

*Working together for clean air*

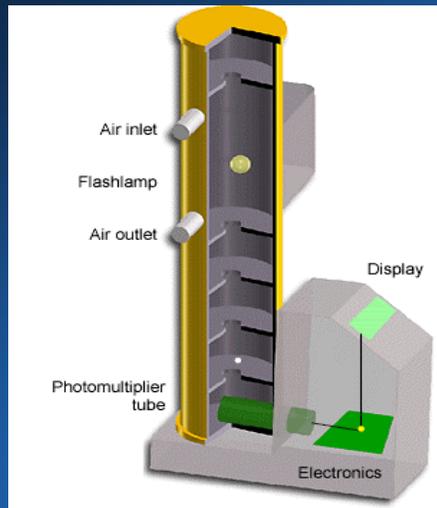
Puget Sound  
Clean Air Agency  
pscleanair.org



# Comparison of CO<sub>2</sub> to R-134a in Calibrating Nephelometers

Puget Sound Clean Air Agency  
Adam Petrusky

## Overview



- PSCAA operates 18 Nephelometers

- 16 Radiance Research
- 2 Ecotech

- Washington Department of Ecology requires the use of R-134a for calibrations

- To mitigate the fiscal and environmental impacts of our nephelometer network we investigated the significance of switching to CO2.



**Why CO<sub>2</sub>**

- CO<sub>2</sub> is an attractive alternative because:
  - Global Warming Potential<sup>1</sup> (GWP) for R-134a is 1300 times stronger than CO<sub>2</sub>
  - R-134a is 7 times more expensive than CO<sub>2</sub>
    - ▲ R-134a costs \$182 per Neph per year
    - ▲ CO<sub>2</sub> costs \$27 per Neph per year
    - ▲ Savings of \$155 per site with only \$128 in hardware costs to switch to CO<sub>2</sub>
    - ▲ PSCAA total network savings of \$2480 per year

<sup>1</sup>Intergovernmental Panel on Climate Change Third Assessment Report (IPCC TAR), 2001, *Direct GWPs*, 6.12.2.



Puget Sound  
Clean Air Agency  
pscleanair.org

GWPs are an index for estimating relative global warming contribution due to atmospheric emissions of 1kg of a particular greenhouse gas compared to 1kg of CO<sub>2</sub>

## Operating and Calibrating Principles

- Measures particulate using a light beam and detector
- Light scattering is measured as back scattering (bscat)
- Bscat directly correlates to PM<sub>2.5</sub>
- Zero with particle free ambient air
- Span using a gas with a higher scattering coefficient than air
- Different gasses have different bscat values
- R-134a has a mid span value of  $8.39 \times 10^{-5} \text{ m}^{-1}$  and CO<sub>2</sub> is much lower at  $2.13 \times 10^{-5} \text{ m}^{-1}$



A Nephelometer measures particulate by employing a light beam and a light detector. As gas enters the sample chamber it scatters light. The light scattering coefficient is measured as back scattering and directly correlates to PM<sub>2.5</sub> without a size selective inlet.

The nephelometer is zeroed by filling the chamber with particle free air so that the readings are proportional to light scattering by particles. The span gas, which has a higher scattering coefficient than air, is used to adjust the span so that the bscat data are directly correlated to engineering units of ug/m<sup>3</sup>.

Span gasses are chosen based on their density. A higher density equates to a higher bscat value.

## Our Objective

- Can CO<sub>2</sub> work as well as R-134a?
- If CO<sub>2</sub> gives same results as R-134a, then success!
  - DoE requires action at 5% out of spec and data invalidation at 7%



## The Method Design

- Lab tests were performed on a Radiance Research Nephelometer
- The nephelometer was tested at 5 different Set Spans over at least 24 hour periods for over a month.
  - ▲ The properly calibrated neph: R-134a gives a value of 8.39 e-5. CO<sub>2</sub> gives 2.13 e-5.
  - ▲ The high action level (5%) neph
  - ▲ The low action level (5%) neph
  - ▲ The out of spec high (7%) neph
  - ▲ The out of spec low (7%) neph
- At each Set Span, the span of CO<sub>2</sub> and R134a were both monitored and recorded
- The zero was also measured every day of the test
- At least 30 data points at each Set Span were recorded



