J Occup Health 2013; 55: 39–42

Journal of
Occupational Health

Brief Report

Generation Rate of Carbon Monoxide from CO_2 Arc Welding

Jun OJIMA

National Institute of Occupational Safety and Health, Japan

Abstract: Generation Rate of Carbon Monoxide from CO_2 Arc Welding: Jun OJIMA. National Institute of Occupational Safety and Health—Objectives: CO poisoning has been a serious industrial hazard in Japanese workplaces. Although incomplete combustion is the major cause of CO generation, there is a risk of CO poisoning during some welding operations. The aim of the present study was to evaluate the generation rate of CO from CO_2 arc welding under controlled laboratory conditions and estimate the ventilation requirements for the prevention of CO poisoning. **Methods**: Bead on plate welding was carried out with an automatic welding robot on a rolled steel base metal under several conditions. The concentration of emitted CO from the welding was measured by a real-time CO monitor in a well-ventilated laboratory that was free from ambient CO contamination. The generation rate of CO was obtained from the three measurements—the flow rate of the welding exhaust gas, CO concentration in the exhaust gas and the arcing time. Then the ventilation requirement to prevent CO poisoning was calculated. **Results**: The generation rate of CO was found to be 386−883 m*l*/min with a solid wire and 331−1,293 m*l*/min with a flux cored wire respectively. It was found that the CO concentration in a room would be maintained theoretically below the OSHA PEL (50 ppm) providing the ventilation rate in the room was 6.6−25.9 m^3/min. The actual ventilation requirement was then estimated to be 6.6−259 m^3/min considering incomplete mixing. **Conclusions**: In order to prevent CO poisoning, some countermeasures against gaseous emission as well as welding fumes should be taken eagerly.
(J Occup Health 2013; 55: 39–42)

Key words: Carbon monoxide, Ventilation, Welding

Carbon monoxide (CO) is a potent, lethal gas that can overcome exposed persons without warning. In recent years, CO poisoning in Japanese workplaces has been slightly increasing and it has become the largest industrial hazard due to chemical substances. Every year about 30–40 workers are absent from work for more than four days due to CO poisoning accidents. In 2010, four fatal CO poisoning accidents at workplaces were reported in Japan. Though CO gas is usually formed by the incomplete combustion of various fuels, some welding operations often produce significant amounts of CO and cause accumulation of CO, especially in poorly ventilated spaces. For instance, CO_2 arc welding, which uses carbon dioxide as an inert gas shield, may produce hazardous concentrations of CO by decomposition of the shielding gas or of carbonates in flux cored wires. Accidental poisoning of welders during work occurs almost every year in Japan, and industrial poisoning of welders was officially alerted by an administrative ruling of the Japanese Ministry of Health, Labour and Welfare in 2011. Although some mechanical ventilation is necessary to prevent the accumulation of CO in poorly ventilated, confined space, it is difficult to estimate the proper ventilation requirements for CO control because the generation rate of CO from arc welding has not been established. Recently, the author demonstrated a welder's personal exposure level to CO experimentally[1], but no empirical evaluation of CO generation rate has been published to date insofar as CO_2 arc welding is concerned. Therefore, the aim of the present study was to evaluate the generation rate of CO from CO_2 arc welding under controlled laboratory conditions and estimate the ventilation requirements for the prevention of CO poisoning.

Materials and Methods

Bead on plate welding was carried out with an automatic welding robot (ARCMAN-RON, Kobe Steel Ltd.,: Japan) on a 150 mm × 200 mm × 10 mm rolled steel base metal under the following welding conditions.

