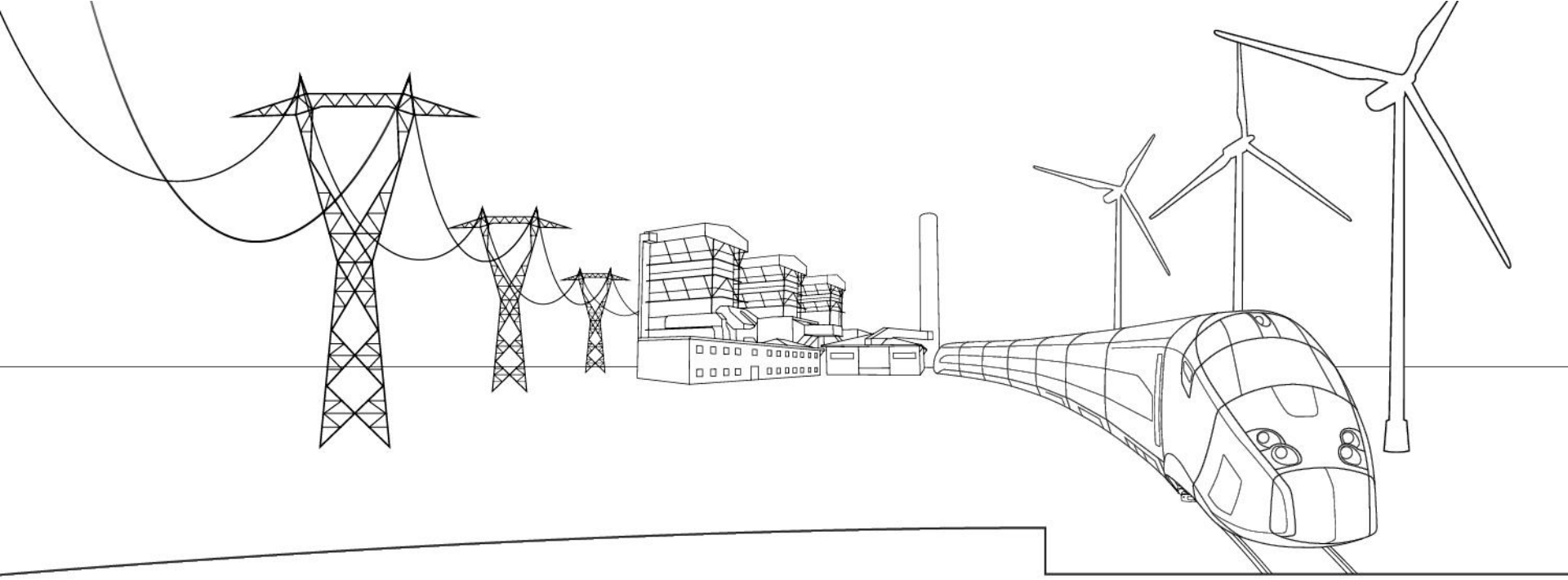

# Advances in Leak Detection in the Manufacturing Process

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ALSTOM
Shaping the future

# Agenda

1. Introduction
2. $SF_6$ Leak Detection Methods
3. Implementation
4. Benefits
5. Conclusions

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# Introduction

- Reduction of leak rates in high-voltage $SF_6$ insulated circuit breakers (1.0% to less than 0.5% per year).
- Implementation of leak detection method into production environment.
- Challenge to keep cycle time within constraints while being capable to verify low leak rates.
- Test on fully assembled circuit breakers.
- Impact on detection rates, process feedback, product reliability, field incidents.

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# $SF_6$ Leak Detection Methods