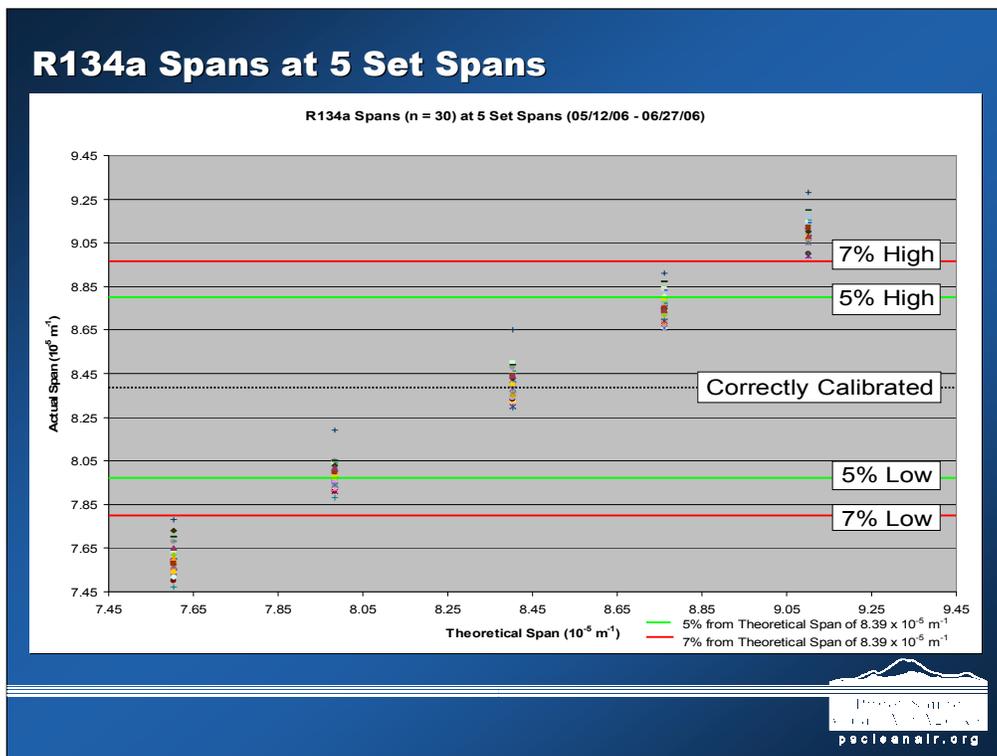
In order to determine if there was a linear relationship

