Development of Indigenous Local Exhaust Ventilation System: Reduction of Welders Exposure to Welding Fumes

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Abstract: Development of Indigenous Local Exhaust Ventilation System: Reduction of Welders Exposure to Welding Fumes: Shakeel ZAIDI, et al. National Institute of Occupational Health, Indian Council of Medical Research (I.C.M.R), India—Two (portable and mobile) local exhaust ventilation (LEV) units were developed in collaboration with the Rural Technology Institute, Gandhinagar, India. Basically, each unit consists of three parts comprising an electric motor, a blower and a fume hood. In both units the motor is fixed in a rectangular iron frame in a foot-mount position and equipped compactly with a blower, which in turn is connected to a fume hood through a flexible hosepipe. The portable unit is light in weight (50 kg) and has a cone shaped metallic fume hood. The mobile unit, on the other hand, differs from the portable model with respect to its weight (150 kg), size, RPM, voltage requirement, hood shape and size, and has a motor enclosure. The efficiency of the portable and mobile units on trial bases was tested by measuring the manganese concentration as a reference metal in welding fumes generated by electric arc welding. The concentration of manganese (mean ± SD) was 0.218 ± 0.06 µg/m³ in the general environment. In the workplace area where joining of metal objects by welding was done, the concentration of manganese was found to be 0.63 ± 0.09 and 3.75 ± 0.56 µg/m³ at a distance of 5 m and 2 m away from the site of operation, respectively. In the breathing zone it was 22.16 ± 20.90 µg/m³ which was reduced to 8.25 ± 4.50 µg/m³ after application of a portable LEV showing about 63% removal of the manganese concentration from the breathing zone of the welder. In another experiment conducted with a mobile LEV unit for heavy-duty work, the concentration of manganese in the breathing zone without operating the mobile LEV was 70.06 ± 37.38 µg/m³ but was lowered to 8.29 ± 1.76 µg/m³ after operating the mobile LEV. This indicated an average removal of manganese content by about 88% from the breathing zone of the welder. In both the experiments locations of sample collection were similar.

Key words: Welders, Welding fumes, Manganese, Health hazards, Portable, Mobile, Local exhaust ventilation

A healthy work environment and the good health of a welder are the prime requirements that a welder needs to perform his job smoothly and effectively. Nevertheless, developing or underdeveloped countries may face challenges in obtaining first-order health and occupational hygiene due to a variety of reasons including cost effective techniques, easy availability and maintenance of exhaust systems, humid and climatic conditions in some countries, etc. Thus the use of ventilation, respiratory protection, and protective clothing are not adequately taken care of, and this may lead to health impairments in welders. Of more than 80 different types of welding and allied processes identified by the American Welding Society¹, several of them, including gas welding, oxygen cutting and gouging, torch brazing and soldering, shielded metal arc welding, arc cutting and gouging, gas shielded arc welding, plasma arc welding, flux cored arc welding, thermal spraying, etc.², and several others that require ventilation may produce metal fumes and gases in excess of their exposure limits. Many of the metals and gases present in welding fumes are among the list of 275 chemicals; some of them in the top 20, declared recently by ATSDR-CERCLA³ as the most hazardous substances for health. Some welding operations² are of real concern from the stand-point of ventilation requirements’ as the inhalation of welding smoke over a long period of time
is known to cause serious health problems in welders4–8). These authors indicated that welders are liable to suffer from eye injuries, skin irritation, metal fume fever, musculoskeletal problems, respiratory and pulmonary disorders, reproductive impairments and central nervous system effects. Increased cancer mortality among arc welders exposed to fumes containing chromium and nickel was also reported9, 10). Recently, Parkinson’s disease (PD) has been reported to be associated with the welding profession in aged workers11). Earlier we have also reported some adverse effects of welding fumes on reproductive12) and thyroid function13, 14).

The quantity of fumes and gases generated during welding operation depends upon a number of factors such as the types of materials being cut or welded, the welding technology employed, fluxes and filler materials used, frequency of operation and process parameters such as energy and temperature adjustment, etc. Different strategies such as general ventilation, dilution techniques, and the use of personal protective equipment are adopted to minimize exposure to welders, but they may not be satisfactory or do not produce the desired effects in the control of health hazards. In such situations, ventilation process enclosures or local exhaust ventilation (LEV) are the principal methods to capture fumes at their source. The National Institute for Occupational Safety and Health (NIOSH)2, 15) U.S.A, is one of the prime organisations evaluating technologies and work practice to limit health hazards in the welding occupation and other processes. It has reported three methods for ventilation systems, namely, the crossdraft table, downdraft table and gun-mounted open hood. And some companies16, 17) abroad are manufacturing a range of models for LEV and marketing them in India. The difficulties in importing, higher capital cost and post maintenance of LEV systems are of great concern, particularly to small shopkeepers, garage workers and small-scale enterprises. Developing countries like India still need low cost technologies that could be safely used by small shopkeepers, garage workers and by small and large-scale industries as well.

