because of doubt for many of the welders had not considered the question before. Others obviously had and I was impressed with the care and honesty with which the opinion was given. In 22 cases the answer was so vague as to be of no value, or was not recorded. The remaining 225 answers are tabulated below, 5 persons stating that two systems were affected so that there are 230 answers.

TABLE XXI
INFLUENCE OF WORK

	Electric Welding	Gas Welding	Mixed	Total
No ill effect ...	111 (66.1%)	29 (78.4%)	17 (68%)	157 (68.3%)
Temporary effect only	20 (11.9%)	3 (8.1%)	2 (8%)	25 (10.9%)
Fumes upset throat, nose ...	13 (7.7%)	—	—	13 (5.7%)
Fumes upset chest	8 (4.8%)	1 (2.7%)	2 (8%)	11 (4.8%)
Fumes upset stomach ...	6 (3.6%)	2 (5.4%)	4 (16%)	12 (5.2%)
Fumes produce lassitude ...	4 (2.4%)	1 (2.7%)	—	5 (2.2%)
Work affects eyesight ...	6 (3.6%)	1 (2.7%)	—	7 (3%)

The temporary effect mentioned was produced mainly by enclosed work. It lasted as a rule only a few hours, rapidly passing off in fresh air. In six cases the symptoms were mainly related to the stomach, e.g. nausea, and in a further four they consisted of loss of appetite. In three cases there was tightness of the chest or similar thoracic discomfort, in three lassitude, and in nine cases a combination of the aforementioned, or merely a vague feeling of discomfort. Twenty two of the 25 persons (88%) performed substantial amounts of enclosed work.

It is not to be assumed that only 25 out of the whole group experienced these temporary symptoms, The question was directed to ascertaining whether the men thought there had been any more permanent effect on the health, and I feel that the great majority of men who have welded in enclosed spaces have at times experienced some discomfort afterwards. As it passed of quickly and left no permanent effects it did not occur to most men to mention it.

Of the remaining 48 cases having more definite or more prolonged symptoms attributed to the work, there is no correlation with the amount of enclosed work; in fact the proportion of men engaged in a substantial amount of enclosed work is slightly less than in the whole group (41.6% as compared with 48.2%).

In many cases the symptoms mentioned as attributable to the effect of work was very slight and were not associated with serious illness. Of the 11 cases who mentioned an effect of fumes on the chest, 7 gave no history

of previous attacks of bronchitis, pneumonia, or pleurisy, and of the 12 cases who thought the fumes upset the stomach, 8 gave no history of any stomach trouble requiring absence from work.

The inference to be drawn from these answers to the question on the effect of welding on the health is that no obvious ill effect has been disclosed, and that the group as a whole do not regard the work as unhealthy. Some men evidently expected that welding would in the long run be unhealthy, as shown by answers such as " healthy so far " or " no ill-effect up to now ". On the other hand there were several men who after many years at the work volunteered the information that they liked welding, and that they did not consider it unhealthy.

(f) GENERAL CONDITION

94. The general condition was noted in 245 cases, and its assessment was based mainly on an appreciation of the build, musculature, nutrition and colour of the individual. The minimum standard qualifying for inclusion in the group of " good " general condition was that the aforementioned items should all be up to average, or if one was slightly below average the other three should be above average. If one item was much below, or if two were slightly below average, the classification was " fairly good ", and the terms " rather poor " and " poor " were used for cases having a lower standard than this. The table shows the classification of the 245 cases.

TABLE XXII

GENERAL CONDITION

	Electric Welding	Gas Welding	Mixed	Total
Excellent, very good, good ...	146	36	23	205
Fairly good	28	3	1	32
Rather poor, poor	8	—	—	8

On examining further the 8 cases classified as in " rather poor " or " poor " general condition, one is struck by the fact that all of them have performed a substantial amount of enclosed work. Six are employed in shipyards, and the other two in boiler making. They have all been exposed mainly or exclusively to the fumes from mild steel welding, some having also worked on galvanized or painted metal. None have had any but the very slightest exposure to fumes from other types of welding such as stainless steel, brass, manganese steel, etc. It would, however, be a mistake to attribute the poor general condition to the fumes. Several of the men regarded themselves as in good health, and considered that welding had had no ill-effect on them, and it is very probable that in most cases the thinness or pallor which led to the classification as rather poor or poor general condition was something inborn or due to long-standing home or social conditions, e.g. diet. One man (case 157) had mitral regurgitation; another (case 23) had on the day of examination just returned to work after 10 days off with bronchitis, and his poor condition was probably temporary and due to his recent illness, and a third case, 226, had suffered from chronic catarrh since boyhood.

These eight cases are summarised in Table XXIII.

TABLE XXIII

GENERAL CONDITION : RATHER POOR, POOR – (8 ELECTRIC WELDERS)

Case No.	Age	Welding Experience (years)	Poor Rather Poor	Condition	Work	Comments
151	49	25	R.P.	Thin ; tired looking, rather pale.	Mild steel. 30% enclosed.	Says present health " fair ". No operations. No serious illnesses except bronchitis several times. Sometimes day off through being run down. Does not attribute lowering of health to welding. Has blowing systolic murmur at apex.
186	23	7	R.P.	Rather thin and pale.	66% of work enclosed in shipyard ; mainly uncoated mild steel, but 1 year on galvanized work.	Pleurisy 3 times since started welding. " Fumes affect chest ; " " has never been the same man since he worked on galvanized metal owing to bronchitis."
240	42	18	R.P.	Thin ; mod. colour with very white sclerae.	75% enclosed work ; little galvanized work which doesn't upset him much.	No serious illnesses. Says health good and that work has had no ill effect. Smokes 40 cigarettes daily.
23	32	7½	P.	Very thin ; slightly nervous. Moist skin, heart action rapid.	Mild steel. 25% enclosed in boiler making.	Just returned to work after 10 days off with bronchitis (first attack). Health usually good and not affected by welding.
226	21	5	P.	Thin, pale, poor musculature. Partial facial paralysis (mastoid op. in infancy). Grade IV for army.	Mild steel work on ships and submarines with substantial amount enclosed.	Says " Health good ; no effect from welding ". Chronic catarrh since boyhood.
230	22	6	P.	Thin, pale, tachycardia ; slightly nervous.	Mild steel on ships and submarines. Substantial amount enclosed work.	No serious illnesses. " Health good." Welding has no effect except temporarily after galvanized work.
235	41	12	P.	Thin, pale ; nearly bald. Looks older than his age.	Mild steel on ships and submarines. 75% enclosed.	Has cough attributed to welding but health otherwise good. No bronchitis or serious illness.
241	39	7	P.	Small, thin, rather pale.	Mild steel on ships. Ship repair work 1½ years. 25% enclosed.	No bronchitis or serious illnesses. Health "good". No effect of work. Slight cough only.

(g) SKIN CONDITIONS

95. The following table shows the past history of skin troubles and the present condition of the skin :—

TABLE XXIV

SKIN CONDITION

	Electric Welding	Gas Welding	Mixed	Total
Past History				
Erythema, rash, " dermatitis ", etc. ...	19	4	1	24
Scabies	8	—	—	8
Boils	12	2	—	14
Impetigo	4	1	—	5
Acne	3	—	—	3
	46	7	1	54
Present Condition				
Erythema from arc	10	—	—	10
Acne	15	5	2	22
Scabies	1	—	—	1
Boils	2	—	—	2
Seborrhœa	2	—	—	2
Sycosis	1	—	—	1
Cheiropompholyx	2	—	—	2
Psoriasis	3	1	—	4
" Dermatitis ", rash, etc.	1	1	1	3
Total	37	7	3	47

Past History

96. It seems that comparatively few of the 54 conditions listed can be attributed to work. At least 6 of the cases classed in the " erythema, rash or dermatitis " group had had erythema which was almost certainly due to exposure to the rays. This occurred on exposed parts, usually neck and/or wrists, but had always been slight and in no case occasioned loss of working time. Three of the remaining cases, all electric welders, spoke of having had " dermatitis " (face, 2 cases and hands, 1 case), and these cases all seem likely to be due to work. The remainder, 15 cases, consisted of persons who gave a history of conditions that seemed unlikely to have been due to work—" itch on body ", " eczema of the perineum and behind ear ", " nettlerash ", etc., and included three cases of probable sycosis, two of cheiropompholyx, and one of erysipelas. Of the remaining group the only one that might have had a possible etiological relationship with the work is that relating to boils, but as this group contains several men who had had only a few boils, or whose tendency to boils seemed to have ceased some years ago, such relationship would not appear to be significant.

Present Conditions

97. The ten cases of erythema from the arc were of the slightest and caused a minimum of discomfort, sometimes none at all. If not specially looked for the condition would sometimes have been missed. The parts affected were the wrists, neck (an open V neck in one case) and ears, and the appearances were merely those of a localised sunburn, maybe showing a fine branny desquamation.

The electric welder with "dermatitis" showed a powdery desquamation over the face not confined to the beard area. He had had two attacks of dermatitis of the face before, 2 years and 4 years previously. There was no actual inflammation when he was seen and it was impossible to attribute it with certainty to his work. The other two cases were unlikely to be due to work—the 'mixed' welder having a "nettlerash" over the upper arms (covered by his sleeves while working), and the gas welder having a localised patch of dermatitis just lateral to the six months old scar of an operation for the excision of a ganglion of the wrist .

This review of the dermatological conditions occurring in this group of welders does not to my mind indicate any undue incidence of skin troubles in welders.

98. It may be of interest to give an analysis of the cases of dermatitis occurring in Scotland voluntarily reported in recent years.

Year	*Total cases reported (All Occupations)*	*Cases reported in welders, burners & assistants*
1944	1232	13
1945	974	13
1946	698	7
1947	500	3
	3404	36

The cases are further analysed below :—

	Males	*Females*	*Total*
Welders	13	6	19
Welders' assistants	2	–	2
Burners	9	–	9
Burners' assistants	3	3	6
	27	9	36

In order to assess the incidence in welders considerable efforts have been made to obtain reliable information regarding the number of welders employed in Scotland but unfortunately without success. However 36 cases out of 3,404 does not seem unduly high. For comparison, in the same period there were in mechanical engineering 726 cases, in electrical engineering 55 cases, in transport engineering 201 cases, in paper manufacture 79 cases, in baking 82 cases, and in woodworking 53 cases.

(h) EYES

99. Conjunctival congestion was found in 84 cases (34%) distributed as follows :— electric welders 60 cases (32.8%), gas welders 14 cases (35.9%), mixed welders 10 cases (40%). A few cases seemed definitely related to a recent 'flash' and a few to a recent foreign body, for instance a piece of slag, but in the majority of cases no such relationship was apparent. Dr. Fraser in his special report also finds a high incidence of conjunctival congestion compared with a control group and suggests that this is due neither to rays nor dust particles but to fumes. In this series it was noticed that in several cases the congestion was associated with pinguecula.

Examination of the fundus was made in 18 cases, 8 electric and 10 gas welders. In every case the result was normal and this is confirmed by Dr. Fraser in 50 cases.

100. By questions to the men about the condition known as "arc" eyes resulting from exposure to the rays from the arc some information was obtained about its frequency and severity. It was found that the gas welders did not complain of the condition at all. In regard to electric welders the information obtained from the first men examined was rather vague and

answers were obtained such as " only had a few flashes " and " used to have a lot of flashes but not now ". The term " flash " was also interpreted differently, some welders meaning merely by the term the seeing of the flash of an arc without ensuing symptoms. Some also are doubtful as to whether a sore eye is due to a flash or due to a foreign body, and it seems probable that conjunctivitis affecting one eye only is more likely due to a piece of slag or other foreign body than to exposure to the rays emitted from the arc. In later questioning of the men a different formula was used such as " Have you ever had sore eyes due to a flash?" and then " when was the last time you experienced this?". The more definite answers obtained from 171 cases, are tabulated as follows :—

Last attack " Arc eyes " within one month	35 cases
" " " " 1 - 3 months ago	16 cases
" " " " 3 - 12 months ago	54 cases
" " " " 1 - 2 years ago	18 cases
" " " " over 2 years ago	48 cases

101. One hundred and fifty two men were asked about the maximum amount of time lost through sustaining a 'flash', with the following results :—

No time ever lost	78
Never more than half a day lost	6
" " " one day lost	45
" " " two days lost	15
More than two days lost ...	8

Most men agreed that they received far more 'flashes' in the early months of employment as welders than later on. Opinions were sought from some of the men as to whether they had acquired resistance to the action of the rays. In many cases the answers received were very doubtful; 16 men did give a definite opinion, 12 saying that they considered themselves more immune, i.e., better able to withstand a flash now while 4 saying that their relative freedom in later years was mainly due to greater carefulness.

102. As shown in the review of the literature, while it is generally believed that the rays from the welding arc had a temporary effect on the superficial structures of the eye only, there have been from time to time allegations of effects on the deeper structures. As no investigation into this aspect was known to have been undertaken in this country it was felt that a special enquiry should be made by a competent ophthalmologist. This was undertaken by Dr. J. D. Fraser, of the Department of Ophthalmology, Glasgow University, working under the guidance of Professor W. J. B. Riddell. Dr. Fraser's report follows :—

"'THE EFFECT of ELECTRIC ARC-WELDING on the EYES of WELDERS'

103. It appeared that no positive data was in existence in this country relating to the incidence of lens changes in welders. An American report stated that a survey of nearly 100,000 shipyard injuries failed to reveal any information of injuries directly chargeable to the effects of infra-red radiation. (See A.P.O. 1/1/1.)

It was decided that a group of electric welders should be compared with a group of non-welders working in shipyards on the Clyde. As far as possible these two groups of shipyard workers were to be of the same age experience and economic condition. Fifty electric welders with a total of 545 years (average 10.9 years S.D. $\pm$ 4.3) experience of welding were compared with fifty other workers consisting of 27 platers and platers helpers, 9 shipwrights and caulkers, 6 joiners and 8 miscellaneous shipyard workers. The welders were unselected but the control group was chosen to be of a comparable age group.

The groups of welders and non-welders were divided into two categories according to age. Those of 35 years and over comprised the older category and their average age was 39 years with a S.D. ±4.7 years. Those of 34 years and under were in the younger category and their average age was 28 years (S.D. ±3.3).

METHOD OF EXAMINATION

104. All the subjects were examined under precisely similar conditions by Dr. J. D. Fraser with a monocular loup, hand slit lamp and undilated pupils in ambulance rooms of the various shipyards. Arrangements were made for the rooms to be darkened. Particular attention was paid to the condition of the conjunctiva, cornea, pupil size, lens architecture. The media and fundi were examined ophthalmoscopically. Visual acuity was not recorded but in the questionnaire it was elciited that there was no unexplained complaint of defective vision.