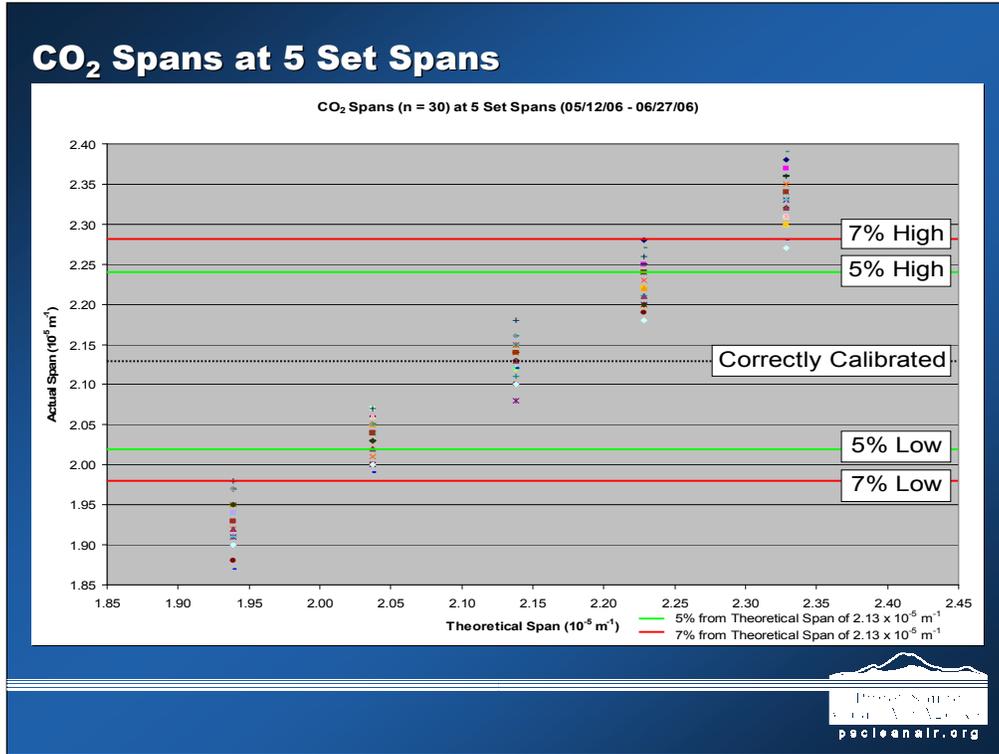
## Measures of Performance

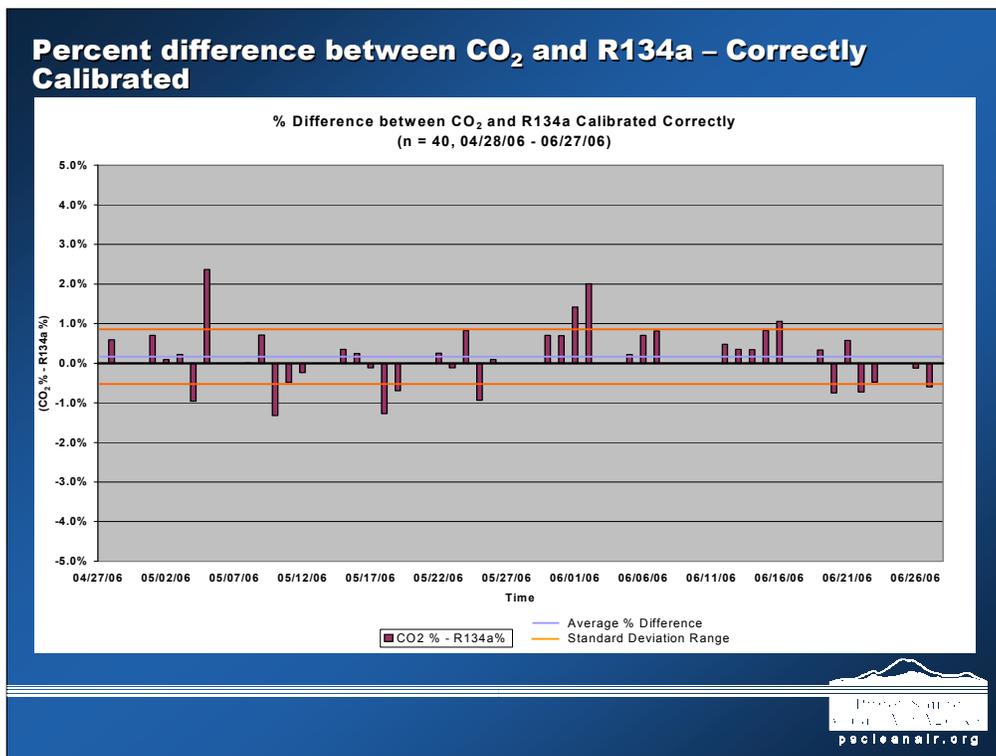
- CO2 predicts, with accuracy, the same decision points as the R-134a calibration gas
- Minimize false positives and negatives
  - The properly calibrated neph, the out of spec high (7%) neph and the out of spec low (7%) neph have low tolerance for errors
    - ▲ Error rate less than 5%
  - The high action level (5%) neph and the low action level (5%) neph are in a calibration state that is borderline without an obvious answer

