

Advancing NO₂ and NO_x Monitoring with Dual-Channel CRDS

REAL-TIME BALTIMORE ON-ROAD TESTING

A CASE STUDY

BACKGROUND

Accurate nitrogen dioxide (NO₂) monitoring is vital for air quality management, public health, and climate research. Traditional single-channel instruments often struggle with measurement noise and data distortion caused by valve-switching between NO₂ and NO_x. These switching events introduce artifacts that reduce both short-term accuracy and long-term data reliability.

This case study presents insights from a mobile platform deployment in Baltimore, USA. It demonstrates how the G60's dual-channel system maintains high accuracy and reliability with good temporal resolution, even in dynamic or polluted conditions. Unlike older systems, G60 prevents data gaps and improves confidence in reported NO₂ levels.

THE CHALLENGE

Air quality regulators, researchers, and industries face a major challenge: how to measure nitrogen oxides (NO, NO₂, and NO_x) accurately (and in real-time) in dynamic environments where air pollution levels are constantly shifting, such as along roadways.

Accurate, real-time measurements of nitrogen oxides are critical for:

- Protecting human health.
- Understanding atmospheric chemistry.
- Supporting compliance and air quality policies.

Traditional analyzers introduce uncertainty as they:

- Use indirect measurement of NO₂.
- Some converters are known to overestimate NO₂.
- Require switching sample streams, leading to delays.
- Lack the resolution needed to capture fast-changing traffic and atmospheric dynamics.

To move beyond these limitations, a new solution was needed, one that could provide reliable, high-resolution, real-time data in the field.

WHO BENEFITS

- **Regulators:** Reliable compliance data.
- **Researchers:** High-resolution insights into atmospheric chemistry.
- **Industry:** Tools for emissions tracking and mitigation strategies.

ACKNOWLEDGEMENTS

Developed in collaboration with US Environmental Protection Agency (USEPA), National Research Council Canada (NRC), National Oceanic and Atmospheric Administration (NOAA), and Environment and Climate Change Canada (ECCC).

THE SOLUTION: G60 DUAL-CHANNEL CRDS ANALYZER

Direct Optics developed a next-generation Cavity Ring-Down Spectroscopy (CRDS) instrument to overcome the challenges described - the G60. This analyzer measures NO_2 and NO_x simultaneously and independently, removing the need for valve-switching. This innovation produces cleaner, more stable signals with greatly reduced noise and data loss.

G60 TECHNOLOGY

The G60 operates based on Cavity-Ring Down Spectroscopy with dual-channel optical cavities capable of independently monitoring NO_2 and NO_x (and NO which is determined through the difference between NO_2 and NO_x).

Dual-Channel: Uniquely equipped with two dedicated channels, allowing simultaneous feedback on NO_2 and NO_x levels. This feature is particularly crucial in dynamic environments where air quality changes rapidly (e.g., roadside monitoring).

Real-Time Monitoring: No switching!

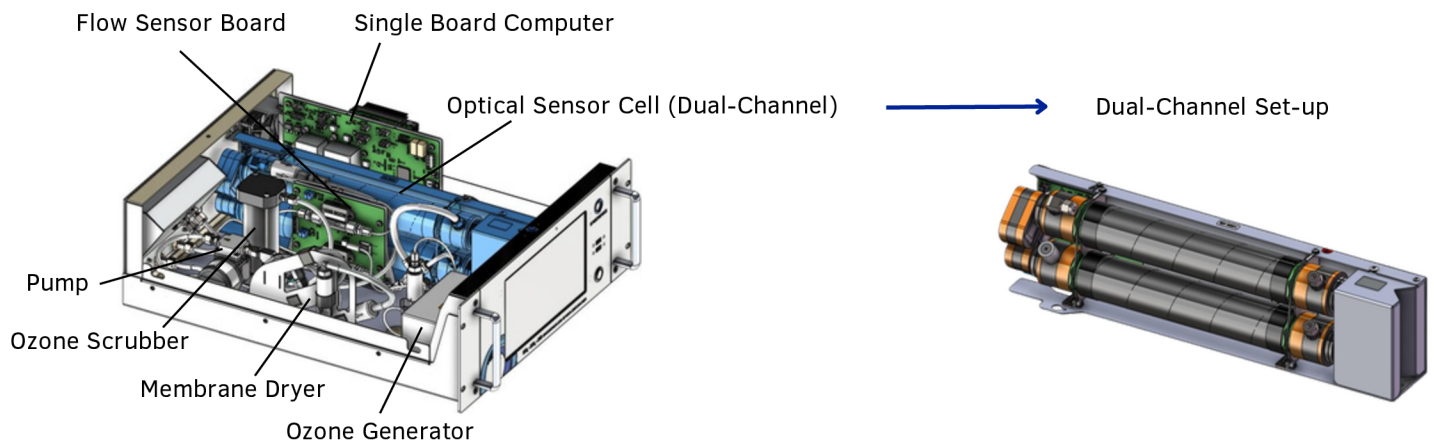
No purge volumes and data gaps during monitoring. This offers instantaneous feedback on NO_2 and NO_x levels. This feature is essential and highly desirable in dynamic environments.