RESULTS :

1. *Conjunctiva and Cornea*

105. The distribution of chronic conjunctivitis or injection of the palpebral conjunctiva is shown in Table 1.

Table 1

Group	Welders		Non-Welders		Total
Age	—34	+35	—34	+35	
Chronic Conjunctivitis	20	18	8	11	57
Normal Conjunctiva	6	6	18	13	43
Total	50		50		100

From this it appears that there is a significant excess of welders in both the younger and older age groups with conjunctival irritation compared with the controls. (χ^2 18.4 P=.01.)

Corneal Epithelial disturbance was found in 8% of all cases (6 in welders and 2 in the others). This suggests that the conjunctivitis may arise from the fumes among the welders rather than from minute metallic particles or the radiation per se, of which there would be corneal evidence. This finding is in keeping with the well known chest condition found in welders (see Doig & McLaughlin, Lancet 1936 : 771 and others).

Arcus senilis was present in 3 cases in each group in the older category.

2. *Pupils*

106. The size of the pupils was recorded with the pupillometer fitted to the ophthalmoscope and the distribution is shown in Table 2. It has been stated that the pupils of welders are small but the data does not support this view.

Table 2

Pupil Size in mm.	Welders	Non-Welders
4	6	7
5	12	9
6	15	22
7	15	9
8	2	3
Total	50	50

3. *Lens*

107. The distribution of lens changes of any kind is shown in Table 3.

Table 3

Group	Welders	Non-Welders	Total
Lens changes	25	33	58
No Lens changes	25	17	42
Total	50	50	100

Thus no significant difference between welders and the control group was found. In fact there was a slight excess of controls with opacities. These figures are much lower than those given by Doggart (Arch. of Ophth. 35 : 280 : 1946) in a survey of partial cataract in men of military age. He found lens opacities, including dust-like ones in 90% of his subjects. This difference between observers does not, of course, affect the difference between the groups of the same observer.

The various lens opacities noted were :—

(a) Anterior Subcapsular

These were present in 12 welders and 24 non-welders. Age was not a factor associated with incidence in both groups.

(b) Anterior Cortical and Coronary

Eleven welders revealed this type compared with 15 in the control group. There was no significant increased incidence of the older men in each group.

(c) Floriform Cataract

This was found in 4 welders and 5 non-welders.

(d) Nuclear. (Between the anterior and posterior Y sutures.)

Such appearance was present in 5 men of both groups examined, the greater proportion (4) being in the younger group of the welders. The remaining 1 case was found in the younger group of the non-welders. Gross changes in the posterior part of the lens comparable to early "puddler's cataract" would be noted by the methods employed including ophthalmoscopic examination of the media. None was found. It is appreciated that fine opacities in the posterior cortex are difficult to demonstrate with a loup and hand slit lamp but the absence of visual or subjective complaints makes it unlikely that any gross defects failed to be observed.

No senile or presenile lens changes were noted in this observation.

4. *Fundus*

108. No apparent abnormality was noted in the group of welders while 4 of the controls had pathological changes in the macular and papillo-macular area. Of these, only one had any complaint of defective vision. He was later examined with a dilated pupil when a moth-eaten appearance was noted at each macula. Serological examination of the blood and radiological examination of the chest and sinuses gave negative findings. These changes at the macula and papillo-macular areas were equally distributed between younger and older groups of non-welders. Three of these men were platers or platers helpers.

SUMMARY AND CONCLUSION

109. (1) Positive evidence of chronic conjunctivitis mainly affecting the eyelids was observed in the welders compared with the non-welders.

(2) There was no diminution in the size of the pupil in electric welders which, with the absence of superficial corneal changes, indicates that the welder is well protected against U.V. radiation. Severe thermal effects of I.R. radiation include a paralytic mydriasis. With the absence of this, in association with the normal fundal appearance in welders, it may be assumed that there is also adequate protection against severe I.R. radiation.

(3) Radiational cataract has characteristic appearance and it is likely that, if common, an association with electric welding would have been made by clinical observers. This has not been generally recognised.

(4) The mean age of the welders examined is relatively young and less than is usually associated with presenile or senile lens changes. If electric welding leads to an acceleration of the usual changes associated with age, this survey should give an indication in that direction. No such indication was found.

(5) By examining patients of an older age group a loss of experimental efficiency would arise owing to the greater incidence of senile lens changes in the population sampled.

(6) It can be said that 10 ± 4.3 years experience of electric welding has produced no change in 50 men whose mean age was 33.5 ± 4.9 years."

(j) THROAT AND NOSE

110. The frequency of upper respiratory symptoms is tabulated below :—

TABLE XXV

	Electric Welding	Gas Welding	Mixed	Total
Nose and throat irritation, tonsillitis, etc.‡	35	4	4	42
Husky Voice	3	—	2	5
Nasal Catarrh*	47 } 68	6 } 6	10 } 11	63 } 85
Frequent Colds†	33 }	— }	4 }	37 }

‡ Single attacks of tonsillitis or sore throat have not been included, but only cases of " occasional " or " repeated " attacks.

* Nasal catarrh is included only if it is frequently experienced.

† Frequent colds are taken as being more than an average of 2 per annum.

The number of cases of " nasal catarrh " and " frequent colds " have been bracketed together to show the total number of persons affected; this is less than the aggregate as several persons appear in both categories.

The number of complaints of irritation of the nose and throat and of sore throat and tonsillitis is substantial. However, it is to be emphasised that this group includes men who complained of occasional, slight or temporary irritation. It is possible that many welders experiencing temporary irritation have not thought fit to mention the fact, but even the more definite types of sore throat of which there were 17 cases amongst electric welders, 3 in gas welders, and 2 in the mixed group, were generally of a slight nature or only experienced at long intervals. Even amongst those welders substantially engaged in enclosed work the incidence is not high. The expected incidence on the basis of all cases in this group is 20.4 cases and the actual number met with is 26. No correlation can be made out between this group and the work of welding brass, cast iron, stainless or high tensile steels or high manganese steels.

Husky voice was met with in 5 cases. In 4 of these the amount of enclosed work was classed as substantial and in the remaining case as slight, although approaching very close to the lower limit of the " substantial " class.

The incidence of nasal catarrh and frequent colds is rather high, 34.4% in the whole group and 37.2% in electric welders. In those persons substantially employed in enclosed work the incidence is 43.3%*. In the workers of galvanized metal the incidence is 66.6%. One worker employed on nickel chrome steel for the previous 4 weeks experienced irritation of the throat, but there was no evidence of an increased incidence in men who had welded brass, cast iron, painted metal or high manganese steel.

Physical examination of the throat and upper air passages showed few abnormalities, the most frequent being a slight reddening and congestion of

* As compared with 16.9% in those having no significant amount of enclosed work.

the nasal mucous membrane. No gross lesions such as ulceration or perforation of the septum of the nose were met with and the amount of dust deposited in the nose was seldom more than slight. It was noticeably a little more in men engaged in confined work. In 15 cases there was faucial congestion but in 10 of these it was of slight degree or confined to one side. Enlarged tonsils were found in 13 cases, being of slight degree in three.

(k) RESPIRATORY SYSTEM

111. The following table shows the symptoms disclosed in an examination of 247 welders, and the signs found in 246, one welder, having willingly come for examination and given his history and other particulars, refusing to undergo the clinical part of the examination. This man, case 77, an electric welder, had a large goitre and probably suffered from some degree of hyperthyroidism.

TABLE XXVI

PULMONARY SYMPTOMS AND SIGNS

	Electric Welding	Gas Welding	Mixed	Total
Symptoms (247 cases)				
No Symptoms	75 (41%)	18 (46.2%)	6 (24%)	99 (40.1%)
Cough	93 (50.8%)	18 (46.2%)	16 (64%)	127 (51.4%)
1—Slight or occasional	64	11	9	84
2—More definite, frequent or constant ...	29	7	7	43
Sputum	75 (41%)	13 (33.3%)	16 (64%)	104 (45.1%)
1—Slight or occasional	49	10	8	67
2—Moderate or constant	26	3	8	37
Dyspnœa (slight) ...	13 (7.1%)	3	3	19 (7.7%)
Examination (246 cases)				
Normal	132 (72.5%)	22 (56.4%)	14 (56%)	168 (68.3%)
Restricted Movements ...	24 (13.2%)	9 (23.1%)	7 (28%)	40 (16.3%)
Hyper-resonance ...	3 (1.6%)	2 (5.1%)	—	5 (2.0%)
Impaired Percussion note	3 (1.6%)	—	—	3 (1.2%)
Dry Sounds	10 (5.5%)	1 (2.6%)	—	11 (4.5%)
Moist Sounds	23 (12.6%)	6 (15.4%)	7 (28%)	36 (14.6%)
Crepitations	16	5	7	28
Rales	7	1	—	8

112. The table shows that practically 60% of the men examined had respiratory symptoms. The commonest was cough, admitted by just over 50%, and in most cases associated with sputum. These symptoms were however slight or occasional in about two-thirds of those affected, and in the remaining one-third was generally not particularly troublesome and occurred most commonly in the morning. For example case 18, aged 43, an electric welder for 25 years had a dry cough every morning, but was fit enough to play football every lunch hour. Dyspnœa was slight in all 19 cases, and sometimes there seemed some doubt about its presence. As might be expected the average age of the dyspnœic cases is rather higher than that for the whole group,—39.5 years as compared with 34.1 years. It is noteworthy that the dyspnœic cases have, on the average, no longer

welding experience than the whole group 12.5 years as compared with 12.7 years, as might have been expected had the dyspnœa been due to the work.

113. The table also shows the predominance of symptoms over abnormal physical signs, the latter being present in rather less than one-third of all cases. Again, they were generally of minor degree. The commonest were slight restriction of chest movements and the presence of moist sounds. The chest movements were measured in all cases by visual examination and palpation, and were accurately ascertained in 83 consecutive cases by tape measure with results shown on Table XXVII.

TABLE XXVII

CHEST EXPANSION – 83 CASES

	Electric Welding	Gas Welding	Mixed	Total
Impaired, i.e., less than 2″	4	—	1	5
Normal 2″—2¾″	28	3	1	32
3″—3¾″	33	4	2	39
4″—4¾″	6	1	—	7

114. Moist sounds were heard on auscultation in 36 cases, and consisted of crepitations in 28 cases and rales in 8 cases. In 14 cases the sounds were of a transient nature, dispelled by cough, and in many others were very localised and slight in degree. One case exhibiting showers of persistent crepitations at both apices with pleural friction at the base (the only case in which friction was found) had moderately advanced bilateral pulmonary tuberculosis. This man (case 63) was aged 32 and had been an electric welder in a large open shop for 6 years having no work in confined spaces. He had a family history of tuberculosis.

115. The table shows comparatively little difference in the respiratory condition of electric and oxy-acetylene welders. Electric welders have relatively a little more cough and sputum but the difference is not great. On the other hand the electric welders have fewer physical signs, especially in regard to restricted chest movements, a finding which is to be expected as the gas welders include a higher proportion of older men.

116. Work in enclosed spaces has had surprisingly little effect in producing symptoms, and none in producing physical signs. For instance it can be seen from the table that 148 (59.9%) of the whole group of 247 workers have symptoms. Of the 120 persons who have performed a substantial amount of their work in enclosed spaces 75 (62.50%) have symptoms (electric welders 64 (60.4%)). Seventy eight (31.7%) of the whole group had abnormal physical signs, but of those who worked substantially in enclosed spaces only 28 (23.3%) had physical signs, electric welders 25 (23.6%). The reason why physical signs are fewer in welders doing enclosed work is obscure. They are not a younger age group and I do not consider it likely that any selection of employees for enclosed work has influenced these findings to any great extent. There was no medical selection of employees at any of the yards concerned.

117. It seems from the evidence, therefore, that the incidence of symptoms related to the respiratory tract, and possibly also of physical signs, is higher than would be expected in the general population. Work in enclosed

spaces had surprisingly little effect in increasing the liability to symptoms, and none in producing physical signs. It must be remembered however, that the incidence of respiratory diseases (bronchitis, pneumonia, pleurisy) was higher in those welders substantially engaged in enclosed work (paras. 89 and 90).

X-Ray Findings

118. 180 cases were subjected to x-ray examination of the chest. Of these 23 (12.8%) showed definite changes of the type associated with the inhalation of dust. These consisted of generalised reticulation in 17 cases, reticulo-nodulation in one case, miliary stippling (i.e. nodulation with the individual nodules no more than pin-head size) in two cases, and nodulation (the individual lesions being larger than pin-head size) in three cases. 142 cases were normal or showed changes of a non-specific type, principally slight or definite increase in the bronchial markings. The remaining 14 cases were regarded as indefinite though suggestive of very early changes of the inhalation type. The changes in them are rather difficult to describe and vary somewhat. The main changes consisted of a very slight degree of reticulation, beading of the lung markings, a ground glass appearance of the background of the film, or a tiny faint stippling. In most cases these changes were general but in a few they tended to be localised in one or other mid-zone.

119. Four men showing definite inhalation type changes had previously been engaged in dusty occupations. It is not considered that this employment is sufficient to account for the changes in any of the cases. It is possible that the dust previously inhaled may have modified or accentuated the effects of the welding fume, but, as the welding experience of each of these men is much longer than the exposure to other dust, and is sufficiently long by itself to account for the changes, the cases have not been excluded from further analysis.

The four cases referred to are :—

Case 43, aged 39, electric welder for 17 years, had served an apprenticeship as a steel moulder for 5 years before the age of 22.

Case 125, aged 62, electric welder for 37 years (including carbon arc and bare rod welding) had been a grinder for 2 years before the age of 25.

Case 127, aged 52, electric welder for 16 years (including carbon arc and bare rod welding) had been a labourer in a steel fettling shop for 10 years, mostly on open air work but wheeling barrows to and from the shop.

Case 151, aged 49, electric welder for 25 years (30% enclosed) had been a coal miner from the age of 14 to 24. He had not engaged in stone work but had been hewing for 2 years.

None of the group showing 'suspicious' x-ray changes had previous exposure to dust.

One man, case 137, showing inhalation type changes had also a valvular heart lesion. The x-ray changes are considered to be due to welding fume and not to hæmosiderinosis because of the long welding history (30 years gas welding, 4 years carbon arc welding), the absence of a history of hæmoptysis or recent disablement due to congestion of the lungs, the absence of any enlargement of the heart on x-ray examination, and the distribution and character of the changes on the film.