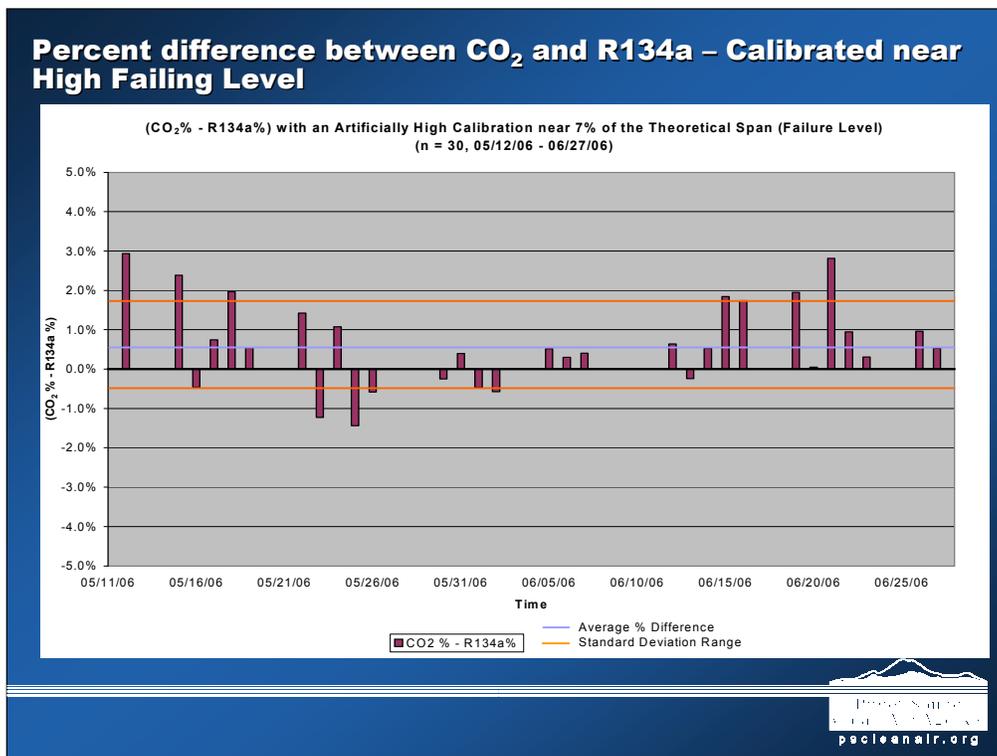


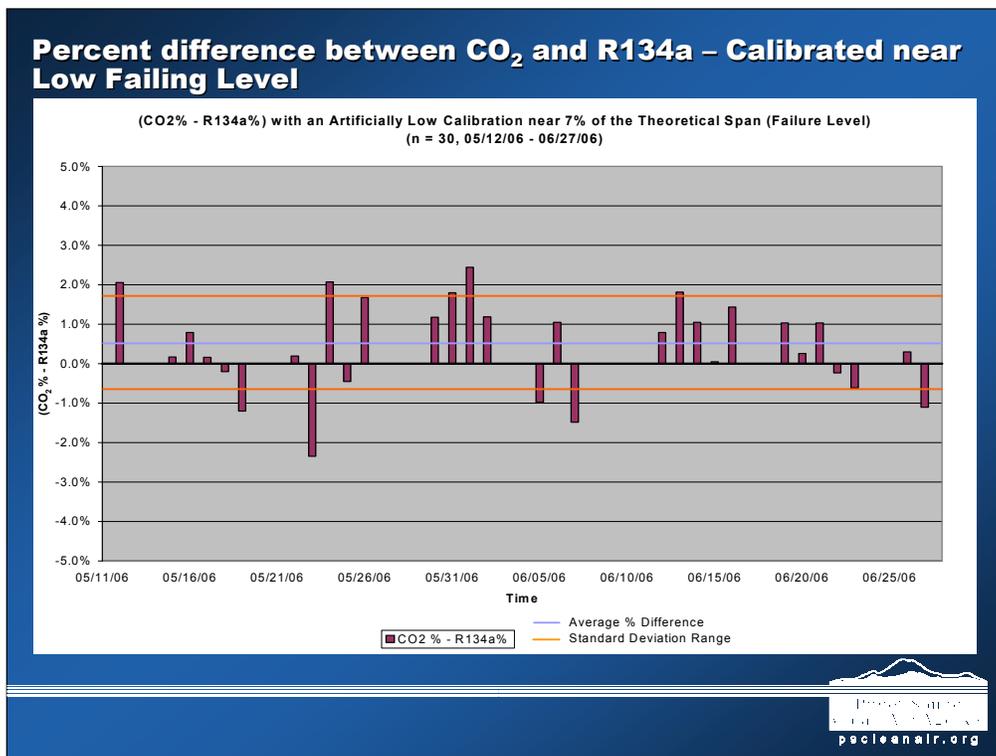
false positives concluding that a recalibration would be necessary with CO2 that R-134a does not predict