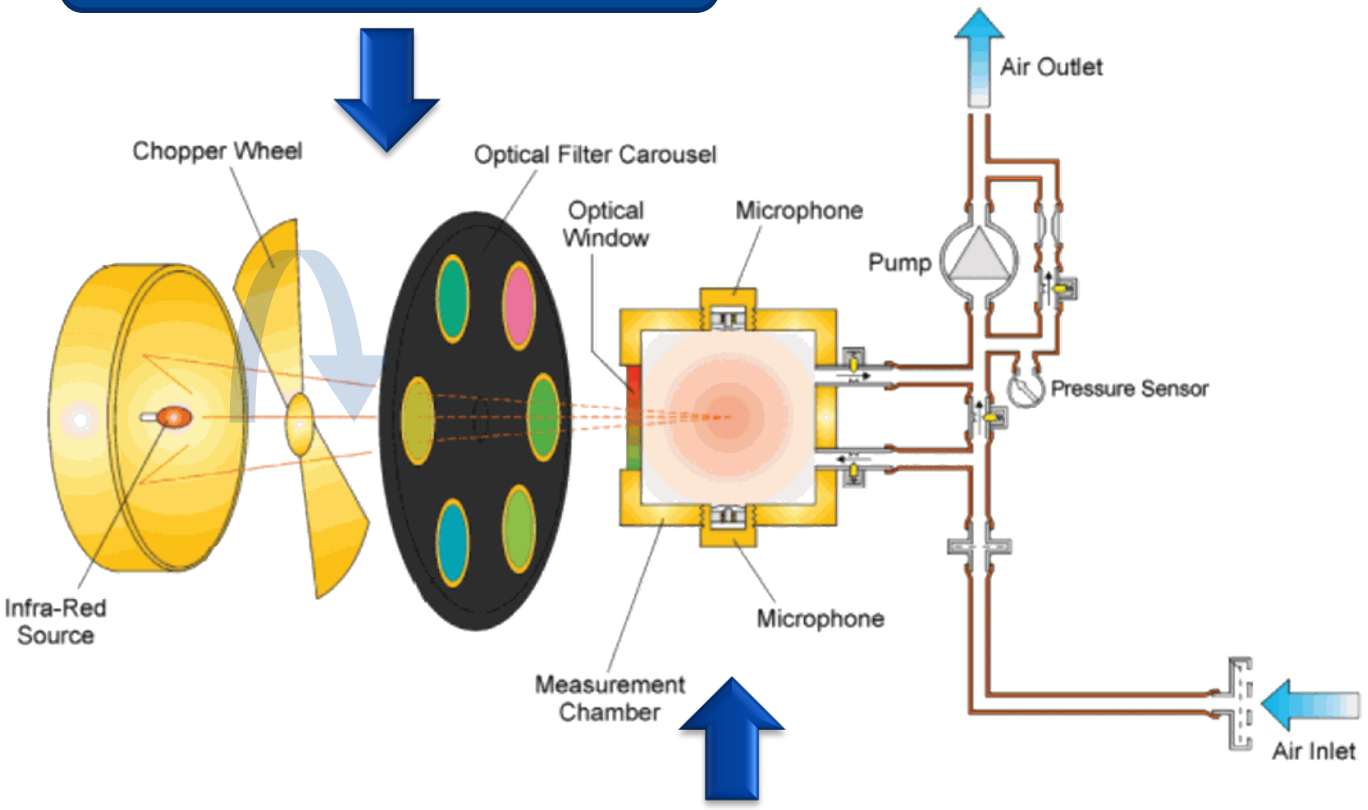
## Comparison of detection methods

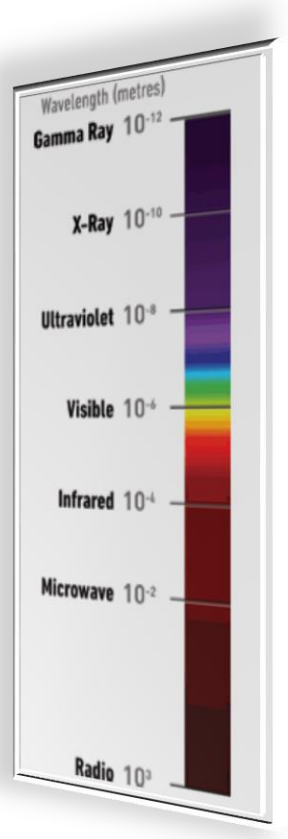
| Method | Sensitivity (kg/year) | Ratio vs. bubble test |
|---|---|---|
| Vacuum increase | 10 | 10 |
| Infrared camera | 1 | 1 |
| Bubble test | 1 | 1 |
| Density monitor | 0.6 | 1.7 |
| Infrared absorption spectroscopy | 0.06 | 16.7 |
| Negative ion detector | 0.02 | 50.0 |
| Electron capture detector | 0.002 | 500.0 |
| Helium mass spectrometer | 0.002 | 500.0 |
| **Photo-acoustic infrared spectroscopy** | **0.0002** | 5000.0 |

- **Greatest Sensitivity and Accuracy**
  - Method used by ALSTOM Grid for Type Tests and Production

# Photo-Acoustic Infrared Spectroscopy

Light passed through a filter impacts SF6 molecules in a sample volume




Pressure increase translates to an acoustic signal

# Photo-Acoustic Infrared Spectroscopy

- Highest sensitivity method for leak detection
  - 5000x sensitivity of bubble test or infrared camera.
  - 10x sensitivity of helium mass spectrometer method
    - 2g/year vs. 0.2 g/year.