120. The cases are tabulated below according to the type of welding performed.

TABLE XXVIII
X-Ray Examinations

	Electric Welding	Gas Welding	Mixed	Total
Normal	51 } 100	16 } 31	4 } 11	71 } 142
Non-specific changes	49 } 75.8%	15 } 93.9%	7 }	71 } 78.9%
Suspicious	12	1	2	15
Definite inhalation changes ...	20 (15.2%)	1 (3%)	2	23 (12.8%)

The x-ray changes occur in direct proportion to the length of employment as shown below :

TABLE XXIX
X-Ray Findings and Welding Experience

X-Ray Findings	Average Years spent as Welder		
	Electric Welding	Gas Welding	Total
Normal	9.7 years	13.4 years	10.5 years
Non-specific changes ...	11 years	20.3 years	13.5 years
Suspicious of Inhalation Change	13.3 years	26 years (1 case)	14.6 years
Definite inhalation changes ...	20.1 years	34 years (1 case)	20.1 years

In table XXVIII it is seen that the electric welders have a higher proportion of inhalation changes than the gas welders and Table XXIX shows that these changes occur much earlier in the electric welders. For instance suspicious signs of early inhalation changes were seen after an average of 13.3 years experience in electric welders, but not until after 26 years in the single gas welder. Definite inhalation changes are seen after about 20 years in electric welders while the one gas welder showing such changes had a welding history of 34 years. In the group showing definite inhalation changes the shortest duration of work was 9 years in the case of an electric welder of mild steel, aged 25 years, who had performed a good deal of his work in enclosed spaces during ship and submarine construction.* The person with the longest experience was also an electric welder, a man aged 62 who had welded for 37 years. For about 15 years he had used the carbon arc and for 22 years the metallic arc and he had performed a great deal of his work, more than half, welding steel which contained 12-14% of manganese. He had not performed any significant amount of work in enclosed spaces. The x-ray changes in each case amounted to reticulation.

Enclosed Work

121. Of the 23 persons showing inhalation changes, 18 have performed a substantial amount of their work in enclosed spaces. 17 of the 20 electric

* An electric welder in McLaughlin & Doig's unpublished series, aged 20 years, has an x-ray picture showing definite inhalation changes after only 5 years exposure, much of it in enclosed conditions.

welders have done so. In other words, 18 of the 120 welders (15%) who have worked substantially in confined spaces show inhalation changes, but of the 127 whose experience of enclosed work is slight or nil, only 5 (3.9%) show such changes. The average duration of employment is less in the case of those workers who have performed enclosed work—18 years, as compared with 27.6 years in those whose work has not included much of this work. The figures for electric welders are 17.9 years and 24.7 years

Symptoms and Signs

122. Although the numbers are small it is perhaps desirable to compare the incidence of symptoms and physical signs occurring in the 23 cases showing radiological changes of the inhalation type with those of the group of 142 welders whose x-ray films showed no specific changes due to dust. Of the 23 welders with x-ray changes, 8 had no symptoms related to the lungs and 15 (65.2%) had one or more symptoms. Of the 142 men without specific x-ray changes 78 (54.9%) had symptoms while 64 were symptomless. Fourteen (60.9%) of the 23 welders had abnormal physical signs in the lungs and the corresponding figure in the group without x-ray changes was 41 (28.9%). The analysis is shown in Table XXX.

TABLE XXX

CASES X-RAYED – SYMPTOMS AND SIGNS IN LUNGS

	X-Ray Film Showing 'Inhalation' type changes—23 cases	X-Ray Film Normal or showing Non-Specific changes —142 cases
No symptoms	8 (34.8%)	64 (45.1%)
With Symptoms	15 (65.2%)	78 (54.9%)
Cough	14 (60.8%)	67 (47.2%
Sputum	11 (47.8%)	51 (35.9%)
Dyspnoea	4 (17.4%)	7 (4.9%)
No abnormal signs	9 (39.1%)	101 (71.1%)
With abnormal signs	14 (60.9%)	41 (28.9%)
Restricted movements	5 (21.7%)	23 (16.2%)
Impaired percussion note	1 (4.3%)	1 (0.7%)
Dry sounds	—	7 (4.9%)
Moist sounds	9 (39.1%)	18 (12.7%)

The table shows that there is evidence of more frequent symptoms and physical signs in those who have x-ray changes of the inhalation type than in those whose x-ray films are normal or in which the changes are of a non-specific nature. In regard to symptoms however, the difference is not very great*. Cough in addition to being a more frequent symptom tended to be rather more severe, being constant or at least more frequent in a higher proportion of cases in the group with inhalation type changes. The cases with sputum were also rather more frequent in the group showing these changes. It will be noted also that the proportion of dyspnœic cases is higher but as this is based on only 4 cases it is impossible to say whether there is a definite association or not.

123. Abnormal physical signs on the other hand are much more frequent, being present in more than half of the men showing x-ray changes of the inhalation type compared with less than one third of those with normal or non-specific films.† The most frequent was the presence of crepitations.

* In regard to symptoms the difference is not significant statistically [$\chi^2 = .091$. $P = .96$].

† In regard to physical signs on the other hand, the difference is of significance, there being odds of rather less than 1 in 100 of a chance association [$\chi^2 = 10.9$. $P = > 0.01$].

These were often localised, most frequently at the bases, and often were dispelled by cough. They were found in about one third of the cases showing x-ray changes of the inhalation type, but as can be seen from the table, were also found in smaller proportion, about one in eight of persons who had no specific changes.

In assessing the significance of these results it must be borne in mind that abnormal physical signs when present were usually slight and in no case could be termed gross, and that the welders with inhalation changes constituted an older group than those with no specific changes, so that some increase in symptoms and physical signs is to be expected.

The average ages of the men in the different x-ray categories are shown below :—

71 welders with 'normal' x-ray films ...	average age 31.1 years
71 welders with 'non-specific' x-ray changes	average age 34.1 years
15 welders with 'suspicious' x-ray changes	average age 36.3 years
23 welders with 'inhalation' x-ray changes	average age 40.5 years

It seems possible that men using bare electrodes, and the carbon arc might be exposed to heavier concentration of fumes than in those using covered electrodes, in which the arc is to some extent shielded by the molten coatings of the rod. Three men of the group of 22 welders who had used the carbon arc and three of the group of welders who had used uncovered rods showed definite inhalation changes in x-ray examination, but their total welding experience which included welding by other means was sufficient to account for the changes without there being evidence of any increased liability from carbon arc or bare rod welding.

Re-examination after 10 *years*

124. Of this group of 247 welders 14 had been previously examined by McLaughlin & Doig (unpublished) in 1936, and all were again x-rayed. The two shop foreman exposed to the welding fumes had also been examined then, and another man, the original case, case 1 in the men described by Doig & McLaughlin (Lancet, 1936, i, 771), was also followed up and a recent x-ray film obtained, making 17 cases reviewed after 10 years.

Of nine men who showed no specific dust changes in 1936, 7 are still negative, one is now classed as suspicious, and one shows a definite but slight degree of reticulation.

Of two who were suspicious in 1936, both now show definite inhalation changes.

Of 6 who showed definite inhalation changes in 1936, five continue to do so, no definite change in the intensity of the abnormalities being seen. The remaining case has become negative, the film showing no specific dust changes.

125. This last result is most important. The total disappearance of a definite pneumoconiosis has not been described by other observers. In those men who continued to work at welding it was reasonable to expect some increase in the x-ray changes either as regards intensity of the lesions, or in the incidence. There has been no increase in the intensity of the lesions in any case, and nothing approaching to coalescence or the formation of massive shadows, as occurs in silicosis, has been observed. The incidence has, however, increased with the further exposure to fume, as shown by one of the negative cases, and both the suspicious cases now being positive. A decrease of the intensity of the lesions to the point of their disappearance is however something new. The welder in question was case 2 of Doig & McLaughlin's published series. He was first seen in 1934 when aged 35