Welding current: 150 A, 200 A, 250 A, 300 A, 350 A
Welding speed: 30 cm/min
Filler wire: 1.2 mm ϕ solid wire JIS Z 3312 (=ISO 14341, 16834),
1.2 mm ϕ flux cored wire JIS Z 3313

Received Jul 25, 2012; Accepted Oct 10, 2012
Published online in J-STAGE Nov 27, 2012
Correspondence to: J. Ojima, National Institute of Occupational Safety and Health, Japan, 6−21−1 Nagao, Tama, Kawasaki, Kanagawa 214-8585, Japan (e-mail: ojima@h.jniosh.go.jp)

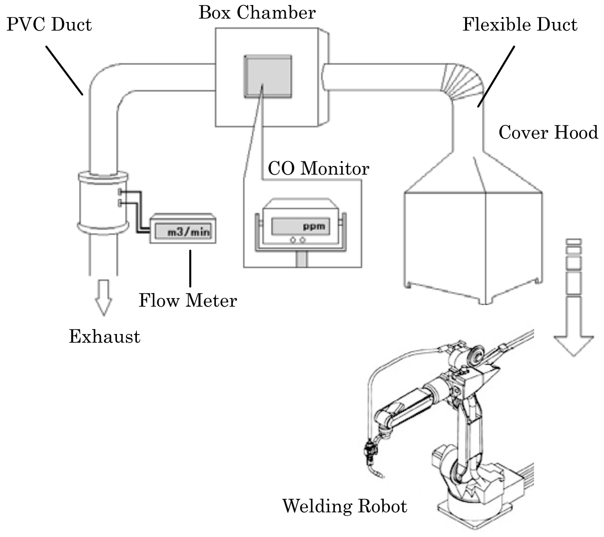

Fig. 1. Schematic diagram of the composition of the CO measurement experiments.

(=ISO 17632, 18276)
Shield gas: CO_2, 20 l/min or 30 l/min
Welding position: flat
Arcing time: 60–90 seconds

The range of the welding current mentioned above was set in accordance with the coverage of the tested filler wires.

The concentration of CO in the welding exhaust gas was measured by means of a controlled potential electrolysis type real-time CO monitor (Gas Detector XC-2200 Model; New Cosmos Electric Co., Ltd., Japan).

Figure 1. shows the experimental setup for this study. During the welding, the torch of the welding robot was enclosed by a cover hood (58 cm(W) × 61 cm(H) × 51 cm(D)) that sucked up all the exhaust gas from the welding. A flexible duct with a diameter of 80 mm was connected to the cover hood, and the exhaust gas passed through a box chamber (30 cm × 30 cm × 30 cm) that contained the CO monitor. The box chamber had an observation window through which the CO monitor could easily be read. The path length of the exhaust gas from the cover hood to the box chamber was about 1.5 m, which was thought to be enough to make the exhaust gas homogeneous[2)]. The flow rate of the exhaust gas was measured continuously by means of a Pitot tube air flow meter (Air Measure AMA 250DA; Shibata Giken Co., Ltd., Japan) located just behind the box chamber. Since the flow rate of the exhaust gas was regulated to approximately 10 m^3/min in this experiment, no leakage of welding exhaust gas from the cover hood opening was observed.

In this study, the generation rates of CO from welding at several welding conditions were obtained by substituting three measurements—the flow rate of the welding exhaust gas, CO concentration in the exhaust gas and the arcing time—into the following equation:

$$G=(V_{ex} \cdot t/60 \cdot C_{CO}) \,/\, (t/60) \qquad (1)$$

where G : generation rate of CO (ml/min)
V_{ex} : average flow rate of the exhaust gas (m^3/min)
C_{CO} : average CO concentration in the exhaust gas (ppm)
t : arcing time (seconds)

All measurements were conducted in a well-ventilated laboratory free from ambient CO contamination.

