National Building Controls Information Program

PRODUCT TESTING REPORT

WALL MOUNTED CARBON DIOXIDE (CO_2) TRANSMITTERS

June 2009

TABLE OF CONTENTS

Program Sponsors

California Energy Commission
Iowa Energy Center

Introduction

Carbon-dioxide (CO_2)[1] transmitters are gaining popularity in building HVAC systems to monitor indoor air CO_2 concentration and to control the outdoor air intake rate. Controlling ventilation air flow rates using CO_2-based Demand Controlled Ventilation (DCV) offers the possibility of reducing the energy penalty associated with over-ventilation during periods of low occupancy, while still ensuring adequate levels of outdoor air ventilation (Emmerich and Persily 2001). A report prepared for DOE (Roth et al. 2005) suggests that DCV can reduce both heating and cooling energy by about 10% or about 0.3 quadrillion BTUs annually.

In CO_2-based DCV systems, the CO_2 level of indoor air is monitored and the outdoor air flow rate is adjusted based on the transmitter output to maintain acceptable CO_2 concentration in the occupied space. The performance of CO_2 transmitters is crucial in this control process. A general guideline often used in DCV is that the CO_2 concentration in a space should not exceed 700 ppm above the ambient CO_2 level. For occupants involved in sedentary activities (such as in an office or classroom) this corresponds to approximately 15 cfm of outdoor air per person. Transmitters which read high will call for more outdoor air resulting in an energy penalty. A transmitter which reads 100 ppm high would result in approximately 17% more ventilation air flow. Transmitters which read low could cause poor indoor air quality. CO_2 transmitters are reported to have technology-specific sensitivities, and unresolved issues including drift, overall accuracy, temperature effect, water vapor, dust buildup, and aging of the light sources etc. (Dougan and Damiano 2004).

Because of their impact on energy usage and indoor air quality, the National Building Controls Information Program (NBCIP) tested and evaluated the performance of Non-Dispersive Infrared (NDIR) wall-mounted CO_2 transmitters used in typical building HVAC applications. NBCIP developed an experimental procedure for testing the CO_2 transmitters, and used this procedure to test fifteen models of CO_2 transmitters.

This NBCIP Product Testing Report provides an overview of factors to consider when purchasing a CO_2 transmitter, presents manufacturer data for transmitters selected for testing, describes the test procedure and test apparatus used by NBCIP to evaluate transmitter performance, and presents test results for accuracy, linearity, hysteresis, repeatability, humidity sensitivity, temperature sensitivity, and pressure sensitivity for each CO_2 transmitter model tested.

[1] *Throughout this report, the CO_2 sensing element is referred to as the sensor. A CO_2 transmitter is a device that consists of a sensor as well as a transducer that converts the sensor reading into an output signal.*

Conclusions

The result from the tests conducted under accurate and repeatable conditions showed a wide variation in transmitter performance among the fifteen NDIR CO_2 transmitter models. In some cases, significant variations in transmitter performance exist between transmitters of the same model while in other cases, all transmitters of the same model showed almost identical behavior.

None of the transmitter models meet their manufacturer specified accuracy statement for all three transmitters of a given model over the full range of test conditions. For some models, none of the transmitters meet the accuracy specifications over the range. Table 12 summarizes the transmitter models and the number of transmitters of the given model that meet the manufacturer's accuracy statement for the model. It is important to note that there is a wide variation in accuracy statements among the manufacturers, and the results presented in the table are not an indication of the performance between the various transmitter models.

Given the test results and that the transmitters were tested under "as received" conditions, it appears that transmitter calibration should be performed before putting a transmitter into service.