- Allows to accurately measure and verify <0.5% per year leakage rate in a production environment.

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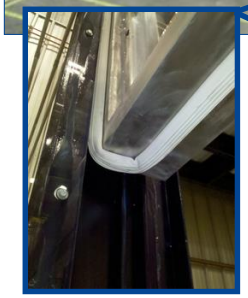
# Implementation

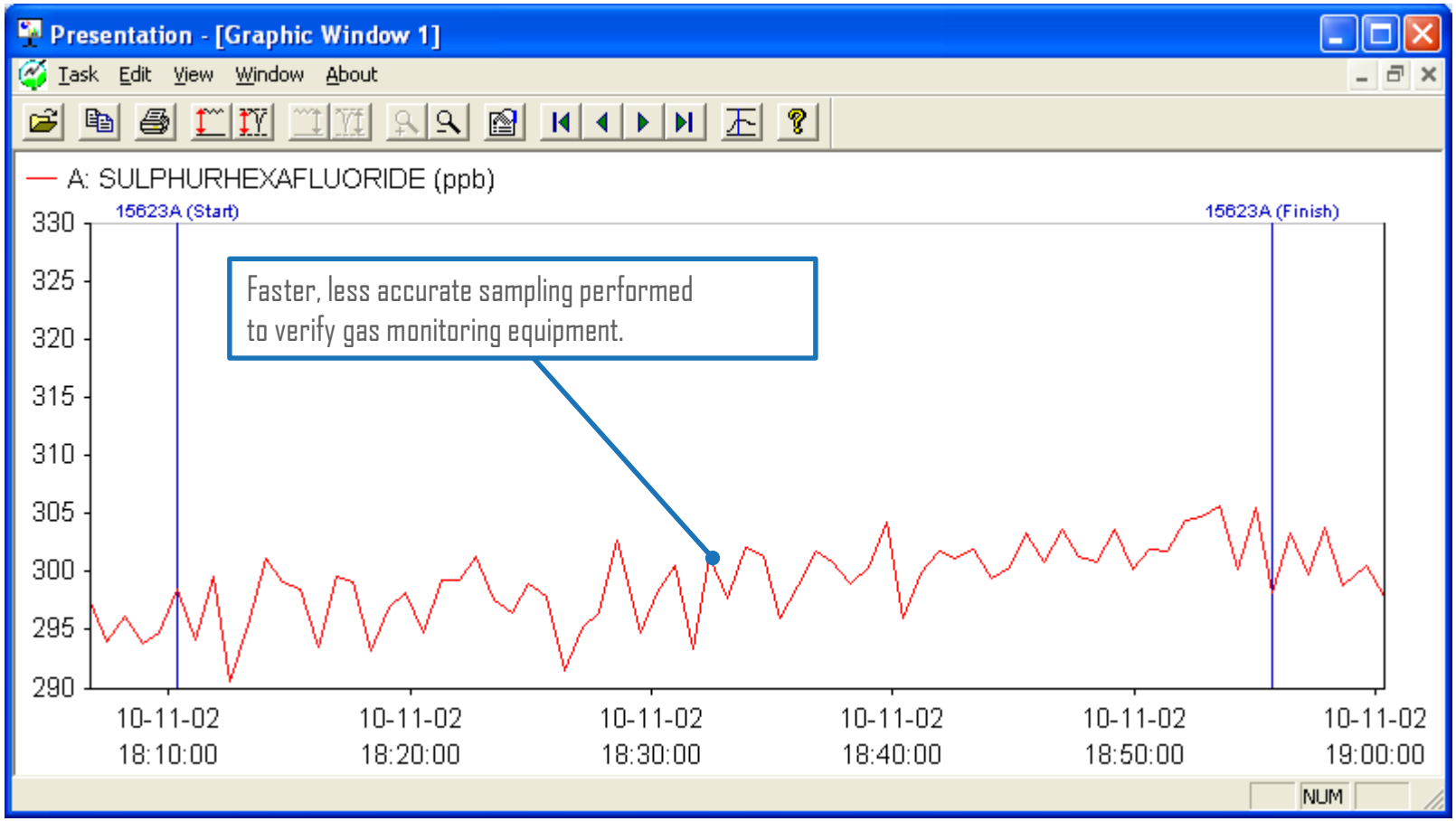
## Concept and Prototype Test Chamber



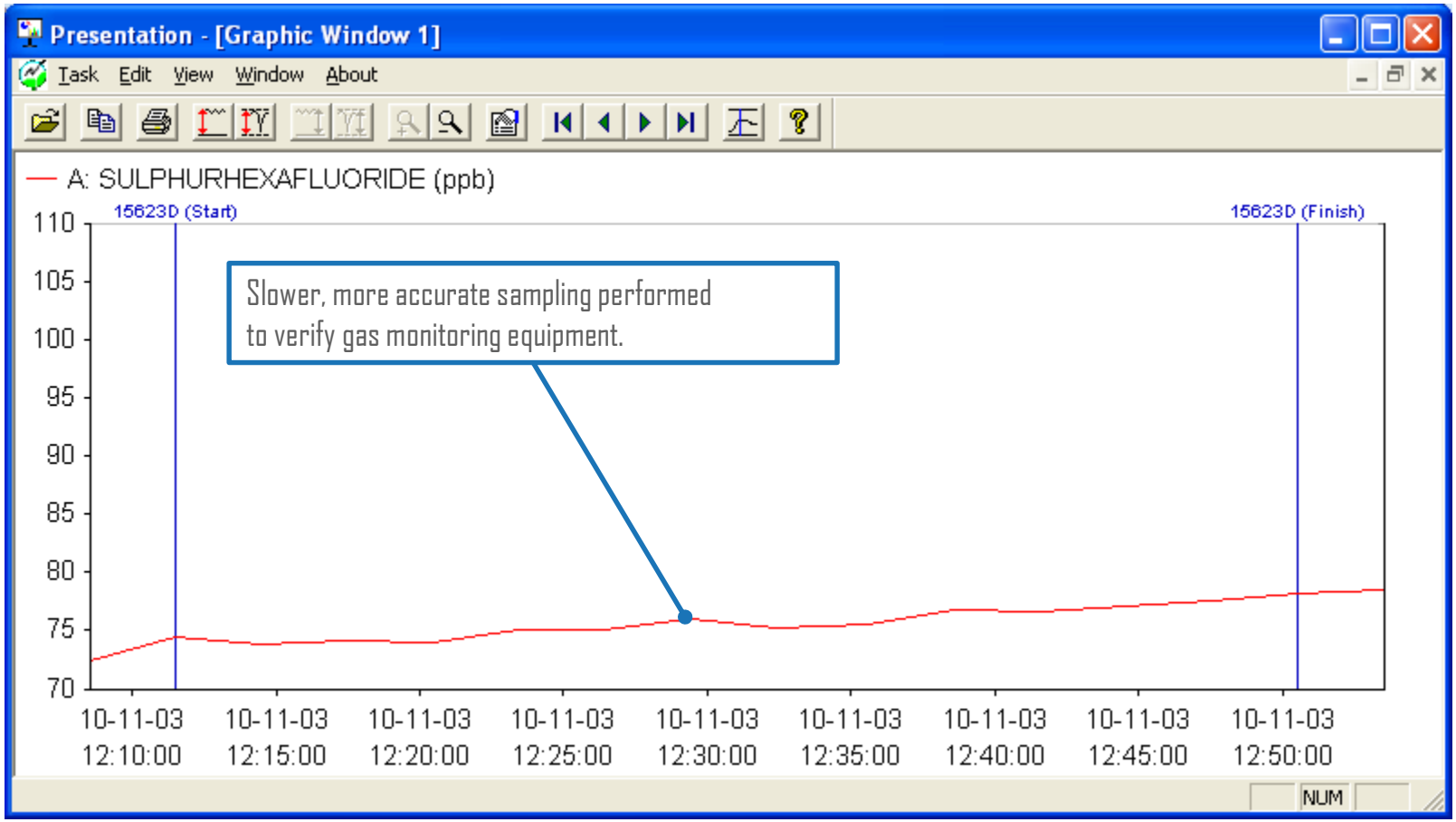
# Implementation

- Testing Criteria:
  - **Pass/Fail Leak Rate: Acceptable SF6 gas loss rate is any rate less than 0.5% of the initial breaker SF6 gas content per year.**
    - A new 72kV breaker contains 29 lbs. of SF6 @ 67 psi pressure.
      - 0.5% of 29 lbs. = 0.145 lbs. per year (10,730 $cm^3$ per year).
      - Adjusted Rate for Testing = .0204 $cm^3$ per minute.
    - Chamber Volume = Approximately $25.5x10^6$ $cm^3$
    - The equivalent SF6 concentration change in the chamber is equal to 36 Parts Per Billion (PPB) over a 45 minute test period.
      - Concentration adjusted for reduced chamber volume with breaker present.
- Production testing
  - Initiated December 2010.
  - Has greatly reduced reported field leaks.
  - High first pass yield for breaker tested.