Results and Discussion

Original CO concentration data are shown in Fig. 2-1 and Fig. 2-2. The generation rates of CO from CO_2 arc welding, which were derived from the original concentration data, are shown in Fig. 3-1 and Fig. 3-2. All data are given as the arithmetic mean of eight repeated tests. The generation rate of CO was proved to be 386–883 milli-liter/min with a solid wire and 331–1,293 milli-liter/min with a flux cored wire respectively. Contrary to expectation, correlation between the welding current and CO generation was not always positive. When a solid wire was used as a filler wire, the CO generation rate changed apparently depending on the shield gas flow rate. The CO generation rate was significantly increased with the increase in shield gas flow rate. On the other hand, the difference in shield gas flow rate scarcely affected CO generation when a flux core wire was used. In this case, the CO generation rate was slightly increased with the increase in shield gas flow rate, but the difference was not statistically significant ($p<0.05$ by Student's t-test). The maximum CO generation was observed at a welding current of 250–300 A with a solid wire. With a flux cored wire, the CO generation rate increased monotonically with the increase in welding current. In most cases, a flux cored wire produced more CO than a solid wire, which may have been due to the fact that the flux core wire contained some carbonates that induced additional CO generation.

In general, the ventilation rate needed to maintain a constant concentration at a uniform generation rate is derived using the following simple formula[3)], which presupposes complete mixing:

$$Q=G \,/\, C \qquad (2)$$

where G : generation rate of contaminant
Q : effective ventilation rate
C : concentration of contaminant

By substituting numerical values for G and C in equation (2), the effective ventilation rate can be readily calculated. According to this equation, the ventilation

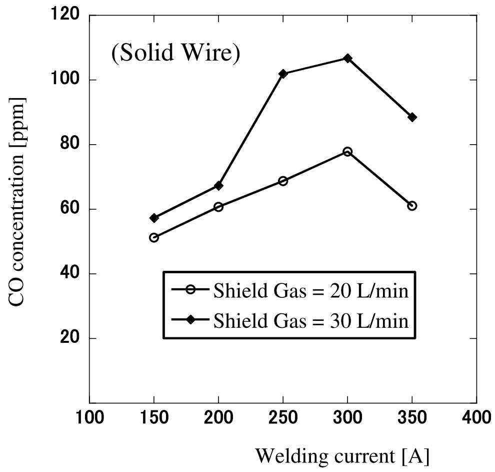

Fig. 2-1. Concentration of CO emitted from CO_2 arc welding with a solid wire. The plots are arithmetic means of 8 measurements.

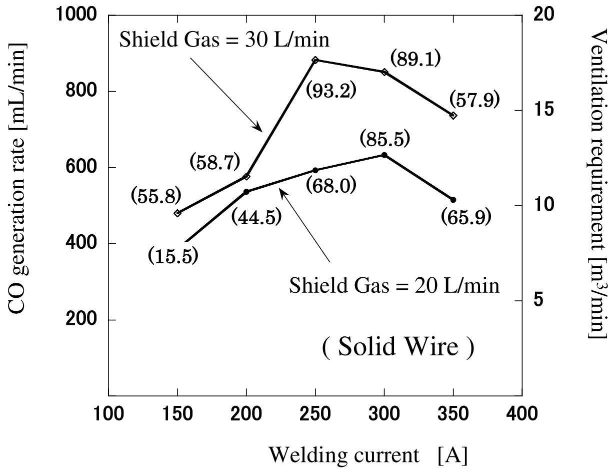

Fig. 3-1. Generation rate of CO from CO_2 arc welding with a solid wire. Ventilation requirements are also presented in this figure. The plots are arithmetic means of 8 measurements, and the standard deviation of each generation rate is shown in parentheses.

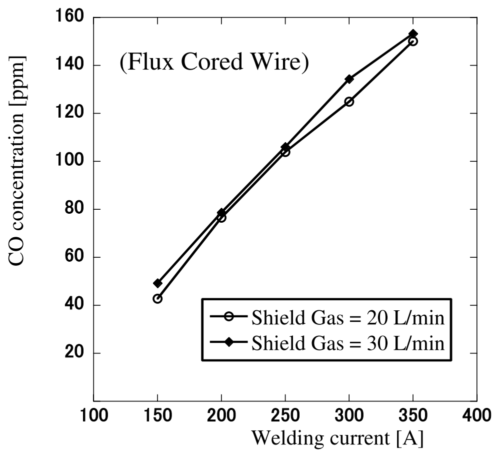

Fig. 2-2. Concentration of CO emitted from CO_2 arc welding with a flux cored wire. The plots are arithmetic means of 8 measurements.