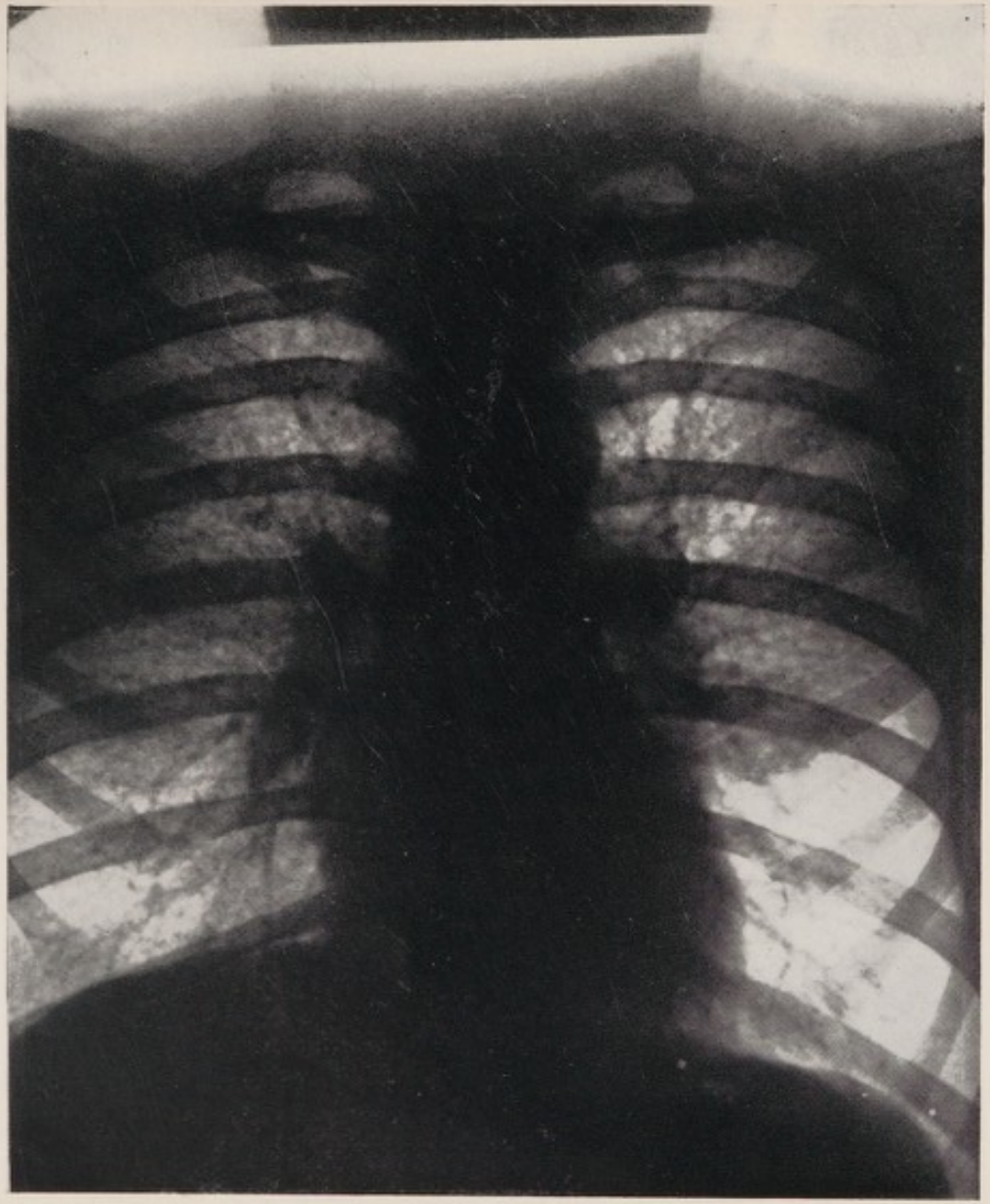


FIG. 1

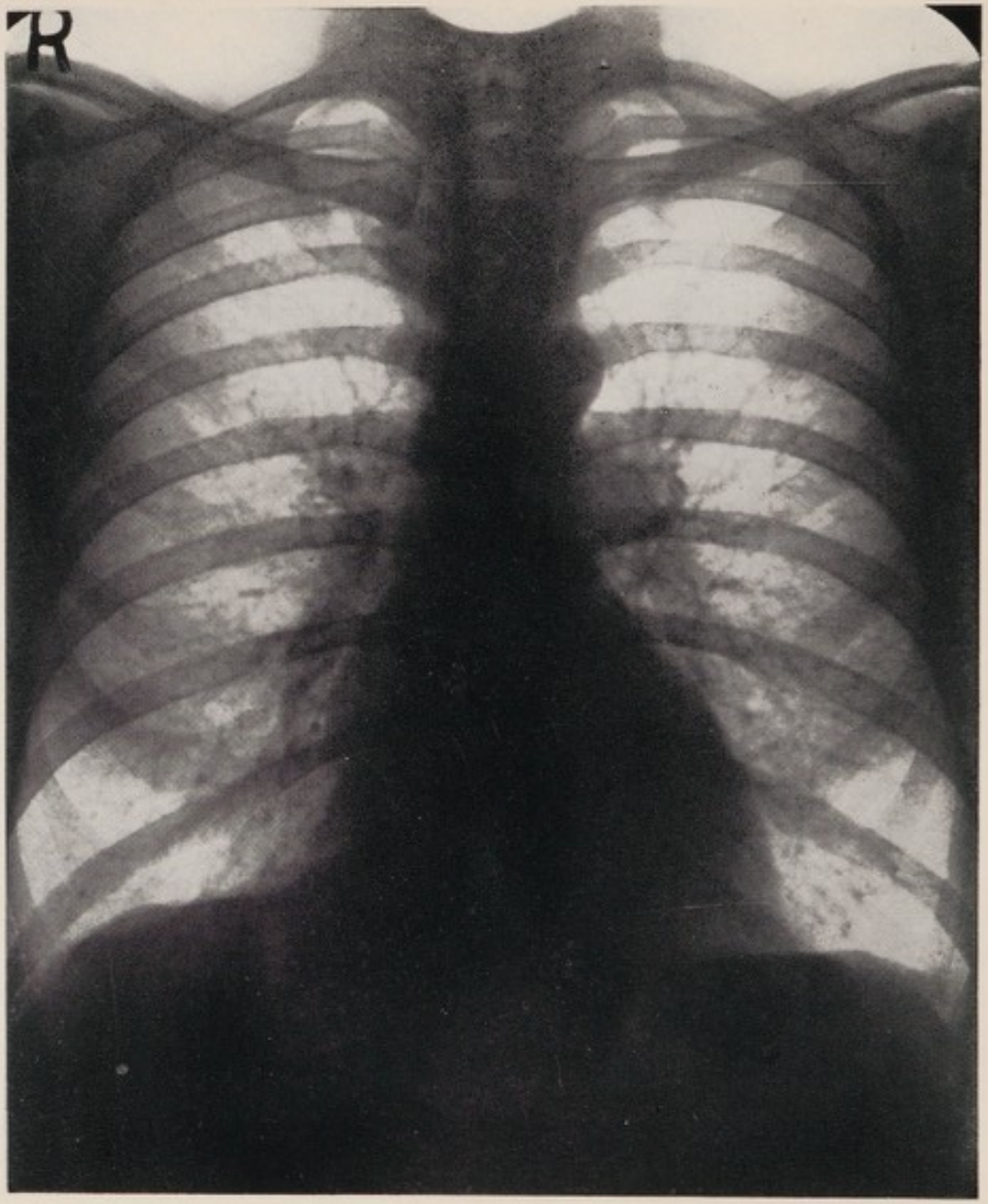
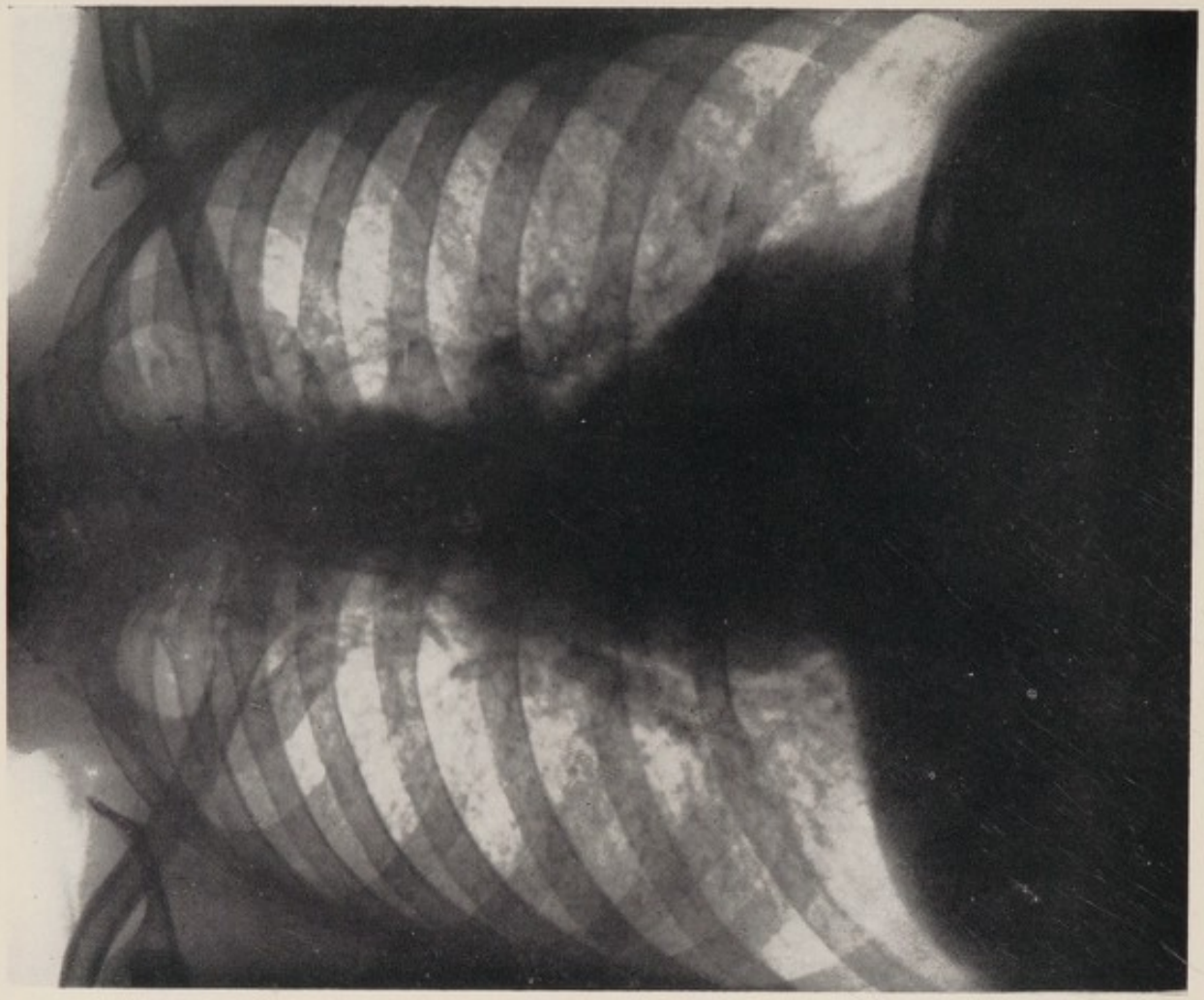
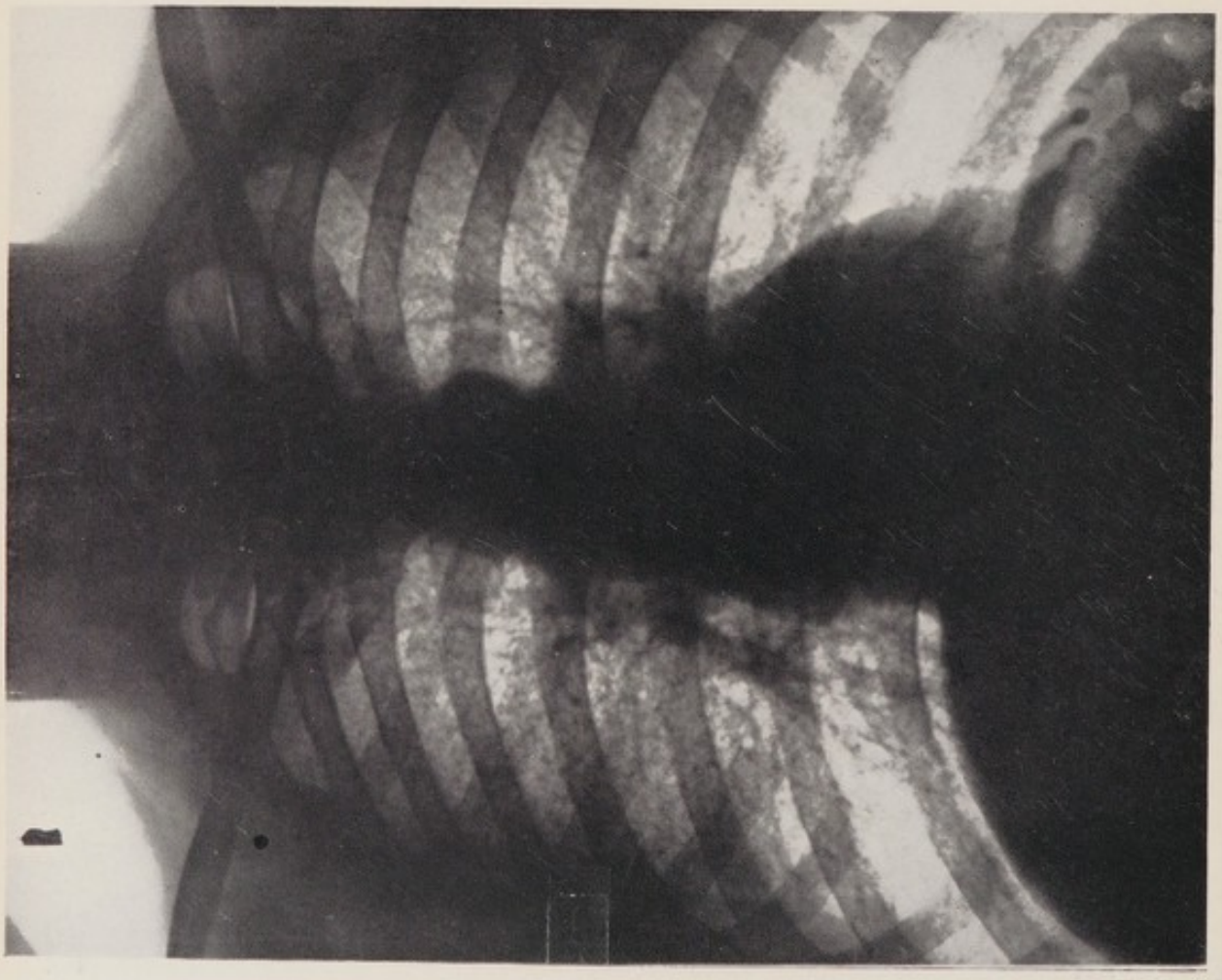


FIG. 2





when he had been an electric welder for 11 years having had no previous exposure to dust. Except for a slight cough and occasional morning sputum he felt in good health and was invited to attend for examination because he was a welder and not because of any possible ill health. He had performed a lot of enclosed work inside various types of storage tanks. Clinical examination revealed that the chest expansion was rather less than normal and that fine crepitations, persisting after cough, were present at the bases. X-ray examination showed a well-marked reticulation. On being told that his x-ray film was not normal the man gave up his work as a welder and became a storekeeper, and had no further exposure to dust or fume. He was examined and re-x-rayed at intervals until 1938. A film taken just over a year after he had given up welding showed that the changes were still present but that the individual lesions, consisting of the reticular strands in the lung fields had become rather blurred. Subsequent films until 1938 showed a continuation of the blurring with a definite decrease in the intensity of the changes. In 1945 he looked and felt well. He said he now did not experience the occasional feeling of constriction in the throat, cough and headache that he used to experience after welding in enclosed spaces. He still had a slight winter cough but no regular morning cough or sputum. Examination disclosed that the chest movements were of moderate degree, and that no abnormal physical signs were present. His x-ray film repeated in 1949, shows merely a slight accentuation of the linear markings without mottling or reticulation. (Figs 1 & 2.)

126. In regard to the question of disappearance of the x-ray abnormalities, the man who was case 1 in Doig & McLaughlin's series is also interesting although in this case the lesions have not entirely disappeared but merely retrogressed. He was seen at the age of 44 in 1933 having been a blacksmith, doing a small amount of electric welding, for 18 years, and a full time electric welder performing a good deal of enclosed work, for 11 years. Clinically he looked very fit, and chest examination showed little abnormality, although there was slight limitation of the chest expansion and a few post-tussic crepitations were heard at the bases. X-ray examination showed inhalation changes that, compared with other welders, must be described as intense. He was re-examined and x-rayed at intervals, without any appreciable change being found. In 1940 he ceased to be a full-time welder and became a welding instructor at a technical college. This meant that his exposure to welding fumes continued, but in much less degree. He says he now welds for only 25% of his working time and that in short breaks. In 1945 he stated he felt very well and had no symptoms. Clinically nothing abnormal was found. The x-ray film shows a considerable diminution in the intensity of the lesions both in regard to the reticulation and the nodulation. (Figs. 3. & 4.)

In 1949 the man was known to be well and at work. An x-ray film then showed no significant change compared with that taken in 1945.

127. These 2 cases then provide very considerable evidence of the inert nature of the pulmonary changes in electric welders, and would seem to confirm the view that these changes are due to deposited particulate matter (mainly iron) which lies in the lungs and their lymphatic vessels without producing any reaction ; the normal scavenging action of the lungs is not interfered with, and later, if the rate of intake of particulate matter falls below that of its removal, the x-ray lesions begin to disappear.

Tuberculosis, etc.

128. Two cases of active tuberculosis were discovered in the group of 249 persons. In one case the disease was manifest clinically and confirmed by x-ray and sputum examination; in the other the disease was in a very early

stage and only demonstrable by radiology. In both cases there was a family history of tuberculosis and it is not considered that welding had any effect either in precipitating the disease or in influencing its course. To this point Sander has paid special attention and as has been mentioned (see paragraph 44) describes the case of a welder who developed pulmonary tuberculosis and in whom spontaneous healing took place without discontinuing work as a welder.

One other of the 1936 cases of McLaughlin and Doig was examined. This man then aged 22, an electric welder for 4 years, had been found to have tuberculosis and had had sanatorium treatment including artificial pneumothorax. As regards inhalation changes his chest x-ray films were always negative. He made an excellent recovery and after 13 months returned to work with the same firm, not as a welder but as a fitter's labourer. When seen in 1945 he was an electrician's mate and was keeping in excellent health, a fact which was confirmed by the local Tuberculosis Officer.

The only other abnormality found in the lungs was a unilateral partial pneumothorax in a man aged 49, an oxy-acetylene welder for 25 years, who denied having had any previous serious illnesses and who felt in good health and was symptomless.

(l) GASTRO INTESTINAL SYSTEM

129. According to the history, the cases have been classed as :

1. Symptomless.

2. Slight indigestion, i.e. symptoms which have never necessitated loss of time from work, medical advice, or hospital investigation or treatment.

3. Moderate indigestion occasioning either lost time, medical treatment, or both.

4. Hospital cases, i.e. cases who have had hospital investigation or treatment.

(a) In whom gastric or duodenal ulcer was diagnosed.

(b) in whom no ulceration was found.

The results are shown in Table XXXI.

TABLE XXXI

GASTRO-INTESTINAL SYMPTOMS

	Electric Welding	Gas Welding	Mixed	Total
1. No symptoms ...	127 (69.4%)	30 (76.9%)	13 (52%)	170 (68.8%)
2. Slight symptoms ...	32 (17.5%)	7 (17.9%)	7 (28%)	46 (18.6%)
mainly acidity ...	13	2	3	18
mainly nausea ...	14	5	4	23
mainly pain ...	5	—	—	5
3. Medical advice or lost time	10 (5.5%)	1	4	15 (6.1%)
4. Hospital investigation	14 (7.6%)	1	1	16 (6.5%)
a } Ulcer	7	1	1	9
b } No ulcer ...	7	—	—	7

Having regard to the slightness of the symptoms in some cases it does not appear to me that these results suggest a higher incidence of gastro-intestinal complaints in welders.

130. The incidence is no higher in the 120 welders who have performed a substantial amount of enclosed work as is shown in Table XXXII(a). This suggests that although slight symptoms of gastric upset may be experienced after work in ill-ventilated spaces this has had no effect in producing long term indigestion or peptic ulceration.