This article intends to introduce prototype models designed indigenously for low cost local exhaust ventilation systems that are light in weight, and easy to maintain and operate to extract welding fumes and gases at source. Some of the basic ground rules described by NIOSH15) to design local exhaust ventilation were taken into account when designing the LEV present models.

### Materials and Methods

#### Design and technical details

Two units, one portable and other a relatively heavy mobile unit were developed in collaboration with the Rural Technology Institute (RTI), Gandhinagar (Gujarat), India. Detailed technical specifications of these models are shown in Table 1. The mobile unit is relatively heavy for a portable unit but is easily wheeled to the site of operation. It has a larger rectangular pyramid hood than the cone shaped hood of the portable LEV.

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Name of the part</th>
<th>Heavy mobile unit (weight: 150 kg)</th>
<th>Portable unit (weight: 50 kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Motor</td>
<td>Single phase 1 HP, 1440 RPM, 50 Hz, 230 volts AC</td>
<td>Three phase 1 HP, 2880 RPM, 50 Hz, 440 volts AC</td>
</tr>
<tr>
<td>2</td>
<td>Motor position</td>
<td>Foot mounted, vertical</td>
<td>Foot mounted, vertical</td>
</tr>
<tr>
<td>3</td>
<td>Blower: Diameter</td>
<td>45 cm</td>
<td>30 cm</td>
</tr>
<tr>
<td></td>
<td>Blower: Width</td>
<td>10 cm</td>
<td>10 cm</td>
</tr>
<tr>
<td>4</td>
<td>Fume hood</td>
<td>Rectangular pyramid, metallic, Dimension 38 × 38 cm</td>
<td>Cone shaped, metallic, Diameter, 30 cm</td>
</tr>
<tr>
<td>5</td>
<td>Suction duct: Bellows type, hose pipe</td>
<td>Diameter, 7.5 cm, Length, 1.5 m, fixed at center of the blower</td>
<td>Diameter, 7.5 cm, Length 1m, fixed at center of the blower</td>
</tr>
<tr>
<td>6</td>
<td>Delivery exhaust: pipe, bellows type, hose pipe</td>
<td>Diameter, 7.5 cm, length, 5 m or as desired, tangential to casing of blower</td>
<td>Diameter, 7.5 cm, length 5 m or as desired, tangential to casing of blower</td>
</tr>
<tr>
<td>7</td>
<td>Flow rate</td>
<td>5.66 cubic m</td>
<td>4.24 cubic m</td>
</tr>
</tbody>
</table>

#### Location and welding technology employed

Professional welders doing manual metal electric arc welding for 15 to 25 yr were engaged to perform welding jobs for the evaluation of LEV efficiency. They did not use any protective devices except shielding glass while doing welding. The study was conducted in the State Transport Workshop, Ahmedabad, India. The workshop had a high tin shaded ceiling (about 8 m high) and open welding cabin units with dimension of about 3 × 3 × 2 m.
Six welding cabins were used for electric arc welding operations and the units were in the same lane adjacent to each other. There was sufficient open space kept free in front of all cabins where no other type of work including welding was conducted.

\textbf{Electrodes}

Mild steel electrodes (XL-60 ASW E 6013, 400 mm × 4.50 mm; length and diameter) were used for mild steel welding or cutting operations. These were obtained from Kobe Steels Pvt. Ltd, India. Ingredients present in electrodes obtained from AIRCO Material Safety Data Sheet (MSDS) contained carbon steel core wire (65 wt %) coated with flux containing manganese less than 5 wt % as manganese compounds and alloys. TLV and PEL as reported in MSDS for manganese in alloys and other compounds were reported to be 0.2 mg/m³ and 1 mg/m³, respectively. And electric current ranging 110–170 amperes was adjusted for welding operations when these electrodes with a size of 400 × 4.50 mm were used.

\textbf{Sample collection and metal analysis}

Personal air samplers (APM 820, Envirotech, New Delhi, India) were used to collect air samples at a flow rate of 1–2 liter per minute (LPM) from different locations performing similar types of jobs with the same welding technology. Samples were taken from the general environment of the premises, and at a distance of 5 m, 2 m from the site of operation, and also from the breathing zone with or without the application of LEV. While collecting samples from the breathing zone and other work environment areas, the location and style of air sample collection were similar in both the experiments. Samples were dissolved in nitric acid, suitably diluted and used for analysis of the manganese concentration as a reference metal in welding fumes by an atomic absorption spectrophotometer (AAS) (Model 3100, double beam, Perkin-Elmer)\textsuperscript{19}

\textbf{Statistical analysis}

Statistical analysis was done with student’s $t$-test to determine significant changes between the control and workplace values obtained for manganese content in various samples.