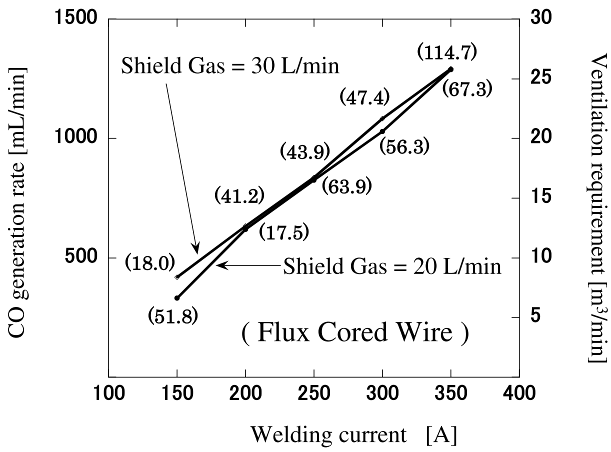

Fig. 3-2. Generation rate of CO from CO_2 arc welding with a flux cored wire. Ventilation requirements are also presented in this figure. The plots are arithmetic means of 8 measurements, and the standard deviation of each generation rate is shown in parentheses.

requirement (theoretical minimum ventilation rate) for CO_2 arc welding to prevent CO poisoning can be obtained when the permissible exposure limit (PEL) for CO is substituted for C. Fig. 3-1 and Fig. 3-2 also show the ventilation requirements for each case. In this study, the current Occupational Safety and Health Administration (OSHA) PEL for CO (50 ppm) was adopted. The calculation results indicate that the CO concentration in a room will be maintained below the PEL providing the effective ventilation rate in the room is 6.6–25.9 m^3/min. It should be noted that the actual ventilation requirement for CO poisoning prevention in the workplace ought to be larger than the presented ventilation requirement because of incomplete mixing. The American Conference of Governmental Industrial Hygienists (ACGIH) introduced a coefficient for incomplete mixing that ranges from 1 to 10 depending on the situation[4].

$$Q' = K\ Q \qquad (3)$$

where Q' : actual ventilation rate

K : coefficient for incomplete mixing

Therefore, the actual ventilation requirements for CO poisoning prevention are 1−10 times larger than the theoretically derived ventilation requirements presented in Fig. 3−1 and Fig. 3−2.

Since welding has been regarded as one of the typical jobs exposing workers to industrial dust, the importance of a dust respirator for welders is widely recognized now. However, hazardous gaseous emissions from arc welding still tend to be overlooked, which may be one of the causes of recurrent CO poisoning. Since a dust respirator has no effect on gaseous contaminants as a matter of course, an air-line mask or equivalent along with some required ventilation mentioned above should be essential for welders, especially when they work in a confined space. In order to prevent CO poisoning of welders, such countermeasures against gaseous emissions as well as welding fumes should be taken eagerly.

References

1) Ojima J. Laboratory evaluation of carbon monoxide exposure in CO_2 arc welding. J Occup Health 2009; 51: 377–9.
2) Hampl V, Niemela R, Shulman S, Bartley D. Use of tracer gas technique for industrial exhaust hood efficiency evaluation—Where to sample? Am Ind Hyg Assoc J 1986; 47: 281–7.
3) Ojima J. Generation rate of carbon monoxide from burning charcoal. Ind Health 2011; 49: 393–5.
4) General Industrial Ventilation. In: American Conference of Governmental Industrial Hygienists, editors. Industrial Ventilation 27[nd] Edition. Cincinnati (OH): ACGIH; 2008. p. 4–1-4–17.