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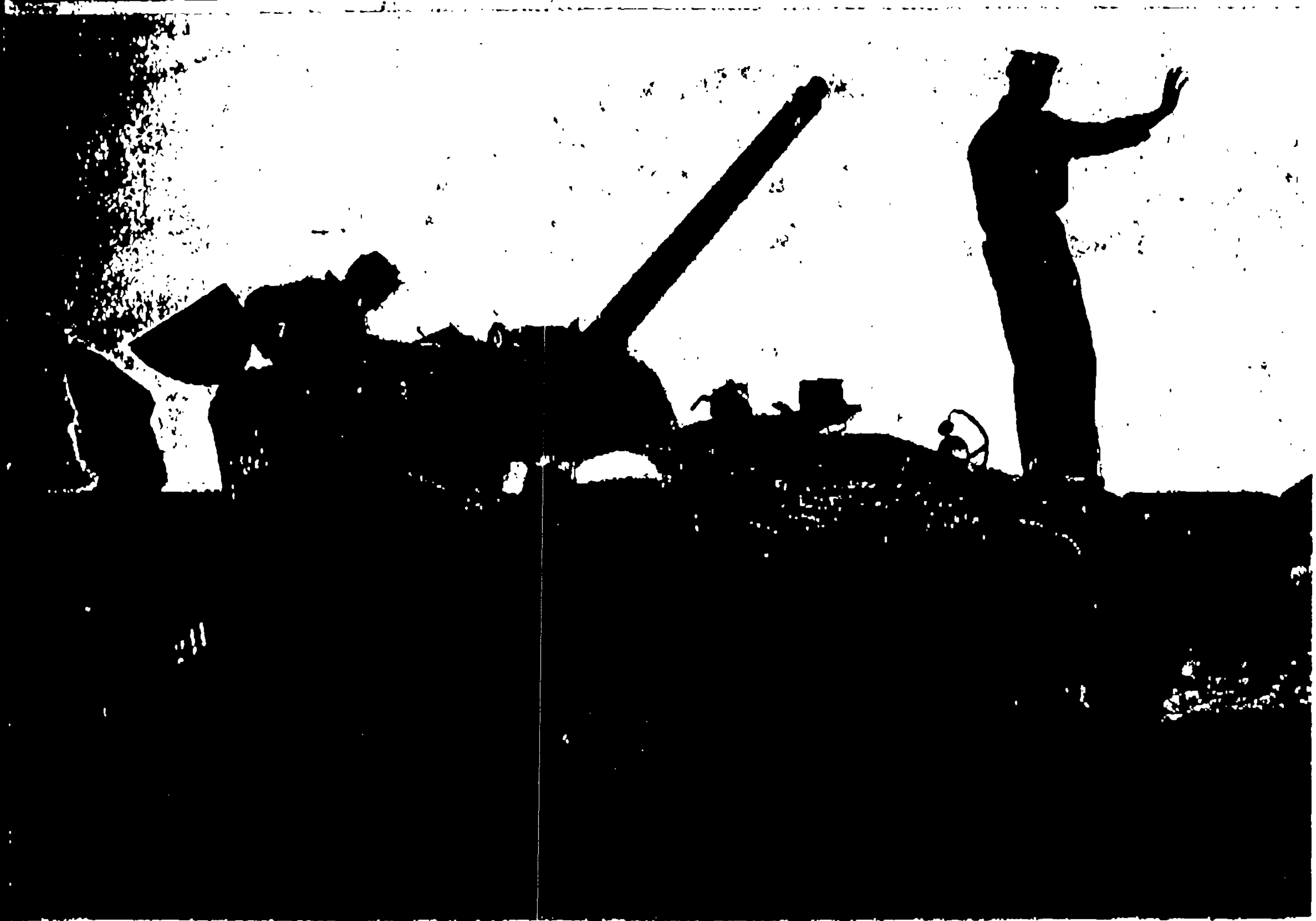
WELDING



Health Aspects of Welding*

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THE purpose of this paper is to offer some practical points for the better protection of the health of welding operators. It is not intended as an exhaustive research document. The health hazards of welding may be classed as "real and unreal." The former should not be ignored, nor should the latter be allowed to cause undue alarm. The real hazards are not mysterious; they should be easily understood by any reasonably well trained operator and means for protection are available and effective when used.

