VALTRONICS Application Note A11: Measurement of CO_2 levels for health & safety

This describes how to apply ***VALTRONICS*** CO_2 monitors for use in health and safety applications (Refer to **ASHRAE STANDARD 62-1989R & App. Note A41 for comfort standards**). The higher CO_2 levels (above 0.2% or 2000 ppm) apply to industrial spaces. The ASHRAE STANDARD recommends keeping the CO_2 level below 1000 ppm in office spaces for comfort reasons. See **Application Note A9** for information about carbon monoxide (**CO**).

Carbon dioxide (CO_2) is a nonflammable, colorless, odorless, slightly acid gas. It is approximately one and one-half times heavier than air. One volume of CO_2 will dissolve in approximately one volume of water at atmospheric pressure and 15°C. In high concentrations it has an acid taste. CO_2 is shipped in I.C.C. Approved, high pressure steel cylinders as a liquid under its own vapor pressure at approximately 830 p.s.i.g. At 70°F. It has a molecular weight of 44.01, a density of 0.1146 lb./ft^3 at 70°F and 1 atm., a sublimation point at 1 atm of -109.3°F (-78.5°C), a triple point at 5.11 atm of -69.9°F (-56.6°C), and a specific gravity of 1.5289 (air = 1.0). Refer to the **M**aterial **S**afety **D**ata **S**heet (**MSDS**), CAS number 124-38-9 Rev. September 1, 1993.

The following is a list of terms and definitions related to different concentration levels of carbon dioxide and its effect on humans:

- The **T**hreshold **L**imit **V**alue, (**TLV**) , of **0.5%** (5,000 ppm) is the maximum continuous CO_2 human exposure limit for an eight (8) hour period of time.
- The **T**ime **W**eighted **A**verage, (**TWA**)[1], for an eight (8) hour period is **0.5%** (5,000 ppm).
- The **S**hort-**T**erm **E**xposure **L**imit, (**STEL**), level is **3.0%** (30,000 ppm). < 15 minutes
- The **A**cceptable **C**oncentration **C**eiling, (**ACC**), level is **3.0%** (30,000 ppm). < 15 minutes
- The **I**mminent **D**anger to **L**ife and **H**ealth, (**IDLH**), level is **5.0%** (50,000 ppm) > 5 minutes.

An effective way to monitor compliance with health and safety regulations concerning CO_2 exposure would be to monitor the level and data log or TREND that data during the time people are present in the area being monitored. In addition to an immediate alarm for a level near and just below the **STEL** of **3.0%**, a log of who was present in the area and a data record of the concentrations during that period are required. From that data record, a TWA could be calculated and checked to ensure an average level below the 0.5% maximum. One approach would be to set the alarm just below the **TLV** of **0.5%** and initiate fresh air introduction. In an environment where large amounts of CO_2 are used for cleaning (CO_2 blasters) or food storage, alarms below 0.5% may be so frequent as to be annoying, yet the level not be hazardous because of the short duration of exposure. An example might be CO_2 excursions for a few minutes to a level of 1.0 to 2.0% that initiate fresh air introduction. The TWA might only calculate to 0.3% (3000 ppm) because of the short duration of this exposure. See the attached example chart.

Threshold Limit Values for Chemical Substances in the Work Environment Adopted by ACGIH is obtainable from the Publications Office, American Conference of Governmental Industrial Hygienists, 6500 Glenway Avenue, Building D-7, Cincinnati, OH 45211-4438 (see Ref C-1; ref C-2 is the West German counterpart). This publication provides 8-hour, 15-minute, and instantaneous case limits. It is a source of concentration limits for many chemical substances and physical agents for industrial hygiene use. In light of the constantly changing state of knowledge, the document is updated annually. It cautions the user, " The limits listed in this book are intended for use in the practice of industrial hygiene as guidelines or recommendations in the control of potential health hazards and for no other use."