# Optimizing the Testing Procedure



# Optimizing the Testing Procedure

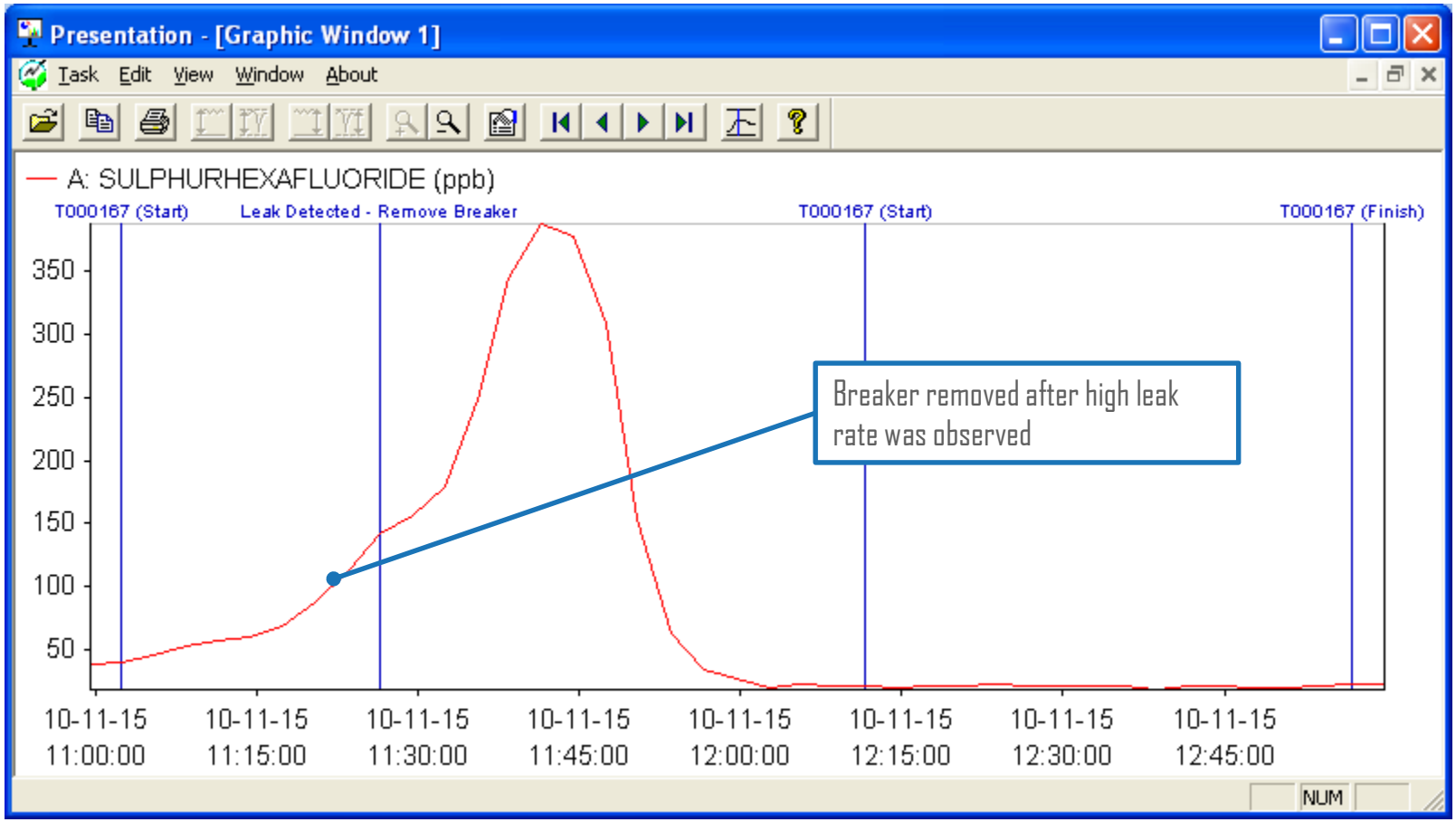


# Case Study

- Details:
  - This breaker passed the current standard tightness test procedure.
    - An SF6 hand 'Sniffer' tool (comparative gas) was used to examine the joints and potential leak points on the breaker.
    - No leaks were detected.
  - The breaker exhibited a leak 4x greater than the acceptable rate after less than 15 minutes in the Volumetric Test Chamber.
    - The breaker was pulled from the chamber and re-checked with the hand sniffer much more rigorously than the standard procedure.
    - The leak was found only after the tip of the was placed this close breaker.
  - Graphs of the test are shown on the following pages.