A welding operator is usually exposed to all the general accident hazards common to the industrial field in which he is working. Structural iron workers, ship builders and the like are exposed to increased accident hazards. As a large proportion of welding operations are in connection with such work, this may be one reason for the common assertion that welding is a dangerous and unhealthy occupation.

Another possible source for the charge that welding is a health hazard is the circumstance that the formulas of most rod coatings are "trade secrets" so that there is an opportunity to indulge in all sorts of speculation as to the danger to health from the "secret" ingredients in these coatings. Actually very few coatings would appear to have introduced any important health hazards. As for the "mystery," most of these coatings have been patented. Not long ago the Bureau of Mines issued an Information Circular[1] giving much detailed information on the composition of welding rod coatings and fluxes. This was based on patent information, purposes served by the various ingredients and analyses of many typical coatings. This and other reports remove the "mystery."

A third and perhaps the most important reason for the assumption that welding is a health hazard, are the dramatic deaths which have been reported in a relatively few instances following massive exposures to welding fumes in strictly confined spaces without suitable protection for the operators. That such incidents do not reflect a general hazard is well shown by the fact that in the past three years the number of welding operators has increased some 400% and in the past ten years consumption of welding rods has increased some 2800% with scarcely any increase in such fatalities.

Until quite recently the health problems of welding have been approached from a speculative rather than scientific viewpoint. Unfortunately in a number of instances even medical men, apparently with little attempt to check exposures or weigh evidence available, have attributed an amazing variety of ills to welding exposures. These include digestive disorders and malnutrition, liver diseases, respiratory affections even including cancer of the lung, circulatory, blood and glandular changes including thyroid disease and Hodgkin's disease, various skin diseases, neurological changes, sterility, and various other complaints. A careful analysis of these reports generally shows little or no evidence of any connection with welding exposures. The agents usually blamed for these various ailments would ordinarily be present in entirely negligible concentrations, if at all.

Such substances as silica, asbestos, manganese, chromium, nickel, cobalt, various other metals and even iron have been given as "potential hazards" in welding fumes. These have been charged with directly causing ill health or serving to activate other conditions such as pneumonia, tuberculosis, etc. With the exceptions shortly to be mentioned, there seems to be no evidence to indicate that they are present in a form or an amount which would constitute a health hazard. Some have stated that welding operators "are dying every day, and others suffering permanent health impairment as the result of their work," and charge that no studies have been made to identify or control the hazards. Anyone at all familiar with the research which has been done and is still going on in this field will realize that such charges must be due to ignorance or prejudice. The very thorough study conducted by Britton and Walsh[2] and the experimental work and observations in this field by many other investigators[3,4,5,6] fail to show any excess of ill health among welding operators, or any outstanding type of illness among them.

The Real Welding Hazards

The real hazards peculiar to welding are essentially from: (1) radiation and (2) air contamination by gases and fumes.

Radiation presents the hazard of intense light, glare and of ultra-violet exposures. Probably all workers even casually acquainted with welding operations are familiar with the need for eye protection in this work. In the case of gas welding there is little, if any, exposure to ultra-violet rays, but only glare from too intense light. The eyes must be protected by suitable colored lenses. In electric arc welding there is not only the glare but enough ultra-violet radiation to call for a deeper shade of protective lens for the eyes, and also a face shield and protective clothing to cover all skin areas which might be exposed. At present no attempt will be made to go into details as to this form of protection, as these are easily available from a number of sources, especially the American Standard Safety Code for the Protection of Heads, Eyes, and Respiratory Organs.[7,8]

Hazards from radiation are not confined to the welding operator alone, but also involve his helpers and others working in the immediate neighborhood, usually considered to be within seventy-five to one hundred feet in the case of arc welding. Any workman within this

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area should be protected either with suitable goggles or by the use of screens. If screens are used they should be so designed as to interfere as little as possible with ventilation. Some types of operation can be done in ventilated booths, which may serve to reduce the hazard to others. Not only must direct rays be kept from the unprotected eye, but reflected rays must be considered. This invariably calls for the use of dull non-reflective paint on areas which may otherwise serve as reflectors.