[1] OSHA TWA (Table Z-1, 29 CFR 1910.1000; Fed. Reg. 06/30/93)

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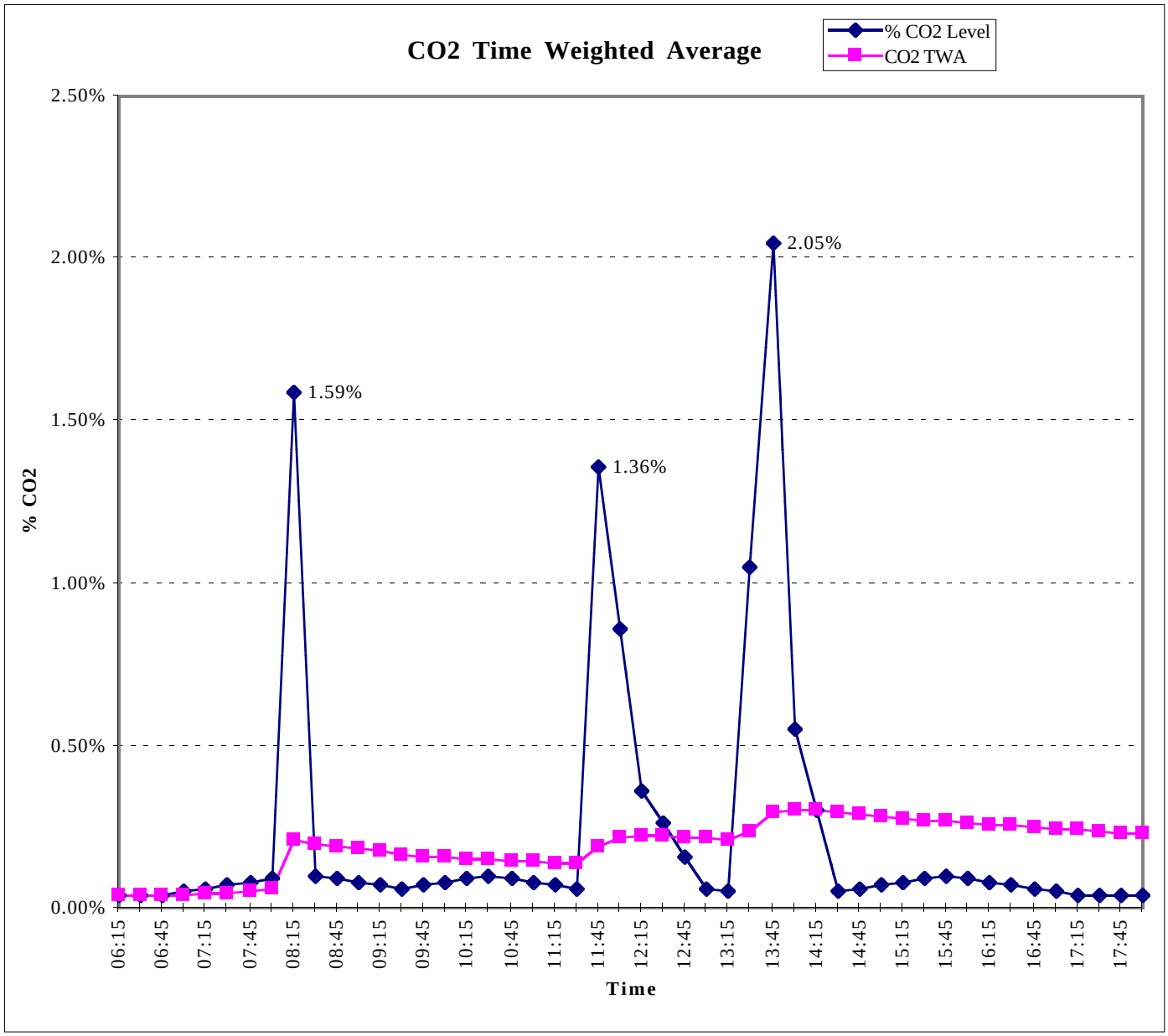
The following graph illustrates an example of what might occur in a work environment where carbon dioxide is used in high concentrations such as: a food storage area or an area where a CO_2 blaster is used for cleaning walls.



Between 07:00 hours when people started work, and 16:30 hours when people stopped work and left the area, the Time Weighted Average (TWA is a simple calculation of averaging all the measured values over a period of time) CO_2 level never exceeded 0.3% (3000 ppm). The Short Term Exposure reached levels above the Threshold Limit Value (TLV) of 0.5% (5000 ppm) three times (measured values) but never exceeded the Short Term Exposure Limit (STEL) of 3.0% (30,000 ppm). If fresh air (about 0.035% CO_2) is pumped in as soon as the measured value exceeds 0.5%, the calculated average CO_2 level (TWA) will not exceed the OSHA limit 0.5% for each worker during that worker's 8 hour work shift.