G60 ANALYZER FEATURES

- Direct, simultaneous detection of NO_2 and NO_x .
- High precision and time resolution (seconds).
- Self-aligned optical cavity for stability during deployment.
- Compact, rugged design for both mobile and airborne use.



G60 ANALYZER INTERNALS

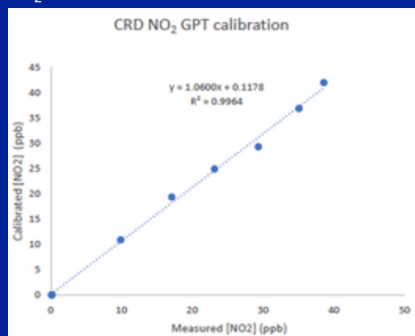


SET-UP/CALIBRATION

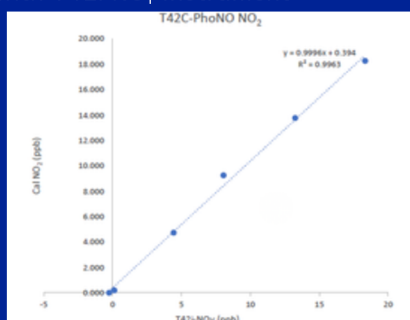
Calibration: Validated against reference analyzers with excellent correlation and linearity.

Below are calibration plots of G60 CRDS Instrument vs Thermo Fischer Scientific 42C equipped with a Photolytic (PhoNO™) converter.

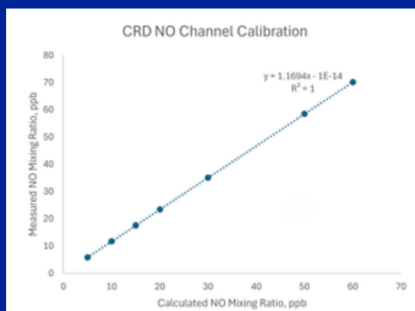
NO₂ Gas Phased Titration Calibration



Expected NO₂ vs measured NO₂ with T42i NO_y instrument



NO Gas Phased Titration Calibration

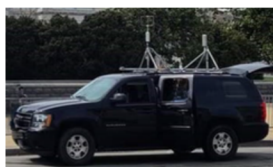


Calibration was carried out using established reference techniques to validate accuracy. Results demonstrated excellent linearity and agreement with traditional methods.

Figures showed a strong correlation between the CRDS system and reference analyzers, confirming reliability for field applications.

SOLUTION IN PRACTICE: ON-ROAD TESTING

To prove our solution, we conducted a road test. Testing took place in Baltimore, Maryland, where the instrument was installed on a mobile platform. Measurements were taken both in the Baltimore Harbor Tunnel and on surrounding streets to provide insights into different environmental conditions.



MOBILE LAB PLATFORM

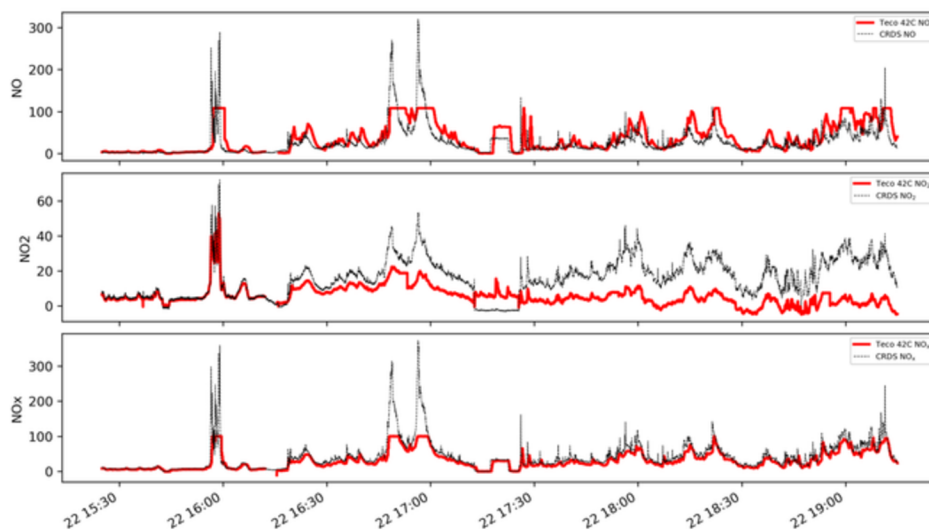


INSIDE MOBILE LAB



BALTIMORE TUNNEL

Below is the time series of the real-time NO, NO₂, NO_x trends on the streets of Baltimore leading into the Baltimore tunnel.