Excessive exposure of the eye to ultra-violet radiation damages chiefly the outer structures of the eye, setting up conjunctivitis of varying degree. The damage is analogous to a blistering sun burn of the skin and if the exposure is severe very painful reactions will occur, with some temporary visual disturbances. Ultra-violet rays do not penetrate the lens or injure the deeper structures of the eye. Experimental cataracts have been produced in rabbits by prolonged exposure to ultra-violet rays, but in actual welding experience lens changes do not occur and optic nerve injury is impossible from a physical standpoint.

Before leaving the subject of radiation it should be mentioned that in welding there is no exposure to short waves like the x-ray. This has been demonstrated repeatedly by having welding operators carry dental x-ray films in their pockets. No systemic effects have been demonstrated as due to the radiation in welding, least of all sterility. This is mentioned because this charge has recently been revived in some quarters. It was originally made during the last World War and several investigations proved it to be unfounded. There is no valid evidence to support such a theory.

Gas Hazards

Among the much discussed hazards of welding are those due to gases. These gases may be essential to the type of welding as the oxygen and acetylene in oxyacetylene welding or they may be produced through the reactions occurring in the welding process as oxides of nitrogen, ozone or in some cases of imperfect combustion carbon monoxide. It is hardly necessary to state that oxygen as used in welding does not produce a health hazard. Misused, for instance, as a substitute for compressed air in ventilating small spaces, it may increase the hazard from burns, as any material will burn more actively in the presence of an excess of oxygen. Ozone, a "peroxygen," may be formed in the welding arc and in concentrations of over 1 p.p.m. may act as a pulmonary irritant. On leaving the arc, ozone rapidly ceases to exist as such and many investigators have demonstrated that even in confined spaces a dangerous concentration is not found in the air breathed by an operator. It is extremely doubtful that ozone is anything but a theoretical hazard in welding.

While speaking of oxygen, mention may be made of the hazard said to be due to "oxygen deficiency" from welding. This could occur only in very confined spaces, as in tanks or some of the small compartments in ship's holds, and the like. There may have been some accidents due to oxygen deficiency in such locations but in all probability investigation would show that this condition already was present in the area before welding operations were attempted. In the case of oxyacetylene welding where a certain proportion of oxygen is drawn from the atmosphere the welding flame will usually become entirely unsatisfactory for its purpose and the deficiency recognized before the oxygen reaches a level low enough to be dangerous to the operator. Also the heat generated by the welding operation under normal atmospheric conditions would usually be unbearable in a confined space before dangerous oxygen depletion occurred. "Oxygen deficiency," then can be put in the category of unreal hazard.

One not infrequently sees references to the toxic effects of unburned acetylene or the "impurities" present in acetylene gas. Acetylene is a simple asphyxiant gas, not in itself a poison. It has had fairly wide use as an anesthetic. A hazard would exist only when the gas is present in such concentration as to reduce the oxygen in the air breathed so that not enough remained properly to supply the body. As the lower explosive limit of acetylene in air is about $2^1/_2$–3% it is evident that in the presence of a flame an explosion would result long before the concentration would appreciably reduce the available oxygen in the air. As for the alleged hazard from impurities—arsine, phosphine, hydrogen sulphide or ammonia—this purely theoretical hazard is based chiefly on early analyses of acetylene made from materials of foreign origin. No significant amounts are present in acetylene produced today from raw materials from North American sources. Recently tests were made for arsine in dissolved acetylene from four commercial producers and not even a trace was detected. The minute amounts of impurities sometimes found in acetylene are, of course, destroyed in the flame. The health hazards from acetylene and its "impurities" belong in the "unreal" class.

Gases formed in the flame or arc are the oxides of nitrogen, sometimes called "nitrous fumes." They are *not* nitrous oxide, but are nitric oxide and other higher oxides of nitrogen. In the concentration present in connection with welding they are so diluted as to be colorless. Under other conditions of exposure these fumes may present other hazards but in welding the real hazard is as a pulmonary irritant. Except in small rooms or in very confined spaces as in tanks, etc., no dangerous concentration would be likely to occur. Just what is a dangerous concentration has been undergoing considerable discussion in the last two or three years. The classic figure of 39 p.p.m. by volume in air admittedly was based on very limited observations but has proved a fairly satisfactory working standard. Just as much more extensive experiments were beginning to indicate that 70 p.p.m. or even up to 100 p.p.m. might be a safe limit for a day's work, others, on what basis is not clear, are advocating a "safe concentration" of only 10 p.p.m. Certainly a study of available evidence indicates that in welding operations concentrations of 50 p.p.m. or less have not produced symptoms, and that probably under many conditions this amount may be exceeded without harm. Protection will be discussed under fume protection.