A ***VALTRONICS*** CO_2 monitor could be used to continuously measure the level and send that data to a micro-processor or data logger. A monitor such as a Model 2166, or 2156 (3% or 5% full scale) with its two level detectors could, for example, initiate the opening of a fresh air damper/fan (caution light) at 0.5% and sound an alarm at 2.0% . These levels are user adjustable.

TOXICITY [2]- In high concentrations, CO_2 can paralyze the respiratory center. Because of this, it is considered an industrial hazard. It is heavier than air and does not diffuse readily. Therefore, it may collect in confined, unventilated areas. Where persons are working in confined spaces, the amount of CO_2 formed by breathing may assume dangerous proportions. CO_2 is the regulator of the breathing function and an increase in the CO_2 inhaled will cause an increased rate of breathing. The body, while exercising, will burn more oxygen. The product of this combustion being higher concentrations of CO_2. It is these higher concentrations which increase the rate of breathing. Excess CO_2 in the air will increase the rate of breathing as indicated in the following table:

Carbon Dioxide in air (volume %)	Increased lung ventilation
0.1 to 1.0% (1000 to 10,000 ppm)	Slight and unnoticeable increase
2.0%	50% increase
3.0%	100% increase
5.0%	300% increase, breathing becomes laborious

Ten percent (10%) in air can be endured for only a few minutes. Twelve (12%) to fifteen (15%) percent soon causes unconsciousness. Twenty-five (25%) percent may cause death in exposures of several hours. The normal concentration of CO_2 in fresh air is 0.03% to 0.04% (300 to 400 ppm).

References[3]

B-1. *ASHRAE Handbook - 1983 Equipment Volume*, Chapter 27, p 27.24. American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc., Atlanta, GA 30329. 1983.

C-1. TLVs *Threshold Limit Values and Biological Exposure Indices for 1986-87*. American Conference of Governmental Industrial Hygienists, 1986, 6500 Glenway, Building D-7, Cincinnati, OH 45211-4438. (Airborne concentrations of substances to which nearly all workers may be repeatedly exposed, day after day, without adverse effect; updated yearly.) 1986.

C-2. *Verein Deutscher Ingenieure, Handbuch Reinhaltung der Luft-* Maximale Imissions-Werte, VDI 2310, September 1974. (West German counter-part of TLVs at Ref C-1).

C-3. Newill, V.A. *Air Quality Standards*, Table III, pp. 462-487, in Vol.V of Stern, A.C. (ed.). *Air Pollution*, 3rd ed, Academy Press, New York, NY (national, by county, ambient air quality standards). 1977.

C-4. Government of Ontario, Regulation 296 under the Environmental Protection Act, Revised Regulations of Ontario, Toronto (current update of Ontario Canada, ambient air quality criteria).

C-5. Martin, W., and A.C. Stern, *The World's Air Quality Standards*, Vol. 11. *The Air Quality Management Standards of the United States*, Table 17, pp. 11-38, October 1974 (available from NTIS PB-241-876; National Technical Information Service. 5285 Port Royal Road, Springfield, VA 22161). 1974.

C-6. U.S. National Academy of Sciences, Committee on Toxicology, National Research Council, Guides for Short-Term Exposure of the Public to Air Pollutants. Microfiche or photocopies of these may be obtained from the National Technical Information Services, by order number. For example: *Ammonia* PB-244-336, November 1972, *Hydrochloric Acid* PB-203-464, August 1971.

C-7. U.S. Environmental Protection Agency, Code of Federal Regulations, Title 40, Part 61 (current national emission standards for hazardous air pollutants).

C-8. U.S. Environmental Protection Agency, National Air Toxics Information Clearinghouse Data Base. Report on State and Local Agency Air Toxics Activities, July 6, 1986 (tabulation of reporting states and communities published standards and guidelines for toxic air pollutants). 1986.

C-9. U.S. Environmental Protection Agency, Code of Federal Regulations, Title 40, Part 50 (current national ambient air quality standards).

[2] Jacobs, M.B., *The Analytical Chemistry of Industrial Poisons, Hazards, and Solvents*, 2nd Edition, Interscience Publishers, Inc. New York, N.Y., 1949, p441.

[3] 1995 ASHRAE *Applications Handbook*, page 41.3, paragraph *"Toxicity"* defines AMP,ACC,TWA8, STEL,TLV and IDHL.