Utilization of CO_2 as a Tracer Gas in Laboratory, Building Science, and Engineering Applications to Determine Air Infiltration in Buildings, Vehicles, or Other Enclosures

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Abstract:

ASTM E741 (***"Standard Test Method for Determining Air Change in a Single Zone by Means of a Tracer Gas Dilution"***) has been a well-established standard for the utilization of tracer gases to determine air infiltration and has provided valuable information for my research.

The utilization of carbon dioxide (CO_2) as a tracer gas to determine air infiltration in building structures or other enclosures can be an invaluable tool to analytically determine the rate of air exchange or infiltration in any building, vehicle, or other enclosure. The determination of air infiltration has engineering/scientific applications that include, but may not be limited to the following applications:

a) Building freeze analysis,
b) Heating/cooling load analysis,
c) Carbon monoxide investigations,
d) Explosions caused by a volatile gas,
e) Children/pets trapped in a hot car,
f) Persons trapped in elevators,
g) Indoor air quality (IAQ) determination for buildings or other living spaces,
h) Virus particle concentration,
i) Building energy consumption, determination of air changes per hour (ACH),
j) Air change rate evaluation of refrigeration warehouses and meat packaging facilities, and
k) Food packaging containers.

It has been documented that CO_2 monitors/analyzers using ***nondispersive infrared technology*** (**NDIR**) are a fraction (commonly 98% less) of the cost of monitors/analyzers for other types of tracer gas that use ***Fourier Transform Infrared spectroscopy*** (**FTIR**) technology. The use of CO_2 as a tracer gas has prompted the need to develop improved protocols for various scientific/engineering applications. The existing equations in ASTM E741 do not account for background levels of CO_2 and are not compatible with any self-generation of tracer gas. Since CO_2 has a measurable presence in the ambient atmosphere (~400 ppm) and can be self-generated by the testing technician due to human respiration, the methodology/mathematics for CO_2 tracer gas air infiltration testing was developed to provide accurate real-time modeling.

The updates in methodology testing protocols were necessary since other types of tracer gases have little if any ambient concentrations and are not self-generated by the testing technician. The use of discrete equations, even with levels of CO_2 self-generation of 1-10 MET (1.0 MET = 0.00733 cfm of CO_2) can determine air change rates with low error rates. The core of this methodology includes an iterative analysis using discrete equations, and numerical techniques.

The presented methodology has been brought forward to offer improved diagnostic opportunities for ***ASTM E741*** and ***ASTM D6245.*** It is further noted that the reduced costs for using CO_2 monitors would also enable tracer gas testing for more applications. This paper will also provide a detailed step-by-step derivation of the mathematics/methodology as well as a sample examples, error analyses, and sensitivity analyses; the reader will be able to be fully informed/educated on completing CO_2 tracer gas evaluations.

Keywords — ACH, carbon dioxide, tracer gas, air infiltration, discrete equations, numerical iterative analysis

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