Carbon Dioxide and Carbon Monoxide

Carbon dioxide is produced by the oxyacetylene flame and by the electric arc but never in concentrations of physiological importance. Carbon monoxide may be produced through imperfect combustion as when starting welding or cutting of cold material or through the combustion of organic matter which may be present on the surface to be welded, or in the coatings of rods used. There is considerable divergence of opinion on the degree of hazard from carbon monoxide in welding. A careful comparison of the various reports seems to indicate that the danger of a significant concentration is very slight under all ordinary conditions of welding. If standards of ventilation indicated by other features of the work are followed the hazard from carbon monoxide should be non-existent.

Probably the most discussed health hazards of welding are those due to fumes. These are chiefly metallic, from the material being welded or used as a coating on that material or in the welding rod or its coating. The composition of welding fumes is so varied that this furnishes a wonderful field for the discovery of hypothetical and unreal hazards. These fumes also are the source of some very real hazards. If proper precautions are taken to avoid the real and recognizable hazards the same precautions should eliminate the theoretical hazards. Welding is now in such general use and the number of metals and their combinations involved is so great that there are probably but few metals which may not be handled by a welding operator.

The most common complaint due to fume exposure is metal fume fever. This, often called "zinc chills," "brass founder's ague" and the like, is really a non-specific reaction which might come from any of a number of metal fumes. The most common source is zinc fume, from welding on galvanized material, or brass, or from using rods with a high zinc content. Zinc should not be considered "highly toxic," however, as this condition is an acute, self-limiting reaction of short duration and without known after-effects or complications. In a large number of those affected a considerable degree of immunity is established so that subsequent attacks are very mild or lacking altogether. The permissible limit for zinc fume in the air has been suggested as 15 milligrams of zinc per cubic meter of air. If this concentration is not exceeded it is unlikely that any cases of metal fume fever will occur.[5]

The most serious condition likely to result from metal fume exposure is probably lead poisoning. This is not a hazard common to all welding operations, but only in the relatively few cases where welding or cutting is done on material previously covered with lead paint, coated with metallic lead, or where lead has been introduced as an alloy as in certain steels. In such cases very definite protective measures will be required.

Next to lead ranks cadmium as a potential hazard. Lately cadmium has come into more general use as a rust-proof coating for steel in place of zinc. It enters into some alloys. The fume may produce a pulmonary irritation and edema resembling in many ways the effects from inhaling oxides of nitrogen.

A wide variety of other metals have been mentioned as injurious: manganese, chromium, cobalt, copper, tin, antimony, magnesium, aluminum, tellurium, vanadium, titanium, and many others. As encountered in welding fumes the amounts are usually definitely less than those known to have toxic effects, and it is doubtful if any reports alleging injury from these metals in welding can be substantiated. Manganese has been most frequently suspected, but a study of the reports of alleged effects fail to show any conclusive evidence and the amounts involved are below those known to have produced effects. The charge that even small amounts of manganese predispose to pneumonia is not borne out by the known experience of welding operators.

Other materials than gases or metals may create fume hazards through air contamination. These may be encountered especially in repair work on various tanks, vats, etc. Their presence calls for special ventilation.

There is one other source of real hazard which may be present in many operations involving aluminum or some of the "stainless" steels and alloy metals. This is from the presence of fluorides in many of the fluxes or rod coatings used for this work. Hydrofluoric acid may be formed and the fume if inhaled in appreciable concentrations or for long periods may cause considerable irritation to the nose and throat or even pulmonary edema.

Prevention

To sum up: The real hazards of welding are not many, are generally easily identified and protective measures are available and effective when used. These real hazards should not be minimized or passed by. Briefly they are due to:

1. Radiant energy—ultra-violet and visible light.
2. Oxides of nitrogen.
3. Metal fumes—lead, cadmium and zinc.
4. Fumes from organic residues or wastes.
5. Fumes from fluoride-containing fluxes and rod coatings.