TABLE XXXII (a)

GASTRO-INTESTINAL SYMPTOMS IN WELDERS WORKING IN CONFINED SPACES

	Electric Welding	Gas Welding	Mixed	Total
1. No symptoms ...	74 (69.8%)	5 (71.4%)	4 (57.1%)	83 (69.2%)
2. Slight symptoms ...	18 (17%)	1	2	21 (17.5%)
3. Medical advice or lost time ...	6	1	1	8 (6.7%)
4. Hospital investigation	8 (7.5%)	—	—	8 (6.7%)

Had the gastro-intestinal symptoms been due to the work one would have expected that the welders with such symptoms would have had a longer duration of employment than those without symptoms. This is not so as can be seen by comparing the average duration of employment of the affected welders with the figures for the whole group. (Paras. 76-79.)

TABLE XXXII(b)

WELDERS WITH GASTRO-INTESTINAL SYMPTOMS
AVERAGE AGES AND DURATION OF WORK

	Gastro-intestinal Symptoms		All Welders
	Average Age	Average Duration of Work	Average Duration of Work
56 Electric Welders ...	31.3 years	11.3 years	11.4 years
9 Gas Welders ...	39.4 years	17.9 years	17.8 years
12 Mixed Welders ...	40.5 years	13.5 years	14.5 years
Total	35.3 years	12.4 years	12.7 years

One must conclude, therefore, that welding has played no significant part in producing indigestion in the group of welders under review.

(m) RHEUMATISM

131. 196 welders gave negative answers as regards rheumatic complaints. Twelve mentioned twinges of pain in joints, usually the shoulder or knees, sometimes across the back, which did not occasion loss of time and which were attributed to working in a cramped position. 37 mentioned symptoms

indicating some form of rheumatism and the type is indicated in the table below as to whether the rheumatism was mainly of the arthitic or joint variety, the muscular variety mainly represented by lumbago, or the nerve variety such as neuritis and sciatica. Many of these cases were only slight in degree and had occasioned little loss of time. Others were rather more severe and led to some weeks absence from work almost every winter. Only one case showed the advanced changes of articular rheumatism characterised by deformity of the fingers, hand and wrists and ulnar deviation of the fingers.

TABLE XXXIII

RHEUMATISM

	Electric Welding	Gas Welding	Mixed	Total
1. No rheumatism ...	144 (78.7%)	32 (82.1%)	20 (80%)	196 (79.4%)
2. Twinges, especially due to awkward posture	9	2	1	12
3. Rheumatism ...	28 (15.3%)	5 (12.8%)	4 (16%)	37 (15%)
Joints	6	3	2	11
Muscular ...	19	1	1	21
Neuritis	3	1	1	5
4. Doubtful	2	—	—	2

Four of the cases in the "rheumatism" group had suffered from acute rheumatic fever and in three of these the first attack had taken place before being employed on welding, the symptoms experienced later being no doubt sequelæ of the original illness.

The two cases classed as doubtful complained of backache which was almost certainly due to kidney trouble. Case 28 was suspected to have a calculus, and case 113 had had nephrectomy after a street accident and had suffered from backache since the operation.

132. No evidence was found of interference with function of the hands or fingers as a result of holding the electrode holder or torch. Stiffness in the fingers from working with heavy gauge rods or from holding the torch for long periods does occur and may be accentuated by heat from badly designed or faulty electrode holders, but this passes off after ceasing work and cannot be classed as dysfunction.

Trigger finger[1] was entirely absent in this series although men were questioned particularly as to its occurrence.

(n) NERVOUS SYSTEM

133. No evidence was found of any involvement of the central or peripheral nervous system.

Particular attention was paid to the group of men who had been engaged on welding high manganese steel. To the 13 men shown in Table X as having spent more than 25% of their working time on this type of steel can

[1] Trigger finger is an acquired condition in which a finger or thumb is prone to lock in one position, normal movement being obstructed, and the other hand having to be employed to effect the completion of the movement. The obstacle to movement is usually overcome with a jerk or snap, suggesting a resemblance to the trigger of a gun.

be added another three who have spent rather less than this proportion of their time at the work. It is estimated that this group of men have spent in the aggregate 164 years welding this type of steel, an average of $10\frac{1}{4}$ years per man. The man with the longest experience is case 125, aged 62 with 37 years of welding, 30 of which, until 1939, were spent working on no other type of metal than high manganese steel. Four others had spent more than 10 years at this work. In each case this type of welding had been performed in an open shop and none of the men had performed substantial amounts of enclosed work. In all 16 cases there was found normal gait, facies and speech, disturbances of which are the outstanding characteristics of chronic manganese poisoning. Patellar reflexes were rather brisker than normal in three cases, one of whom was case 125 with the longest experience, and another was case 136 with the shortest experience—only about a year. Case 125 also showed rather sluggish pupils, the only one to do so, and a fine tremor. Fine tremor was also found in case 135 but in no others. Romberg's sign was absent in all cases.

No evidence has been found therefore of any degree of poisoning by manganese in welders working in open workrooms on steel containing 12-14% of manganese.

Three of this group show definite x-ray changes in the lungs of the inhalation type but the welding experience of these men, 16, 34 & 37 years, seems sufficient to account for these changes without attributing any particular significance to this special type of work.

(o) ENDOCRINE SYSTEM

134. No evidence of involvement of the endocrine system was found.

Enlargement of the thyroid with slight hyperthyroidism was found in only one man, case 77. He was aged 28 and had been welding for $3\frac{1}{2}$ years, broken by army service. His first symptoms tachycardia and weakness, appeared when he was 17 years old, that is 5 years before he commenced welding. He was however accepted for the army in 1941, his goitre being apparently considered non-toxic. This case has obviously no occupational etiology.

135. In 111 unselected cases the pulse rate was taken. It was performed after the man had been seated for 5-10 minutes giving particulars of his history and present health and before the clinical part of the examination commenced. The rates were as follows :—

Pulse rate less than 80 per minute	...	50 cases
Pulse rate between 80 & 88 per minute	...	40 cases
Pulse rate between 90 & 98 per minute	...	11 cases
Pulse rate between 100 & 118 per minute		7 cases
Pulse rate more than 118 per minute	...	3 cases

136. Mention may be made of one man, case 48, aged 32, who had been an oxy-acetylene welder for 16 years. He was of fairly good build and moderate nutrition, but pale. There had recently been a marked falling out of the hair which had left him nearly bald. He was of a nervous disposition and showed a marked tachycardia at first with irregularity of the pulse. He suffered from periodical indigestion and stated he had been worrying about his hair. I found no evidence of organic disease. This case seems to be of the type described by Kny (Arch. f. Gewerbepth u. Gewerbehyg, 1942, 11.369) as "welders disease" and also approximates to some of those described by Warrick (Arch. f. Gewerbeh u. Gewerbefs, 1939, 9.1). As this is the only case in this series one cannot attribute any etiological significance to his occupation as a welder.

(p) BLOOD PRESSURE

137. The classification adopted for recording the blood pressures of the group examined is as follows :—

(a) Systolic pressure below 110 mm. Hg.

(b) Systolic pressure 110-149 mm. Hg. and diastolic less than 90 mm. Hg.

(c) Systolic pressure 150-159 mm. Hg. or diastolic 90-94 mm. Hg. or both.

(d) Systolic pressure 160-179 mm. Hg. with diastolic under 100 mm. Hg., or systolic pressure under 160 mm. Hg. with diastolic 95-99 mm. Hg.

(e) Systolic pressure 180 mm. Hg. or over or diastolic 100 mm. Hg. or over, or both.

TABLE XXXIV
BLOOD PRESSURE

Group	Electric Welding	Gas Welding	Mixed	Total
a	3	1	1	5
b	114 } 125	12 } 14	12 } 18	138 } 157
c	8	1	5	14
d	7	1	—	8
e	6	1	—	7

The classification adopted is based on that used in the investigation into chronic pulmonary disease in South Wales coal miners by the Medical Research Council (M.R.C. Special Report Series No. 243). In that investigation three classes were used. The normal group in that investigation, Group A, was defined as " systolic under 160 mm. with diastolic under 95 mm. ". It will be seen that this group corresponds to the conbined a, b, & c groups of my classification. This splitting of Group A was done in order to obtain more precise information, especially as regards the possibility that welders might develop a lowered blood pressure. The abnormal groups b & c of the M.R.C. investigation correspond to the groups d & e of my classification.

The table shows that the distribution of blood pressure appears to be normal, there being no loading at either end of the scale.

(q) EXERCISE TOLERANCE

138. The exercise tolerance test was carried out on 120 men consecutively. Each subject placed and kept a foot on the seat of a chair approximately 18″ in height, and raised the body to the erect position on the chair 20 times in 60 seconds. The degree of respiratory embarrassment was then estimated and recorded as in one of four categories—category 1, no, or only slight, respiratory embarrassment; 2, definitely breathless; 3, respiratory distress; 4, breathless at rest;—or in the intermediate half category 1½. This test and classification was that adopted by the M.R.C. workers in their investigation into chronic pulmonary disease in South Wales Coalminers (Hart et al, 1942).

The results are shown in Table XXXV.

TABLE XXXV

EXERCISE TOLERANCE

	Electric Welders	Gas Welders	Mixed	Total
Category 1	85	8	7	100
„ 1½	13	1	1	15
„ 2	2	—	—	2
„ 3	1	2	—	3
	101	11	8	120

The diminished exercise tolerance of the men in categories 2 & 3 can be accounted for by conditions other than welding. The two cases in category 2 comprise the following men :—

Case 125. Age 62, electric welder for 37 years. States that welding has not affected health. Loses little working time.

Case 131. Age 43, electric welder for 8 years. Nervous disposition. Dizzy turns and moderate health since his mother's death 4 months previously.

In category 3 are :—

Case 132. Age 61, electric welding 10 years. Very corpulent, florid, and showing slight dyspnœa during examination.

Case 137. Age 58, gas welder 34 years. Has valvular disease of the heart, with loud blowing systolic murmer in all areas.

Case 156. Age 56, gas welder 20 years. Corpulent. Had "myocarditis" 2 years previously.

The average age and welding experience in the different categories is shown below :—

TABLE XXXVI

EXERCISE TOLERANCE : AGE AND WELDING EXPERIENCE

	Average Age	Average Welding Experience
Category 1	30.3	11
Category 1½	37.9	15.9
Category 2 & 3	56	21.8

139. In this group of 120 persons there were 77 who were x-rayed (67 electric welders, 9 gas welders and 1 mixed welder). 13 showed changes of

the inhalation type. Of these 6 (46.2%) were in category 1. Of the 64 without definite inhalation changes 61 (95.3%) were in category 1. There is thus a much higher proportion of persons with a lowered exercise tolerance in the group showing inhalation type changes but again age can be shown to play an important part. The six welders with inhalation type changes and with a normal (category 1) exercise tolerance had an average age of 33.2 years, whereas the 7 with a lowered exercise tolerance had an average age of 48.7 years. 5 of these men were placed in category 1½, their capacity for exercise being only slightly lowered, hardly to the extent of being pathological. The remaining two were men whose diminished capacity for exercise could be explained by other causes being cases 125 (aged 62 years) and 137 (with valvular lesion of heart) already mentioned.

This analysis suggests that the work of welding does not lead to any impaired exercise tolerance, for of 120 men with an average of 12 years welding experience, only 5 men have a definitely abnormal capacity for exercise, and in each of these cases a sufficient reason other than any presumed effect of welding fumes exists, i.e., age, nervous debility, corpulence or impaired heart function. Even in the presence of lung changes due to inhalation of fume particles, exercise tolerance was classed as definitely abnormal in only two cases, in both of which an adequate non-occupational cause exists.

(r) BLOOD EXAMINATIONS

140. In 36 cases blood examinations were made, the men being quite unselected and comprising the first two or three men presenting themselves in a session. There were 25 electric welders, 3 gas welders, and 8 mixed welders. Unfortunately owing to accidental factors complete examinations were attained in only 30 cases. The results are shown below :—

Hæmoglobin (30 cases)	11-12 gms/100 c.c. ...	4 cases
	12-15 gms/100 c.c. ...	21 cases
	more than 15 gms/100 c.c.	5 cases
Red Cells (31 cases)	less than 4 million/c.mm.	1 case
	4-5 million/c.mm. ...	10 cases
	5-6 million/c.mm. ...	20 cases
White Cells (35 cases)	less than 5,000/c.mm. ...	1 case
	5,000-7,000/c.mm. ...	7 cases
	7,000-10,000/c.mm. ...	15 cases
	10,000-14,000/c.mm. ...	11 cases
	more than 14,000/c.mm. ...	1 case

DIFFERENTIAL COUNTS

Polymorphs

Relative Counts (36 cases)		Absolute Counts (35 cases)		
35—45%	6	1,000—2,000	1	
		2,000—3,000	3	11
45—55%	17	3,000—4,000	7	
55—65%	12	4,000—5,000	9	
		5,000—6,000	8	
65—75%	1	6,000—7,000	4	24
		7,000—8,000	2	
		8,000—9,000	1	

Lymphocytes

Relative Counts (36 cases)		Absolute Counts (35 Cases)		
25—35%	10	1,000—2,000	1	11
		2,000—3,000	10	
35—45%	18			
		3,000—4,000	13	24
45—55%	5	4,000—5,000	9	
		5,000—6,000	2	
55—65%	3			

141. The hæmoglobin counts do not call for much comment being generally at a very satisfactory level. Red cell counts somewhat above normal were met with in almost two-thirds of the cases. The white cell count shows evidence of a fairly frequent mild leucocytosis in which polymorphs and lymphocytes share, the latter to a relatively greater extent as shown by the relative counts. Twelve cases with leucocyte counts over 10,000 were electric welders although one was technically classed as a mixed welder because he had performed a substantial amount of his time as an oxy-acetylene welder. Inhalation of fume from galvanized metal or alloy steel cannot be the cause of the leucocytosis as ten of the men were engaged in mild steel work only. Neither is there any correlation with the amount of enclosed work performed as only three of the men have been substantially engaged on this. There is no relation between it and the presence of colds, sore throats or other temporary infections. It is possibly due to the inhalation of fume from mild steel. However if this were so one would have expected to find it more frequently in those engaged in enclosed work, but this is not so. Thirteen of the men who had blood examinations were engaged in enclosed work but only three had counts exceeding 10,000 and 5 had counts less than 7,000.

This alteration of the blood picture is of slight degree and is not associated with the presence of any degree of anæmia, or with abnormal red or white blood cells. It may be due to dietic or social reasons or to some stimulating effect on the hæmopœtic system by the fumes. Leucocytosis in cases of metal fume fever is known to occur, (Sturgis et al, 1927; Drinker et al, 1927), and it has been suggested that iron oxide may cause metal fume fever (Holstein, 1930; Schiotz, 1947; Ariola, quoted by Kœlsch, 1923) although this is unconfirmed and denied by some workers. It may be that freshly formed iron oxide, or other fume constituent, produces a symptomless condition which falls short of metal fume fever but leads to the establishment of a mild leucocytosis.