However, for transmitters with an automatic baseline adjustment algorithm, it is impossible to predict the transmitter's performance over a prolonged time period during which the transmitter baseline might make multiple adjustments. In fact, the product data for several transmitter models that incorporate an automatic baseline adjustment algorithm claim that the transmitters do not require calibration. Given the transmitter is "self adjusting" using an arbitrary baseline reading of 400 ppm, it is unclear how the transmitter manufacturer can claim an absolute accuracy for their transmitter. However, some of the models that utilize automatic baseline adjustment algorithm do appear to be "accurate" if one accounts for the bias created by the baseline adjustment. For example, all three AirTest Technologies TR9290 transmitters (Figure 9a) would perform as specified if the transmitter readings were adjusted downward by approximately 50 ppm. The same is true for several other non self-adjusting transmitters that show a relatively constant value of deviation as the CO_2 concentration is increased. For transmitters that show increasingly larger values of deviation as the CO_2 concentration increases (see Figure 9g), a simple bias adjustment would not make the transmitter reading accurate over the full range of CO_2 concentrations.

Table 12. CO_2 Transmitter accuracy summary.

Manufacturer	Model Number	All 3 transmitters meet the manufacturer's accuracy statement	2 transmitters meet the manufacturer's accuracy statement	1 transmitter meets the manufacturer's accuracy statement	None of the transmitters meet the manufacturer's accuracy statement
AirTest Technologies	TR9290			■	
AirTest Technologies	EE80-2CT3				■
Automation Components Inc.	ACI/CO2-VDC-R		■		
Digital Control Systems Inc.	AirSense™ M307				■
Greystone Energy Systems Inc.	CDD1A2000				■
Honeywell	C7232A1016				■
Intec Controls Inc.	I-310E				■
Johnson Controls	CD-WA0-00-0				■
Sensata (Texas Instruments)	4GS-1				■
Siemens	QPA2000				■
Telaire (GE Sensing)	Ventostat®8001			■	
Telaire (GE Sensing)	Ventostat®8002			■	
Vaisala	GMW21				■
Veris Industries	CWE SC			■	
Vulcain	90DM4SM-C-2000		■		

Table 1. Technical information for carbon dioxide transmitters tested by NBCIP.

Manufacturer	AirTest Technologies	AirTest Technologies	Automation Components Inc.	Digital Control Systems, Inc.	Greystone Energy Systems, Inc.	Honeywell Inc.	Intec Controls
Model Number	TR9290	EE80-2CT3	ACI/CO2-VDC-R	AirSense™ M307	CDDIA 2000	C7232A1016	I-310e
Price paid by NBCIP	$186	$273	$248	$195	$402	$277	$231
Technology (NDIR)	Single lamp, single wavelength, automatic baseline adjustment	Two lamps, single wavelength	Single lamp, single wavelength, automatic baseline adjustment	Single lamp, single wavelength, automatic baseline adjustment	Single lamp, single wavelength, automatic baseline adjustment	Single lamp, single wavelength, automatic baseline adjustment	Single lamp, single wavelength, automatic baseline adjustment
Accuracy	± 1% of measurement range + 5% of measured value	< ± (50 ppm + 2% of measure value) at 20°C	± 50 ppm or + 3% of reading (@ 25°C at standard pressure)	± 5% of reading or 75 ppm, (whichever is greater)	± 75 ppm or 3% of reading (whichever is greater) (15°C to 32°C (59°F to 90°F))	± (30 ppm + 2% of reading)	± 5% of reading or ± 75 ppm
Operating Range	32°F to 122°F (0°C to 50°C) 0% to 95% RH	23°F to 131°F (–5°C to 55°C) 0% to 90% RH	59°F to 90°F (15°C to 32°C) 0% to 95% RH	32°F to 122°F (0°C to 50°C) 5% to 95% RH	32°F to 122°F (0°C to 50°C) 0% to 95% RH	32°F to 122°F (0°C to 50°C) 0% to 95% RH	32°F to 122°F (0°C to 50°C) 0% to 90% RH
Temperature Sensitivity	5 ppm/°C	5 ppm/°C	+/– 0.15% FS/°C	NA	0.2 %FS/°C	NA	NA
Pressure Sensitivity	NA	NA	0.13% of reading per mmHg from 760 mmHg	NA	0.13% of reading per mm Hg	1.4% change in reading per 1 kPa deviation from 100 kPa.	Calibrated for sea level, adjustable to altering altitude levels by setting correction multiplier
Calibration Interval	Automatic baseline correction for self calibration (15 years) lifetime self calibration (15 years)	15 Years	ABC Logic™ Automatic self calibration software	5 year	5 year	Typically, calibration is unnecessary	Three to five years, Span only, zero adjustment, automatically self-tuned
Response Time	T90 = < 2 minutes	T63 = < 90 seconds	< 2 minutes	NA	2 minutes for 90% step change	2 minutes	Less than 1 minute