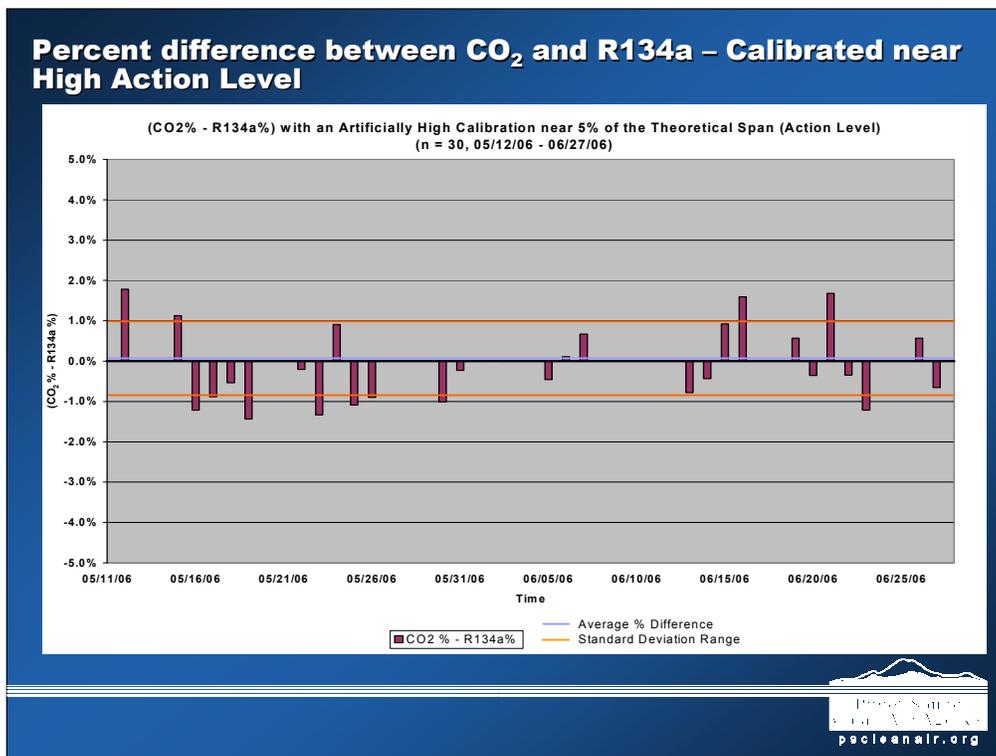


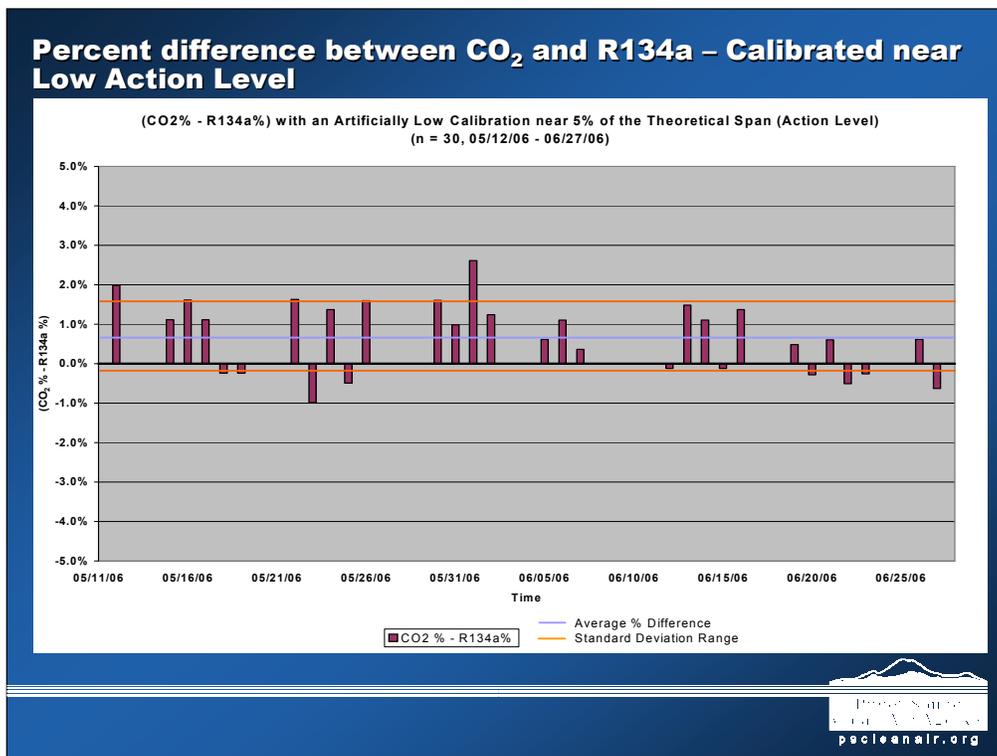












### **Our Conclusions**

- **The data shows that the CO<sub>2</sub> and the R134a calibration gases are always within 3% of each other**
- **When the instrument was calibrated near failing levels, both gases exhibited the same results and were both out of specification**
- **When the instrument was calibrated near action levels, both gases exhibited the same results and were both in specification**



## Yet to Be Done

- **Wood smoke vs. industrial emissions**
  - **2 nephs at a wood smoke site and 2 at a industrial site**
  - **Are there variances in the high range in winter months?**