Protection from radiant energy has already been outlined. Protection from the rest is almost wholly a question of ventilation. Various means of approach have been tried to establish standards for ventilation. Standards in terms of concentration of contaminant expressed in parts per million by volume for the gases or milligrams per cubic meter for metallic and other fumes have been suggested, as have standards expressed in number of air changes per time unit. Both methods have value and studies made along these lines have done much to solve some of the difficult points in ventilation requirements. Unfortunately, it is very difficult to obtain quickly and easily a determination of fume concentration on a given operation. Local conditions may also change the efficiency of measures based on rate of air change. Notwithstanding some of the practical difficulties in applying such standards in specific cases, several general rules on ventilation have been evolved which have proved to be of considerable help.

Various studies of present-day practice have been made which indicate that welding out of doors or in large shops seldom results in any serious air contamination except in the case of lead. In spaces of less than 1000 cu. ft. and especially inside tanks, ship holds, etc., special ventilation is necessary. Usually the exhaust of contaminated air is much more effective than an attempt to force fresh air into the space. In stationary locations this can generally be done with properly located exhaust fans or by the use of hoods and ducts to withdraw fumes as near as possible to their source. Portable exhaust systems have been designed which are adapted to field needs.

In the case of gases such as oxides of nitrogen, or the rare instances of carbon monoxide, if sufficient ventilation is maintained from the beginning of the operation and sufficient to insure good visibility and to insure a comfortable temperature there should be no gas hazard even in confined spaces.

If lead or cadmium fumes are present the only complete protection is by the use of air supplied masks. These are of three types—air supplied by special blower, air supplied from compressed air system and masks with larger hose without use of forced air supply. If compressed air is used from a general supply, special filters and pressure regulators are required. In the last-named type with no forced air supply the length of hose can seldom be over 50 ft. In confined spaces one of the above devices should be used. Out of doors or in large well-ventilated shops and for moderately short exposures, one of the filter type respirators approved by the Bureau of Mines for lead fumes may be satisfactory. In any confined space at least local exhaust ventilation is required when there is exposure to zinc or fluoride fumes, or to fumes from heavy deposits of organic wastes and sludge. Air supplied respirators offer, of course, the most positive protection.

Briefly, a minimum standard of ventilation is one that will be sufficient to insure good visibility at the point of operation, and insure a temperature within a reasonably confortable limit. In confined spaces this would call for exhaust ventilation. In case of lead or cadmium exposures air-supplied masks are required. No serious hazard is apt to be present except in confined spaces or when lead is involved. Special standards for ventilation in welding of leaded steel have been given by Halley.[8] General requirements for ventilation are given in more detail in the reports of Tebbens and Drinker,[6] in Special Bulletin No. 5 of the U. S. Department of Labor, "Control of Welding Hazards in Defense Industries"[9] and by Hemeon.[10]

Summary and Conclusions

1. Health hazards in welding may be divided into "real" and "unreal."

2. Real hazards should not be ignored or minimized. They are usually easy to recognize and effective preventive measures are available.

3. Unreal and hypothetical hazards are often alleged. If indicated precautions are taken to guard against the real hazards, the unreal will disappear entirely.

4. Hazards from radiation in welding are limited to eyes and skin. No systemic effects have been demonstrated. Means of prevention are well known and available.

5. Hazards from air contamination can usually be controlled by ventilation and in some instances, by respiratory protective equipment. Hazard from gas is essentially limited to oxides of nitrogen. Ozone and carbon monoxide hazards are of minor importance. Oxygen deficiency, if present, is usually not due to the welding operation but to other causes. Fume haza[rds] for practical purposes are limited to fumes from le[ad,] cadmium, zinc or fluorine, and rarely from orga[nic] wastes or sludges. Fumes from other materials, wh[en] present, are usually in non-toxic amounts, or would [be] removed by protective measures indicated for th[e] well-recognized hazards just mentioned.

6. No reliable evidence has been presented to sho[w] that welding operators have any poorer health an[d] accident records than other tradesmen working in th[e] same environment, or that they show any characteristi[c] type of illness which could be associated with their wor[k.]

7. That the health hazards due to welding exposure[s] are not great and can be well controlled is evident from the enormous increase in welding and its applications without a corresponding increase in illness.

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