142. Further blood examinations in welders have been undertaken by Dr. Ethel Browning of the Department, and her report follows. It will be seen that her results are very similar to those given above, although the increase in red and white cell counts is less frequent and milder in degree.

Blood examinations were made in 100 unselected welders, 93 males, 7 females, employed in shipyards. 84 were electric welders, 4 were gas welders and 12 were mixed gas and electric welders.

		Cases		
		Male	*Female*	*Total*
Hæmoglobin	10-11 gms./100 c.c.	1	0	1
	11-12 gms./100 c.c.	1	1	2
	12-15 gms./100 c.c.	54	6	60
	more than 15 gms./100 c.c.	37	0	37
		93	7	100

Red Cells	Less than 4 million/c.mm.	0	0	0
	4-5 million/c.mm.	37	6	43
	5-6 million/c.mm.	54	1	55
	more than 6 million/c.mm.	2	0	2
		93	7	100
White Cells	Less than 5,000/c.mm.	3	0	3
	5,000-7,000/c.mm	30	3	33
	7,000-10,000/c.mm.	52	3	55
	10,000-14,000/c.mm.	8	1	9
	More than 14,000/c.mm.	0	0	0
		93	7	100

DIFFERENTIAL COUNTS

Polymorphs

Relative Counts				Absolute Counts			
	Male	*Female*	*Total*		*Male*	*Female*	*Total*
30—35%	2	0	2	1,000—2,000	1	0	1
35—45%	10	1	11	2,000—3,000	18	1	19
45—55%	39	2	41	3,000—4,000	31	3	34
55—65%	36	4	40	4,000—5,000	23	2	25
more than 65%	6	0	6	5,000—6,000	14	1	15
				6,000—7,000	4	0	4
	93	7	100	7,000—8,000	2	0	2
				8,000—9,000	0	0	0
					93	7	100

Lymphocytes

Relative Counts				Absolute Counts			
	Male	*Female*	*Total*		*Male*	*Female*	*Total*
Less than 25%	2	0	2	1,000—2,000	6	0	6
25—35%	27	3	30	2,000—3,000	49	4	53
35—45%	40	2	42	3,000—4,000	26	2	28
45—55%	21	2	23	4,000—5,000	11	1	12
55—65%	3	0	3	5,000—6,000	1	0	1
				6,000—7,000	0	0	0
	93	7	100		93	7	100

Gas Welders Only (4 cases)

Hæmoglobin	12-15 gms./100 c.c.	4
	over 15 gms./100 c.c. ...	0
Red Cells	over 5 million	2
White Cells	over 10,000	1
Relative Lymphocytosis	... ...	1

Gas and Electric Welders (12 cases)

Hæmoglobin	12-15 gms./100 c.c.	11
	over 15 gms./100 c.c.	1
Red Cells	over 5 million	4
White Cells	over 10,000	1
Relative Lymphocytosis	... ...	1
Leucopenia	... ...	1

The results show a fairly high incidence of high total red cell counts and hæmoglobin levels, a tendency to high total white cells and relative lymphocytosis. Thus, hæmoglobin levels of over 15 gms. per 100 cc. were found in 37%, total red cell counts over 5 millions per c.mm. in 55%, total white cell counts over 10,000 in 9%, and a lymphocyte percentage over 45% in 26%."

143. Combining Dr. Browning's results with those given above and recording the findings for electric welders, gas welders and mixed welders, the following results are obtained :—

Hæmoglobin over 15 *mgms.*/100 *c.c.*

Electric Welders	...	39 cases out of 105 subjects	= 37.1%
Gas Welders ...	...	0 cases out of 7 subjects	
Mixed Welders	...	3 cases out of 18 subjects	= 16.6%
Total	...	42 cases out of 130 subjects	= 32.3%

Red cells over 5 million per c.mm.

Electric Welders	...	65 cases out of 106 subjects	= 61.3%
Gas Welders ...	...	3 cases out of 6 subjects	
Mixed Welders	...	9 cases out of 19 subjects	= 47.4%
Total	...	77 cases out of 131 subjects	= 58.8%

White cells over 10,000 *per c.mm.*

Electric Welders	...	18 cases out of 108 subjects	= 16.6%
Gas Welders ...	...	1 case out of 6 subjects	
Mixed Welders	...	2 cases out of 21 subjects	= 9.5%
Total	...	21 cases out of 135 subjects	= 15.5%

Relative Lymphocytosis over 45%

Electric Welders	...	29 cases out of 109 subjects	= 26.6%
Gas Welders ...	...	2 cases out of 7 subjects	
Mixed Welders	...	3 cases out of 20 subjects	= 15.0%
Total	...	34 cases out of 136 subjects	= 25.0%

WELDING SHOP FOREMEN

144. McLaughlin & Doig had included two welding shop foremen in their 1936 series, in order to ascertain whether their exposure to fumes in the welding shop over a number of years had produced any effects. Neither of these men had ever performed welding, and in both cases examination, clinical and radiological was negative.

In November, 1944, the men were aged 36 and 58 and had 18 years and 21 years employment respectively in the welding shop. Both were found to be in good health and there were no symptoms or abnormal signs relating to the skin, eyes, nose or throat or digestive tracts. One man had some cough but in both cases the lungs were found to be quite normal on clinical and radiological examination.

Evidence from Statistics

145. It is extremely difficult to obtain up to date and reliable sets of figures comparing the sickness records of welders with other workmen. Many full-time works medical officers of factories where much welding is performed have been written to in an endeavour to obtain information relating to large numbers of welders, but with comparatively little success. Some of the doctors

sent me some figures relating to the health or attendance records of welders which, being based on only a few welders or over a period of only a few months, were of little value. During the war owing to lack of staff and other difficulties many firms cut down their office work to essentials. Most of those which did analyse the amount of sickness amongst their workers did so on a broad basis finding the average amount of sickness absence for all workers or comparing that of males with females. If sub-divisions were made they usually related to different departments of the factory, not to special occupations. Sometimes also where a satisfactory system of recording sickness in different occupations was in vogue the number of welders employed was too small to be of value. The following information comprises that which I have been able to collect on the subject from sources in this country.

146. With regard to mortality of welders the most recent information I have is that obtained from the Registrar General's Decennial Report relating to the years 1930-32. At the Census of 1931 there were in England and Wales 11,541 welders and cutters (electrical and oxy-acetylene) who were classified as a separate group (163) in the Occupational Mortality Supplement on page 311. The deaths in this group totalled 123 compared with 161 expected on the basis of the age-rates of all males, and no cause of death distinguished showed any excess except pneumonia (15 as compared with 13 standard). These figures are valuable and reassuring, but it must be remembered that in 1930-32 welding was a comparatively new process and we cannot be sure that the position is the same today. It is unfortunate that no more recent figures are available, and will not be available at the General Register Office until the publication of the Registrar General's next Report on Occupational Mortality.

147. With regard to morbidity I obtained very helpful information from the Medical Officer of a large dry dock and shiprepairing Association (Firm A). This relates to sickness absence of various groups of workers subdivided into cardiovascular, respiratory, gastro-intestinal, rheumatic, and unclassified causes. The tables relating to the years 1943-44, 1944-45, 1945-46, and 1946-47 are considered to be of such value as to warrant their being given in full.

TABLE XXXVII

FIRM A — ANNUAL SICKNESS ABSENTEE RETURN — JULY 1943/JUNE 1944

Occupation	Average No. of Workers	Manpower days in period	Absentees	Manpower days lost in period		Over 28 days duration		Cardio-Vascular			Gastro-Intestinal			Respiratory			Rheumatic			Unclassified		
				No.	%	No.	%	Men	Days	%	Men	Days	%	Men	Days	%	Men	Days	%	Men	Days	%
Arc Welders and Mates ...	239	87474	115	1281	1.39	261	.23				29	283	.32	49	472	.53	8	69	.07	29	394	.45
Blacksmiths and Strikers ...	226	82716	104	2664	3.22	1756	2.12	1	37	.04	5	178	.21	50	1121	1.35	14	423	.51	34	905	1.09
Coppersmiths	72	26352	20	293	1.11	70	.26				1	18	.06	11	171	.64	3	30	.11	5	74	.28
Coverers	118	43188	48	904	2.09	567	1.31				6	146	.33	25	434	1.00	5	79	.18	12	245	.56
Drillers and Boys	128	46848	62	1002	2.13	537	1.14	3	65	.13	8	75	.16	32	513	.109	7	98	.20	12	251	.53
Electricians and Assistants ...	914	334524	388	7163	2.14	3844	1.14	4	101	.03	46	832	.24	205	3290	.98	31	647	.19	102	2293	.68
Fitters, Turners and Mates ...	1919	702354	871	18310	2.60	10769	1.53	15	468	.06	108	2551	.36	403	7243	1.03	100	1984	.28	245	6064	.86
Foundry Workers Inc. Labs. ...	107	39162	18	463	1.17	274	.69				3	118	.30	6	122	.31	3	121	.30	6	102	.26
Joiners and Patternmakers ...	869	318054	300	6106	1.92	3618	1.13	1	20	.01	40	825	.25	137	2541	.79	39	832	.26	83	1888	.59
Painters and Polishers	514	188124	343	9240	4.91	6445	3.42	21	1119	.59	29	1021	.54	143	2936	1.56	44	998	.53	106	3166	1.68
Platers, Riveters, Helpers ...	2100	768600	855	20167	2.61	12520	1.62	16	824	.10	102	2720	.35	434	9808	1.27	95	1856	.24	208	4956	.64
Plumbers and Mates	738	270108	400	8204	3.03	4761	1.76	8	234	.08	55	1181	.43	177	3346	1.23	32	599	.22	128	2844	1.05
Scalers	572	209352	212	4566	2.18	2596	1.25	2	28	.01	27	573	.27	86	1960	1.23	34	559	.26	63	1446	.69
Shipwrights	578	211548	204	4222	1.99	2213	1.04	2	52	.02	18	297	.14	109	1796	.84	16	413	.19	59	1664	.78
Tinsmiths (S.M. Workers) ...	102	37332	39	750	2.01	336	.90	1	5	.01	6	117	.31	15	259	.69	5	65	.17	12	305	.81
General Labourers	2043	747738	851	19540	2.61	12721	1.70	14	526	.07	118	2572	.34	334	7766	1.03	90	1574	.21	295	7102	.94
Totals	11239	4113474	4830	104812	2.54	63288	1.53	88	3478	.08	601	13507	.32	2216	43778	1.06	526	10347	.25	1399	33702	.81

TABLE XXXVIII

FIRM A — ANNUAL SICKNESS ABSENTEE RETURN — JULY 1944/JUNE 1945

Occupation	Average No. of Workers	Manpower days in period	Absentees	Manpower days lost in period		Over 28 days duration		Cardio-Vascular			Gastro-Intestinal			Respiratory			Rheumatic			Unclassified		
				No.	%	No.	%	Men	Days	%	Men	Days	%	Men	Days	%	Men	Days	%	Men	Days	%
Arc Welders and Mates ...	267	97455	109	2255	2.31	1397	1.43	1	60	.06	21	659	.67	49	944	.96	5	51	.05	33	541	.55
Blacksmiths and Strikers ...	222	81030	88	3117	3.3	2630	3.23	2	99	.12	9	289	.35	34	1188	1.46	10	308	.37	33	1233	1.55
Coppersmiths	65	23725	20	420	1.77	236	.99	1	9	.03	2	98	.41	8	146	.61	3	44	.18	6	123	.52
Coverers	93	33945	28	654	1.92	380	1.12	—	—	—	3	88	.25	14	320	.94	3	49	.14	8	197	.58
Drillers and Boys	127	46355	37	825	1.78	595	1.28	—	—	—	7	244	.52	11	152	.32	5	195	.42	14	234	.50
Electricians and Assistants ...	871	317915	313	8646	2.71	6294	1.98	2	101	.03	50	1170	.36	122	2879	.90	33	512	.16	106	3984	1.25
Fitters, Turners and Mates ...	1950	711750	800	21696	3.04	15049	2.11	18	717	.10	131	3767	.52	296	7280	1.02	93	2518	.35	262	7414	1.04
Foundry Wkrs. Inc. Labs. ...	100	36500	14	337	.92	221	.60	—	—	—	4	176	.48	4	68	.18	—	—	—	6	93	.25
Joiners and Patternmakers ...	770	281050	263	8170	2.90	6193	2.20	5	260	.09	33	777	.27	101	2810	1.00	31	944	.33	93	2279	1.20
Painters and Polishers	483	176295	263	9030	5.12	6568	3.72	17	1378	.78	39	1229	.69	103	2920	1.66	43	1232	.69	61	2271	1.29
Platers, Riveters, Helpers ...	2076	757740	906	27255	3.59	19976	2.57	17	686	.09	119	3644	.48	361	10400	1.37	109	2867	.37	300	9658	1.27
Plumbers and Mates	624	227760	225	5981	2.62	4232	1.85	3	99	.04	51	1486	.65	81	1792	.78	29	940	.41	61	1664	.73
Scalers	564	205860	197	5475	2.66	4025	1.95	2	27	.01	30	583	.28	60	1533	.74	18	491	.24	87	2841	1.38
Shipwrights	524	191260	168	4164	2.17	2786	1.45	2	85	.04	9	207	.10	74	1501	.79	46	1434	.75	37	937	.49
Tinsmiths	93	33945	55	819	2.41	428	1.26	1	14	.04	7	84	.24	11	229	.67	5	104	.31	11	388	1.14
General Labourers	1913	698245	845	22034	3.15	13839	1.98	11	340	.04	123	2906	.41	337	8231	1.18	109	3020	.43	265	7537	1.08
Total	10742	3920830	4311	120878	3.08	84849	2.16	82	3875	.09	638	17407	.44	1666	42393	1.08	542	14709	.37	1383	42494	1.09