Day 1 – Baltimore Tunnel Driving Test (as shown above):

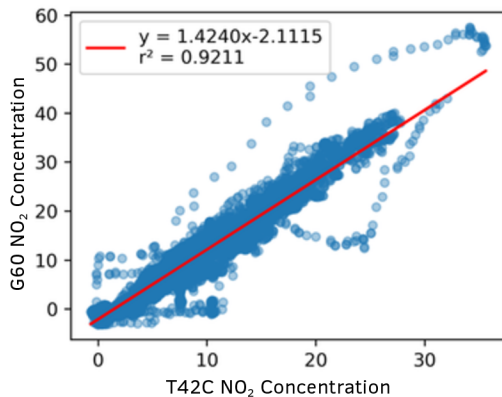
On Day 1, we compared the G60 NO_x-CRDS with the T42C-PhoNO driving through the Baltimore Harbor tunnel. At 22:15 in slow traffic, both instruments showed similar NO₂ readings. By 22:16, as traffic cleared and the mobile lab reached ~50 MPH, readings diverged: the T42C at ~10-second resolution versus the G60 at 1 second. This demonstrates the importance of fast-response instruments for near-road, on-road, and urban monitoring.

Day 2 – Baltimore City Streets:

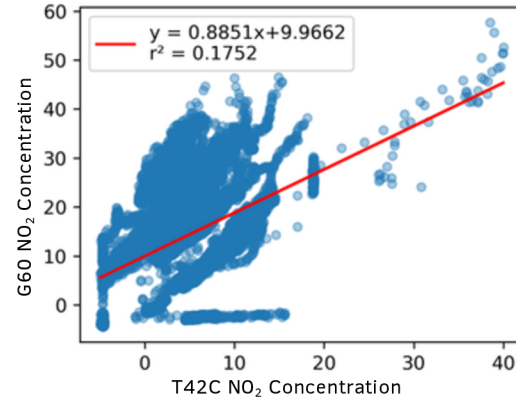
On Day 2, from 11 AM to 1 PM, the mobile lab navigated congested Baltimore streets at ~20 MPH. Under these conditions, NO₂ readings closely matched between instruments ($r^2 > 0.9$). In contrast, during the tunnel's fast traffic, agreement was poor ($r^2 < 0.1$). This highlights how rapidly changing conditions cause mismatches, reinforcing the need for true real-time 1-second resolution in dynamic environments such as flight studies, near-road, and urban monitoring.

During the trial, the G60 successfully tracked variations in NO, NO₂, and NO_x from real-world traffic emissions, demonstrating both high temporal resolution and excellent sensitivity.

1. Regression Analysis of NO₂ from G60 vs T42C at 20 mph



2. Regression Analysis of NO₂ from G60 vs T42C at 50 mph



The regression analysis graphs above show measurements based on our two scenarios.

1. Regression Analysis of NO₂: G60 vs. T42C – Mobile Platform moving slowly (20 mph) on the streets of Baltimore

This regression demonstrates a strong correlation ($R^2 = 0.9211$) between the two instruments. The slope (1.4240) indicates that the G60 generally measures higher NO₂ concentrations than the T42C, though in a consistent and predictable manner. Street-level sampling provided a more stable environment, allowing the relationship between the two instruments to be much clearer. Here, the G60 performed strongly, offering a consistent and robust signal that tracked NO₂ concentrations with high confidence.

2. Regression Analysis of NO₂: G60 vs. T42C – Mobile Platform moving at top speed (50 mph) inside the Baltimore Tunnel

In contrast, this regression shows a weak correlation ($R^2 = 0.1752$) with significant scatter around the line of best fit. The slope (0.8851) suggests the G60 tends to report slightly lower NO₂ concentrations compared to the T42C. These results highlight the challenges of sampling in the tunnel environment, where rapidly changing conditions and complex exhaust plumes can reduce instrument agreement.

RESULTS AND CONCLUSIONS

Field results demonstrate the G60's exceptional value for real-time air quality monitoring.

- Its 1-second temporal resolution provides fast, high-fidelity insights into NO₂ and NO_x dynamics, capturing rapid fluctuations that traditional systems often miss.
- Direct NO₂ measurement eliminates artifacts associated with indirect monitoring, while the dual-channel design further ensures precision and accuracy by removing errors from stream switching.
- Setup and calibration are straightforward using familiar GPT techniques, enabling rapid deployment in both laboratory and field environments.
- Strong agreement with established monitoring methods confirms the instrument's reliability, and its versatility opens new possibilities for near-road, on-road, and airborne monitoring.

Overall, the G60 delivers stable, high-resolution data, representing a significant advancement in timely and accurate air quality assessment.

For more information, email us at solutions@direct-optics.com.