\textbf{Results}

\textit{Development of local exhaust ventilation}

The portable local exhaust ventilation is shown in Fig.1A, while Fig.1B shows its application during welding. Fig. 2 shows emission of welding fumes through the flexible duct away from the site of operation to the safe outdoor environment.
outside. Good results were obtained in still air when the fume-collecting hood was kept as close to the source of emission as possible (about 15–20 cm away) and positioned in the path of emission of fumes. Fumes were collected conveniently and the application of LEV produced no hindrance to the welder.

Airborne manganese concentrations at various locations with or without the application of LEV are shown in Table 2. The average concentration of manganese in the general environment of the premises was found to be 0.218 ± 0.06 µg/m³ (mean ± SD). Without applying local exhaust, the concentration of manganese at a distance of 5 m from the site of operation was 0.63 ± 0.09 µg/m³, when the distance was reduced to 2 m from the source, it increased to 3.75 ± 0.56 µg/m³. Both of these values from the work environment were significantly higher (p<0.005) than those obtained from the general environment. The concentration of manganese in the breathing zone was 22.16 ± 20.90 µg/m³. When a portable LEV was used, the manganese concentration in the breathing zone was significantly (p<0.005) reduced to 8.25 ± 4.5 µg/m³. Thus, by applying LEV a reduction in exposure to the manganese concentration of about 63% was obtained. But the average reduced value for manganese (8.25 ± 4.5 µg/m³) was still significantly (p<0.005) higher than the concentration in the general environment (Table 2), but all the values for manganese content (as shown in Table 2) were well below the TLV of manganese (0.2 mg/m³) as recommended by ACGIH. In 1995, ACGIH had reduced TLV of manganese from 1 mg/m³ to 0.2 mg/m³. Again in 2003, the current TLV of manganese (0.2 mg/m³) has been proposed by ACGIH to be 0.03 mg/m³ as a notice of intended changes (NIC).

The mobile LEV (150 kg) is shown in Fig. 3. It appears more suitable for heavy-duty work. Fig. 4A shows a cutting operation on iron plate commonly known as a ‘c-column’ with manual electric arc welding without the use of an LEV. A fume cloud was very evident in the breathing zone, which air was inhaled by the welder, but when the mobile LEV was put into operation, it extracted most of the fumes from the breathing zone of the welder (Fig. 4B). In the breathing zone the concentration of manganese without application of the mobile LEV was found to be 70.06 ± 37.38 µg/m³, which reduced to 8.29 ± 1.76 µg/m³ after operation of the LEV, showing thereby an average removal of manganese content of about 88% from the breathing zone of the welder. Nevertheless the fume-capturing capacity of the mobile LEV was reduced

![Fig. 3. Mobile Local Exhaust Ventilation System.](image-url)
to about 56% and 34% when air samples were collected at a distance of 2 m and 5 m, respectively, from the source of operation. While the mobile LEV was functioning, the concentration of manganese in outdoor air, close to the outlet duct was found to be 62.67 µg/m³, which decreased to 35.2 µg/m³ when measured in a surrounding area about 1 m from the outlet duct. Thus the removal of fumes from the breathing zone and work environment and the presence of a high concentration of manganese in outdoor air, as observed in this study, indicate the effectiveness of our LEVs system.

Discussion

Data on manganese content determined in this study indicated low emission of manganese, which was much below the TLV of manganese reported by ACGIH (20) (0.2 mg/m³), but the very recently proposed TLV in terms of NIC for manganese (0.03 mg/m³) by ACGIH (21) may indicate potential risk to the welders at very low dose levels. A reduction of about 63% in the manganese concentration by the portable LEV and 88% by the mobile LEV in the workplace area suggests that these LEVs in the light of NIC for manganese (0.03 mg/m³) could be significantly useful in lowering the welder’s exposure to welding fumes. Results of this study also reflect the removal of other toxic metals and their oxides, and gases generated during welding.

The general criteria established by NIOSH for evaluating the performance of ventilation systems, which are based on the ability of the system to reduce the very high TLVs of contaminants in question to the normal level or below the TLV for those contaminants was not much observed in the present investigation as a low-manganese producing electrode (XL-60 ASW E 6013) was used for mild steel welding or cutting operations. If the 2003 TLV-NIC of ACGIH (21) for various metals and compounds are considered, the use of our LEVs seems quite beneficial.

It is noted that very low doses over a long period of time have been reported to cause clinical signs and symptoms of Parkinson’s disease (PD) in manganese miners or workers exposed to manganese or its compounds (22). Thus, the continuous use of LEVs in welding operation and other processes may provide protection to welders and other workers exposed to potentially toxic substances or chemicals that cause serious health effects. The present prototype models function at a constant speed and do not have an air cleaning device or dust collector. It needs further improvements and experimentation.

Conclusion

Local exhaust ventilation systems developed in this investigation are indigenous. The portable handy unit is more suitable for small shops or fieldwork and is easily affordable by shopkeepers or garage owners. The heavy mobile unit appears to be suited more for small-and large-scale industries for heavy-duty work. Simple and low cost LEVs developed by us might prove useful in developing or underdeveloped countries.

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