TABLE XXXIX

FIRM A — ANNUAL SICKNESS ABSENTEE RETURN — JULY 1945/JUNE 1946

Occupation	Average No. of Workers	Manpower days in period	Absentees	Manpower days lost in period		Over 28 days duration		Cardio-Vascular			Gastro-Intestinal			Respiratory			Rheumatic			Unclassified		
				No.	%	No.	%	Men	Days	%	Men	Days	%	Men	Days	%	Men	Days	%	Men	Days	%
Arc Welders and Mates ...	210	76650	64	1590	2.07	1021	1.33	1	12	.01	7	237	.31	30	581	.75	7	305	.39	19	455	.60
Blacksmiths and Strikers ...	220	80300	92	2012	2.50	1211	1.50	1	8	.01	14	255	.31	43	1083	1.35	18	320	.39	16	346	.43
Coppersmiths	60	21900	20	415	1.89	229	1.04	—	—	—	2	34	.15	9	235	1.07	3	43	.19	6	103	.47
Coverers	75	27375	25	456	1.66	245	.89	—	—	—	2	16	.05	12	269	.98	—	—	—	11	171	.62
Drillers and Boys	102	37230	45	1295	3.47	975	2.61	6	297	.79	4	82	.22	13	276	.74	4	117	.31	18	523	1.40
Electricians and Assistants ...	775	282875	274	7379	2.60	4940	1.75	2	120	.04	29	902	.32	119	2826	1.00	38	1126	.39	86	2405	.85
Fitters and Mates	2107	769055	802	21765	2.83	15129	2.04	23	1190	.15	120	3321	.44	363	8257	1.07	71	1618	.21	225	7379	.95
Foundry Wkrs. Inc. Labs. ...	99	36135	35	500	1.38	229	.63	—	—	—	4	58	.16	14	252	.70	5	69	.19	12	121	.33
Joiners and Patternmakers ...	726	264990	233	5790	2.25	3847	1.45	2	29	.01	29	789	.29	99	2391	.90	27	497	.18	76	2264	.85
Painters and Polishers	571	208415	212	8051	3.86	6176	2.96	12	980	.47	26	642	.30	96	2361	1.13	28	1407	.67	50	2661	1.27
Platers, Riveters, Helpers ...	1895	691675	740	21265	3.07	15481	2.24	8	331	.04	88	2812	.40	367	10028	1.45	82	1809	.26	195	6285	.90
Plumbers and Mates	579	211335	231	6985	3.30	4980	2.35	—	—	—	42	1535	.72	110	2725	1.29	34	1508	.71	45	1217	.57
Scalers	571	208415	139	3669	1.76	2666	1.27	3	124	.06	25	592	.28	51	1295	.62	15	438	.21	45	1220	.58
Shipwrights	515	187975	133	3448	1.83	2174	1.15	4	122	.06	7	239	.12	48	906	.48	26	747	.39	48	1434	.76
Tinsmiths	100	36500	54	1035	2.83	560	1.53	—	—	—	12	215	.58	27	515	1.41	3	73	.20	12	232	.63
General Labourers	1973	720145	723	19173	2.66	12733	1.76	10	412	.05	93	2808	.39	298	7049	.97	93	2923	.41	229	5981	.83
Total	10578	3860970	3822	105008	2.70	72596	1.88	72	3625	.09	504	14537	.37	1699	41049	1.06	454	13000	.33	1903	32797	.84

TABLE XL

FIRM A — ANNUAL SICKNESS ABSENTEE RETURN — JULY 1946/JUNE 1947

Occupation	Average No. of Workers	Manpower days in period	Absentees	Manpower days lost in period		Over 28 days duration		Cardio-Vascular			Gastro-Intestinal			Respiratory			Rheumatic			Unclassified		
				No.	%	No.	%	Men	Days	%	Men	Days	%	Men	Days	%	Men	Days	%	Men	Days	%
Arc Welders and Mates ...	190	69350	39	621	.89	336	.47	—	—	—	4	27	.04	17	196	.28	5	124	.17	13	274	.39
Blacksmiths and Strikers ...	225	82125	83	2269	2.76	1527	1.85	2	85	.10	12	241	.29	40	1068	1.30	11	344	.42	18	531	.64
Coppersmiths	53	19345	22	478	2.47	257	1.32	—	—	—	1	41	.21	13	241	1.24	5	161	.83	3	35	.18
Coverers	18	6570	1	10	.15	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	10	.15
Drillers and Boys	90	32850	23	636	1.93	524	1.59	—	—	—	1	14	.04	7	90	.27	2	29	.08	13	513	1.56
Electricians and Assistants ...	692	252580	150	3629	1.43	2413	.95	—	—	—	24	498	.19	67	1615	.64	16	306	.12	43	1210	.48
Fitters and Mates	2146	783290	728	16898	2.15	11170	1.42	9	402	.05	105	2542	.32	313	6426	.82	90	1898	.24	211	5630	.72
Foundry Wkrs. Inc. Labs. ...	120	43800	20	390	.89	232	.53	—	—	—	6	164	.38	7	70	.16	3	107	.24	4	49	.11
Joiners and Patternmakers ...	834	304410	231	6291	2.06	4354	1.43	4	51	.01	36	1437	.47	101	2779	.91	26	565	.18	64	1459	.48
Painters and Polishers	662	241630	139	5048	2.08	4024	1.70	7	469	.19	11	204	.08	53	1440	.60	16	598	.24	52	2337	.96
Platers, Riveters, Helpers ...	1699	620135	686	19658	3.16	14241	2.29	9	246	.03	94	2555	.41	305	8845	1.42	88	2052	.33	190	5960	.96
Plumbers and Mates	542	197830	155	4531	2.29	3178	1.60	9	233	.12	26	955	.48	61	1492	.75	17	645	.32	42	1206	.61
Scalers	336	122640	84	2008	1.63	1197	.97	1	60	.04	10	334	.27	36	1001	.81	15	268	.22	22	345	.28
Shipwrights	502	183230	156	3514	1.91	2141	1.17	2	181	.09	17	267	.14	72	1597	.87	27	491	.27	38	978	.53
Tinsmiths	110	40150	42	592	1.47	58	.14	1	15	.03	11	194	.48	20	221	.55	3	40	.09	7	122	.30
General Labourers	2054	749710	584	15836	2.11	10951	1.46	13	687	.09	92	2706	.36	244	6546	.87	65	1230	.16	170	4667	.62
Total	10273	3749645	3143	82409	2.19	56603	1.49	57	2429	.06	450	12179	.32	1356	33627	.90	389	8848	.23	891	25326	.67

It will be seen that in all the periods, the arc welders and their mates compare favourably indeed with most other groups and for the total employees in regard to most subdivisions of the tables. The total manpower days lost in the period is consistently less for welders than for all employees, as also is the sickness of over 28 days duration. Respiratory illness is also lower for welders in all four periods and in 1943-44 was only a half of, and in 1946-47 was less than a quarter of that recorded for the whole group. Rheumatic diseases were less in 3 periods being slightly above the average in 1945-46 and gastro-intestinal diseases were less in 2 periods being greater than average in 1944-45 and exactly average in 1943-44.

This series of records, relating as it does to large numbers of employees, and enabling welders to be compared with other occupations in shipyards is the most valuable statistical information that has so far come to my hand regarding sickness absence in welders.

148. The late Professor Ryle of the Institute of Social Medicine, Oxford, sent me the following analysis relating to a metal work department of a large firm. (Firm B.) The figures relating to welders are based on a small group but bear out the information given in the preceding tables, namely, that the average number of days lost by welders due to respiratory illness, and from all causes, is less than that for all employees.

TABLE XLI

Shop	Total Possible Working Days	Respiratory Disease (Excluding colds and influenza)		All Causes		No. Employees Average Monthly
		Days Lost	%	Days Lost	%	
Welding ...	62285	140	.22	796	1.28	31
Soldering ...	104050	228	.22	779	.75	50
Assembly ...	31685	124	.39	1264	3.99	15
Petrol Tanks	83436	132	.16	1342	1.61	41
All Shops In Factory ...	2007201	7016	.35	551656	2.75	943

149. From another firm (Firm C) an analysis has been obtained of the monthly amount of absence from (a) all causes, and (b) for medical reasons only, in a group of 38 male electric welders and other male workers. The period covered is five months and the results shown below show that, here also male electric welders compare favourably with other males both as regards lost time from medical causes, and from all causes.

TABLE XLII

Month	Male Electric Welders			Other Males		
	No. of men	Hours lost per man —Medical Causes	Hours lost per man —All Causes	No. of men	Hours lost per man —Medical Causes	Hours lost per man —All Causes
May	38	8.21	41.045	326	17.484	136.38
June	38	4.421	32.842	325	10.264	72.381
July	38	24.00	57.157	325	7.79	77.28
August ...	38	2.21	25.894	306	10.666	85.215
September ...	38	1.263	36.000	306	11.267	87.528
Average for 5 months	38	8.020	38.589	317	11.494	91.756

150. Reliable figures have also been obtained from the medical department of a large engineering works (Firm D) with over 9,000 employees. The following table shows that over a period of a year the average days lost per welder is only about half of the average for the rest of the workers, and that this proportion holds good for the sub classifications, colds and influenza, digestive system, and rheumatism group, while diseases of the respiratory system have caused only about a quarter of the sickness in welders that it causes in other workers.

TABLE XLIII

Disease Code No.	Class of Sickness	Welders—All Classes—Electric, Gas, Spot, etc., Total Strength, 279				All other workers Total Strength, 8889			
		No. of Cases	No. of Days Lost	% of Total Days Lost	Average Days Lost per 100 Workers In Group	No. of Cases	No. of Days Lost	% of Total Days Lost	Average Days Lost per 100 Workers
1	Colds and Influenza ...	19	264	17.20	94.62	1207	15913	20.72	179.00
2	Respiratory System	6	82	5.35	29.39	700	11506	12.02	129.44
3	Digestive System	20	286	18.64	102.50	1150	18199	19.74	204.73
4	Rheumatism Group	8	151	9.84	54.12	551	8860	9.46	99.67
5	Nervous Disorders (Functional)	2	16	1.04	5.73	135	2345	2.31	26.38
6	Accidents at Work	12	230	14.99	82.43	424	6044	7.28	67.99
7	Unclassified ...	31	505	32.92	181.00	1656	27368	28.43	307.88
	Total	98	1534	99.98	549.79	5823	90235	99.96	1015.09

151. A further set of figures have been obtained from a large firm (Firm E) engaged in heavy engineering where about 60 welders were engaged, many of them welding high manganese steel. In this case the welders are shown to have a sickness and injury absence higher than the figure for the whole works, though only slightly so.

TABLE XLIV

ABSENCE DUE TO SICKNESS OR INJURY

	1942	1943	1944
Whole Works	5.4%	6.0%	5.8%
Welders	6.1%	6.5%	6.2%
Pattern Shop	—	—	5.6%
Foundry	—	—	6.0%
Fettling Shop	—	—	8.4%
No. 1 Machine Shop ...	—	—	6.7%

152. From a shipyard (Firm F) employing an average of 2,300 of whom about 100 are welders, information has been obtained that for the year 1945 the average hours lost per week for all workers was 5.37 and for welders 5.66. From another small Shipyard employing 237 workers the absence due to sickness for 12 months was 2.99 hours per man per week for all workers, and 1.86 hours for welders, but the total number of welders was only 8 so that these figures are not significant.

153. The statistical evidence that is available certainly suggests, therefore, that welders are favourably placed in regard to their sickness rates compared with non-welding workers.

SUMMARY

(A. T. Doig)

154. The literature relating to the effects of welding on health has been reviewed. That the occupation carries certain definite risks to health is not generally disputed. There is no question as to the effects of the ultra-violet rays in producing temporary kerato-conjunctivitis. The liability to gassing by nitric oxides while performing work in unventilated compartments, particularly when using the oxy-acetylene or other gas flame, is also accepted. Allegations of the harmful effects of other gases are generally vague or unsubstantiated but the possibility of poisoning from impurities in the gases used in gas welding must be borne in mind. Toxic effects of fumes arising from certain types of metal, e.g. some alloys, or from metallic coatings are also well known. These include metal fume fever, effects of cadmium, lead from volatilised paint or lead alloys, manganese, etc. Apart from specific poisonings it is recognised too that fumes either from the metal or electrodes may contain constituents which are obnoxious and lead to temporary irritation of the respiratory tract, e.g. fluorides. Furthermore the inhalation of fumes over many years may lead to changes in the x-ray picture of the lungs. The majority of investigators agree that this condition is not associated with pulmonary fibrosis or impaired working capacity. The changes are regarded as being due to the deposition in the lungs of the finely divided metallic particles of which the fume is composed, mainly iron oxide. Only one detailed description has been found in the literature of a post-mortem report on a welder who showed these changes during life. This confirmed the above assumption and the absence of fibrous tissue.

155. Apart from these generally accepted conditions reports have been made that welders may suffer more than the general population from various common forms of ill-health, for instance catarrhal infections of the respiratory tract, pneumonia, gastro-intestinal disorders. About these conditions there is a considerable diversity of opinion as there are about an equal number of reports opposing these views. Reports of a disease specific to welders, of liver damage, and of endocrine involvement made some years ago by various writers on the Continent have not been confirmed.

156. The clinical part of the investigation related to the examination of 247 male welders of whom 180 had x-ray films taken of the chest. The average age of the group was 34 years and the average length of welding experience was 12.7 years. The group consisted of 183 electric welders, 39 gas welders or burners, and 25 mixed welders who had performed both electric and gas welding.

157. Welders are exposed to sources of skin irritation mainly from the rays emitted from the arc but to some extent also from dust, oil and other contamination of the work. The usual clothing, together with gloves and face

shield are normally sufficient to give adequate protection from the rays. Sparks thrown off by sputtering of the arc may lead to multiple tiny burns of the skin—especially on the front of the trunk. Perhaps the result most complained of by the men is the disintegration of their clothing. Other sources of skin irritation would not appear to be important and are no more peculiar to welders than many other groups of metal workers. Occupational dermatitis in welders does not appear to be a frequent or serious cause of disability or discomfort.

158. Radiation from the arc has an intensely irritating effect on the conjunctiva leading to an acute painful congestive condition known as "arc eyes". The condition may be severe enough to be disabling but rarely for more than a day or two. It is not found in gas welders, unless they have been exposed to unscreened rays from a neighbouring arc. The literature contains reports of various effects on the lens and deeper structures of the eyeball attributed to welding but as these were largely unconfirmed and as no ophthalmological investigation appeared to have been made in this country such an investigation was carried out by Dr. J. D. Fraser, of the Department of Ophthalmology, Glasgow University. Dr. Fraser's investigation covered 50 electric welders working in shipyards. Their mean age was 33.5 ± 4.9 years and their welding experience 10 ± 4.3 years. They were compared with a group of shipyard non-welders of the same age groups and with similar economic backgrounds. Evidence of superficial irritation in the form of chronic conjunctivitis, mainly affecting the eyelids was found but Dr. Fraser found no evidence of any change in the lens, fundus or other deep structures of the eye, and he concludes that welders are adequately protected against infra-red radiation and, apart from carelessness or accidental exposure, against ultra-violet radiation also.