Table 1. (Continued)

Manufacturer	Johnson Controls Inc.	Sensata (Texas Instruments)	Siemens	Telaire	Telaire	Vaisala	Veris Industries	Vulcain
Model Number	CD-WA0-00-0	4GS-1	QPA2000	Ventostat 8001	Ventostat 8102	GMW21	CWE SC	90DM4SM-C-2000
Price paid by NBCIP	$433	$444	$252	$265	$379	$787	$426	$369
Technology (NDIR)	Single lamp, dual wavelength	Two lamps, single wavelength	Two lamps, single wavelength	Single lamp, single wavelength, automatic baseline adjustment	Single lamp, dual wavelength	Single lamp, dual wavelength	Single lamp, single wavelength, automatic baseline adjustment	Two lamps, single wavelength
Accuracy	< ± [30 ppm + 2.0% of reading] at 68°F (20°C)	± 75 ppm if 0–1500 ppm: ± 5% if > 1500ppm (readings @ standard pressure 760 mm Hg & 25°C)	≤ ± 50 ppm + 2% of measured value	±100 ppm or 7% whichever is greater	± 50 ppm or 5% whichever is greater (7% for levels over 1500 ppm) @ 60°F–90°F (15°C–32°C)	< ± [30ppm + 2% of reading] at 25°C (77°F)	± 30 ppm ± 5% of measured value	± 100 ppm + 3% of reading
Operating Range	23°F to 113°F (–5°C to 45°C) 0% to 85% RH	32°F to 122°F (0°C to 50°C) 5% to 95% RH	23°F to 113°F (–5°C to 45°C) 0% to 85% RH	60°F to 90°F (15°C to 32°C) 0% to 95% RH	32°F to 122°F (0°C to 50°C) 0% to 95% RH	23°F to 113°F (–5°C to 45°C) 0% to 85% RH	32°F to 122°F (0°C to 50°C) 0% to 95% RH	32°F to 100°F (0°C to 40°C) 0% to 95% RH
Temperature Sensitivity	< 0.056% of Full Scale/°F (< 0.1% of Full Scale/°C)	5 ppm/°C over operating temperature	+/– 2 ppm/°C	NA	NA	0.15 %FS /°C (reference 25°C)	NA	NA
Pressure Sensitivity	Without compensation for an altitude range of 0 to 1,969 ft (0 to 600m) above sea level. To compensate for higher altitudes, see the installation instructions.	0.19% of reading per mm Hg	NA	Add 0.13% of reading per mm Hg decrease from 760 mm Hg	Add 0.13% of reading per mm Hg decrease from 760 mm Hg	NA	NA	NA
Calibration Interval	NA	3 years	Not required	ABC Logic™ Automatic self calibration software	5 year calibration guarantee	5 year	5 year	NA
Response Time	1 Minute	< 30 seconds to 63% of step changes	(0 to 63%) 1 minute	0-90% < 1 minute	0-90% < 1 minute	(0 to 63%) 1 minute	< 60 seconds for 90% step change	Less than 60 sec. (for 90% of the reading)

Notes:

1. The information in this table was obtained first from the product data supplied with the transmitters, or next from the product documents available on the mfg web site, or last from the mfg web page.
2. NA indicates that the information was not available in the manufacturer's product literature.
3. NBCIP tested the wall-mounted carbon dioxide transmitters using a supply voltage of 24 VDC or 24VAC as specified by manufacturers.
4. NBCIP tested the wall-mounted carbon dioxide transmitters using VDC output. Current output from Honeywell transmitters was converted to VDC using 1% 250-ohm resistors.
5. None of the manufacturers reported humidity sensitivity of their transmitters.