159. Slight and transient irritation of the throat and nose is not uncommon and is frequently experienced after work in confined spaces under conditions of inadequate ventilation. Depending on the constituents of the parent metal or electrodes, the fume arising from certain types of welding, for example galvanized metal or stainless steel, can be irritating even under conditions of good general ventilation. These effects are in general transitory and often amount only to discomfort of a few hours duration. Severe effects on the throat, nose and larynx are unusual. Metal fume fever, a condition regarded as being a reaction due to protein liberated from cells of the respiratory tract impaired by inhaling certain metallic fumes, accounts for almost all acute effects of a severe nature. The illness is usually short, commencing a few hours after the noxious exposure, and subsiding within 12 hours. In severe cases it may be followed by complications, such as pneumonia, but available statistics do not indicate that welders suffer more from pneumonia than the general population.

160. About 60% of the welders had chronic respiratory symptoms, mainly cough, and about half of these had abnormal physical signs in the chest. Both symptoms and physical signs were generally slight and there was no evidence of any associated pulmonary fibrosis or impairment of function. Exercise tolerance tests were well performed. Symptoms and physical signs were found in much the same proportion in welders who had performed substantial amounts of enclosed work and in those who had not, but the previous medical histories of those who had performed much enclosed work showed a higher incidence of acute respiratory diseases. X-ray films of the chest were made of 180 welders and showed changes of the inhalation type in 13.3%. This type of change was found in only one gas welder in this series, and it is believed that it is relatively less frequent and later in appearing in these

welders. It was more frequent and appears earlier in welders who have performed much work in enclosed spaces than in those who had always worked in open shops. In those showing such changes, the average length of welding experience was 20 years in electric welders and 34 years in the gas welder. Symptoms were slightly more frequent and physical signs definitely so in the group showing inhalation type changes. In regard to symptoms the slight difference might be due to the difference in age grouping, but this does not wholly explain the increased number of men with physical signs the commonest of which were crepitations. These were probably due to slight increase in bronchiolar and alveolar secretion following increased congestion in the lungs not necessarily reactive but possibly merely an indication of increased activity of the scavenging mechanism. The inertness of the material deposited in the lungs is shown not only by the absence of signs of pulmonary fibrosis and impairment of function in those showing the x-ray changes, but also in the fact that in several men examined these x-ray changes have persisted for 10 years without producing any diminution in working capacity. Furthermore the changes are not permanent and may retrogress if the intake of fume falls below the rate of removal from the lungs. Two cases illustrating this are described.

161. No evidence is adduced of any increased susceptibility to tuberculosis in welders, or of any tendency for such disease, if contracted, to assume a more serious form.

162. The analysis of gastro-intestinal symptoms in welders has not indicated any higher incidence than would be expected amongst the general population. While slight symptoms, usually nausea and distaste for food, may result after welding in enclosed spaces without adequate ventilation, or the welding of certain alloys or coated metal, these are generally short-lived and quickly disappear on ceasing the particular aggravating work. Welders performing much enclosed work have not been shown to suffer more than others from either the slighter or the more severe types of indigestion.

163. Twinges of pain in the arm or hands from holding the electrode holder or torch, or across the back or in the legs from awkward posture may be experienced by welders but there is no evidence of increased incidence of any form of chronic rheumatism. No evidence is found of any interference with function of the hand or fingers and no case of trigger finger was discovered.

164. No evidence of involvement of the nervous system was found even in the group of welders substantially engaged in working with high manganese steel. Blood pressure findings were generally in normal limits and indicated no change due to the work. No indication of involvement of the endocrine system was obtained.

165. Examination of the blood showed a blood picture that was slightly altered although not associated with any degree of anæmia, or the presence of abnormal red or white blood cells. Hæmoglobin levels and red and white cell counts tended to be slighty raised. This may be due to slight stimulation of the bone marrow by some constituent of the fumes. Such a supposition could be confirmed by a careful series of animal experiments.

166. Apart from the clinical examinations information on the health of welders has been sought from statistics. The amount of material available is disappointing, but is on the whole reassuring as regards the relative amount of absence due to sickness compared with non-welders.

167. In regard to death rates it is unfortunate that no information from the Registrar-General more recent than 1931-32 can be obtained. Figures

based on returns for that period show that the occupational mortality of welders was considerably below that expected on the basis of the age-rates for all males. Returns of comparative absence for different occupational groups in factories give much more up-to-date information and this also is reassuring in that it shows no excess of morbidity amongst welders, and in fact that sickness amongst welders is frequently less than amongst other groups of workers and the factory employees as a whole. The figures relating to the firm A and firm D are especially convincing.

CONCLUSIONS

(A. T. Doig)

168. In regard to welding of uncoated mild steel the following conclusions may be drawn :—

1. Welders do not suffer from any specific disease due to their occupation that could be described as " welders' disease ".

2. Occupational dermatitis in welders does not appear to be a frequent or serious cause of disability.

3. Electric welders and those exposed to the rays emitted from the arc may suffer from acute irritation of the superficial parts of the eyes, a condition known as " arc eyes ". This is a transient condition which has no permanent effect on the vision or on the deeper structures of the eye. Electric welders however, do suffer to a greater extent than other workers from a slight superficial non-disabling chronic inflammation mainly affecting the eyelids.

4. Slight irritation of the throat is not uncommon in welders who have been exposed to high concentrations of fumes. The discomfort usually passes off in a few hours. No serious effects on the throat or nose were observed and there was no evidence to suggest any implication of the larynx. The incidence of nasal catarrh and frequent colds is higher than would be expected in the general population, especially in welders working in enclosed spaces and with galvanized metal.

5. The incidence of symptoms related to the respiratory tract, mainly cough and sputum, was higher than would be expected in a comparable non-welding group, and the evidence suggests that abnormal physical signs in the lungs are also more frequently to be found. These symptoms indicate a mild form of bronchial irritation and are not associated with evidence of pulmonary fibrosis or of impaired exercise tolerance.

6. In a certain number of welders with a long duration of employment, particularly those who have performed much enclosed work, abnormal x-ray appearances are observed. These indicate the deposition of fume in the lungs. This fume consists mainly of iron oxide; it lies inertly in the lymph spaces and lymphoid tissues of the lungs and causes no fibrous reaction with the cells of these tissues or the lung parenchyma. When exposure to fume decreases or stops the particulate matter may be removed by the normal scavenging action of the respiratory tract so that the abnormal x-ray appearances eventually disappear. The x-ray picture is therefore of little significance by itself. It is not necessarily associated with symptoms or physical signs, although symptoms were slightly more frequent and physical signs definitely so in the group showing specific x-ray changes.

7. Exposure to welding fume does not predispose to pulmonary tuberculosis; pulmonary tuberculosis developing in welders does not run a

more severe course than would be expected in non-welders. There does not appear to be an increased liability for old lesions to be reactivated.

8. In regard to gastro-intestinal troubles the evidence suggests that, although temporary symptoms may follow exposure to high concentration of fume the incidence of peptic ulcer and chronic indigestion is no higher in welders than in the general population. No suggestion of liver involvement was found, and the reports of this which appeared in the Continental literature a few years ago remain unconfirmed.

9. Rheumatism did not appear to be excessive in the group under review. No evidence of any special type of dysfunction of the muscles, joints, or tendons, such as trigger finger, was found.

10. No evidence was found of any involvement of the central or peripheral nervous systems.

11. No evidence of involvement of the endocrine system was found. Suggestions in the literature of effects on the thyroid, or of impotence or loss of libido have not been confirmed.

12. No effects on the blood pressure were found.

13. Blood examinations showed in certain cases, changes of a slight nature suggesting a stimulation of the blood forming organs. There was no suggestion of organic changes in these organs, and no abnormal blood cells have been seen.

14. There is little danger of gassing during welding in conditions of good or moderately good ventilation. In ill-ventilated spaces, welding or burning may cause considerable discomfort, or respiratory, or gastro-intestinal upset. Severe respiratory symptoms are usually due to the inhalation of oxides of nitrogen which are especially liable to be produced in toxic concentrations by the use of the gas flame for welding or burning. The fumes from galvanized metal may also lead to severe chest illness in enclosed spaces. The danger from gases other than oxides of nitrogen is remote

15. The available evidence from statistics is reassuring as showing no increased mortality rate or morbidity rate. Some of this evidence however, is unsatisfactory as it is insufficient and much of it relates to too small groups to be significant.

16. Numerous clinical studies of welders have been made in recent years, some of them on large groups. The evidence obtained from the field study described in this report is corroborative of the results of other investigations and it is not felt that further investigation on similar lines would be productive of new or worth while information. Further and more precise information is required, however, regarding mortality and morbidity rates in welders, and further research of a statistical nature should be instituted in order to ascertain with precision whether any particular disease (e.g. pneumonia) or group of diseases (e.g. gastro-intestinal) occurs in greater incidence in welders engaged on particular types of work than in the general population.

The welding or burning of coated metals, alloy and steels and certain non-ferrous metals may carry certain specific risks, e.g., lead poisoning, metal fume fever; these should in most cases be readily anticipated and precautions instituted.

PRESENT LEGISLATION

(L. N. DUGUID)

169. Certain provisions of the Factories Act, 1937 and of Regulations made under that Act require steps to be taken to prevent the inhalation of dusts and fumes by the workpeople. The relevant parts are as follows :—

Factories Act, 1937, *Section* 4, *sub-section* (1)

" Effective and suitable provision shall be made for securing and maintaining by the circulation of fresh air in each workroom the adequate ventilation of the room, and for rendering harmless, so far as practicable, all fumes, dust and other impurities that may be injurious to health, generated in the course of any process or work carried on in the factory."

Factories Act, 1937, *Section* 47, *sub-section* (1)

" In every factory in which, in connection with any process carried on, there is given off any dust or fume or other impurity of such a character and to such extent as to be likely to be injurious or offensive to the persons employed, or any substantial quantity of dust of any kind, all practicable measures shall be taken to protect the person employed against inhalation of the dust or fume or other impurity and to prevent its accumulating in any workroom, and in particular, where the nature of the process makes it practicable, exhaust appliances shall be provided and maintained, as near as possible to the point or origin of the dust or fume or other impurity, so as to prevent it entering the air of any workroom."

Shipbuilding Regulations, 1931, *No.* 18(*a*)

" Adequate ventilation to secure the removal of injurious fumes or gas shall be provided where, in any enclosed or confined space

(i) .....

(ii) an oxy-acetylene burner or electric welding apparatus is being used."

There are further provisions which require the protection of the eyes of persons employed in welding, as follows :—

Factories Act, 1937, *Section* 49

" In the case of any such process as may be specified by regulations of the Secretary of State, being a process which involves a special risk of injury to the eyes from particles or fragments thrown off in the course of the process, suitable goggles or effective screens shall, in accordance with any directions given by the regulations, be provided to protect the eyes of the persons employed in the process."

The section is applied by the " Protection of Eyes Regulations 1938 " to various processes including:

" Welding or cutting of metals by means of an electrical, oxy-acetylene or similar process ".

Shipbuilding Regulations, 1931, *No.* 51.

" Suitable goggles fitted with tinted glass eye-pieces shall be provided for all persons using acetylene burners or blowpipes."

Building (*Safety, Health & Welfare*) *Regulations* 1948, *No.* 84.

" Where there is carried on any process specified in the Second Schedule to these Regulations suitable goggles or effective screens shall be provided to protect the eyes of persons employed in the process."

The Second Schedule includes :—

" (5) Welding or cutting of metals by means of an electrical, oxy-acetylene or similar process."

PERSONAL PROTECTION OF THE WELDER

(L. N. DUGUID)

170. Apart from protection against fumes the welder needs protection against the effects of radiation on the eyes and the skin and from hot particles which fly during the deposition of the weld metal. Such protection is afforded by shields, goggles, screens, gloves, aprons, etc. Useful advice on these matters is given in the " Memorandum on Electric Arc Welding ", Factory Department Form 329, which also deals fully with the important problem of electrical risks.

There are two British Standards of particular interest in this connection. They are B.S. 679-1947, " Protective filters for welding and other industrial operations " and B.S. 1542-1949, " Equipment for eye and face protection during welding ".

RECOMMENDATIONS

(A. T. DOIG AND L. N. DUGUID)

171. It will be obvious that as the main health risk under consideration is due to fumes the remedy is ventilation. The principal difficulty is in determining when and where special provision for ventilation should be made. There exists so much variation in the different welding processes that to a large extent the problems at each firm must be considered individually. It is possible, however, to make some recommendations in general terms as follows :—

(1) Where only occasional welding jobs are done as for example, in connection with the maintenance work of a factory, no special precautions are necessary unless any of the very toxic elements are present in considerable quantity.

(2) Where gas welders in small or large numbers are working, the problem should be treated as one of ensuring good general ventilation of a workroom in which a fairly hot process is carried on.

(3) Where articles are electrically welded on benches or stands particularly where the welder spends all or most of his working time at one point, close localised exhaust ventilation should be applied, as much advantage as possible being taken of the convection currents rising above the work.

(4) The welding of large articles of mild steel such as vehicles or prefabricated parts of bridges, ships, etc., necessitates constant change of position of the welding point. Such work is usually performed on the floor of a large workroom. In such cases although localised exhaust draught is desirable there are obvious practical difficulties in applying it. Fixed ducts with joints for down-coming flexible hoses at various points should be provided where possible. Where good practical methods cannot be evolved it will be necessary to rely on general ventilation. As a rough standard of ventilation it may be taken that there should be no visible fume in the atmosphere away from the immediate vicinity of the welding point and any visible fume near the arc should be rapidly dispersed. The services of an expert ventilating engineer should be obtained where necessary.

(5) Where the fume evolved contains substances which are liable to be present in sufficient quantities to be poisonous or irritating, exhaust ventilation should be provided so as to draw away the fume close to the welding point.

(6) Where welding is to be done inside vessels or compartments, generally described as confined spaces, exhaust draught should be provided as close to the welding point as possible. Portable plant with flexible hose is convenient for this purpose and in most cases there would be no objection to the discharging of the fume (e.g., from a boiler under construction) into the general air of the workroom. In some cases, blower fans may be found more practicable. Particular attention should be given to the ventilation, preferably by exhaust draught, of confined spaces in which gas torches are used or in which dangerous or irritating fumes are liable to be evolved. In such cases if the fumes cannot adequately be removed by exhaust ventilation, the welders should be provided with breathing apparatus which allows the breathing of fresh air.

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