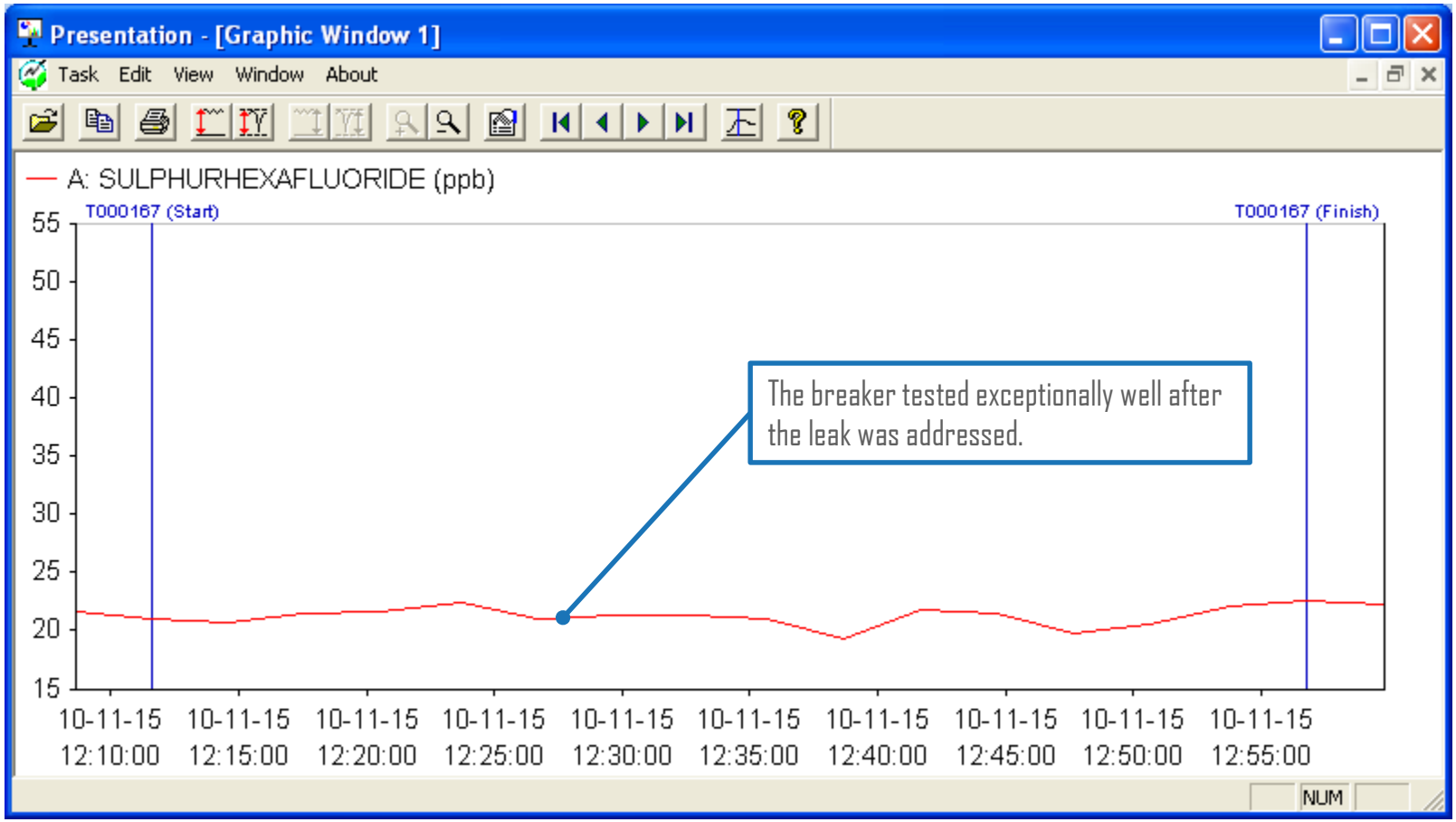
# Case Study

## Graph of Leak Indication

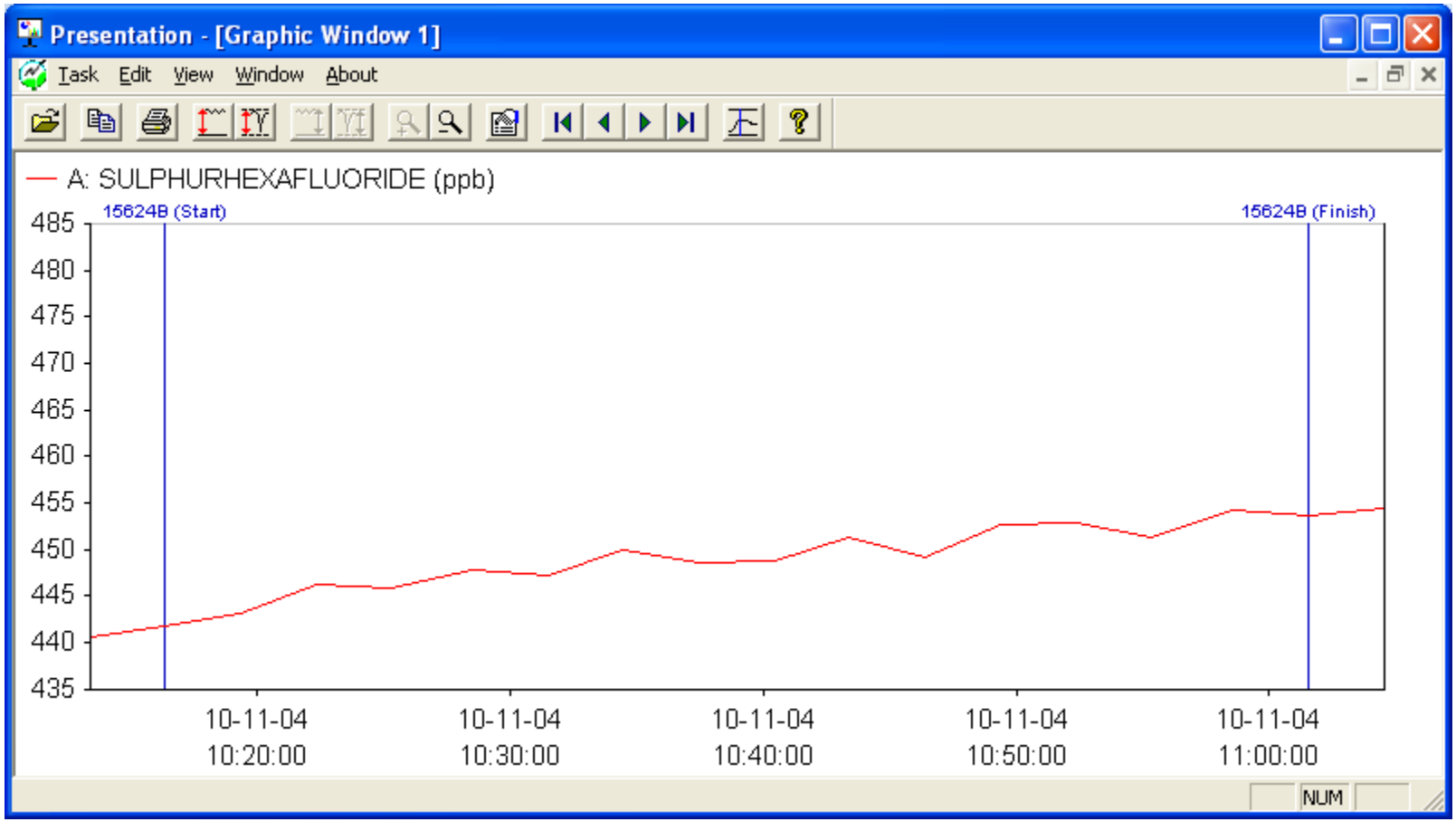


# Case Study

## Graph after Leak Repair



# Example: Typical Production Test Graph

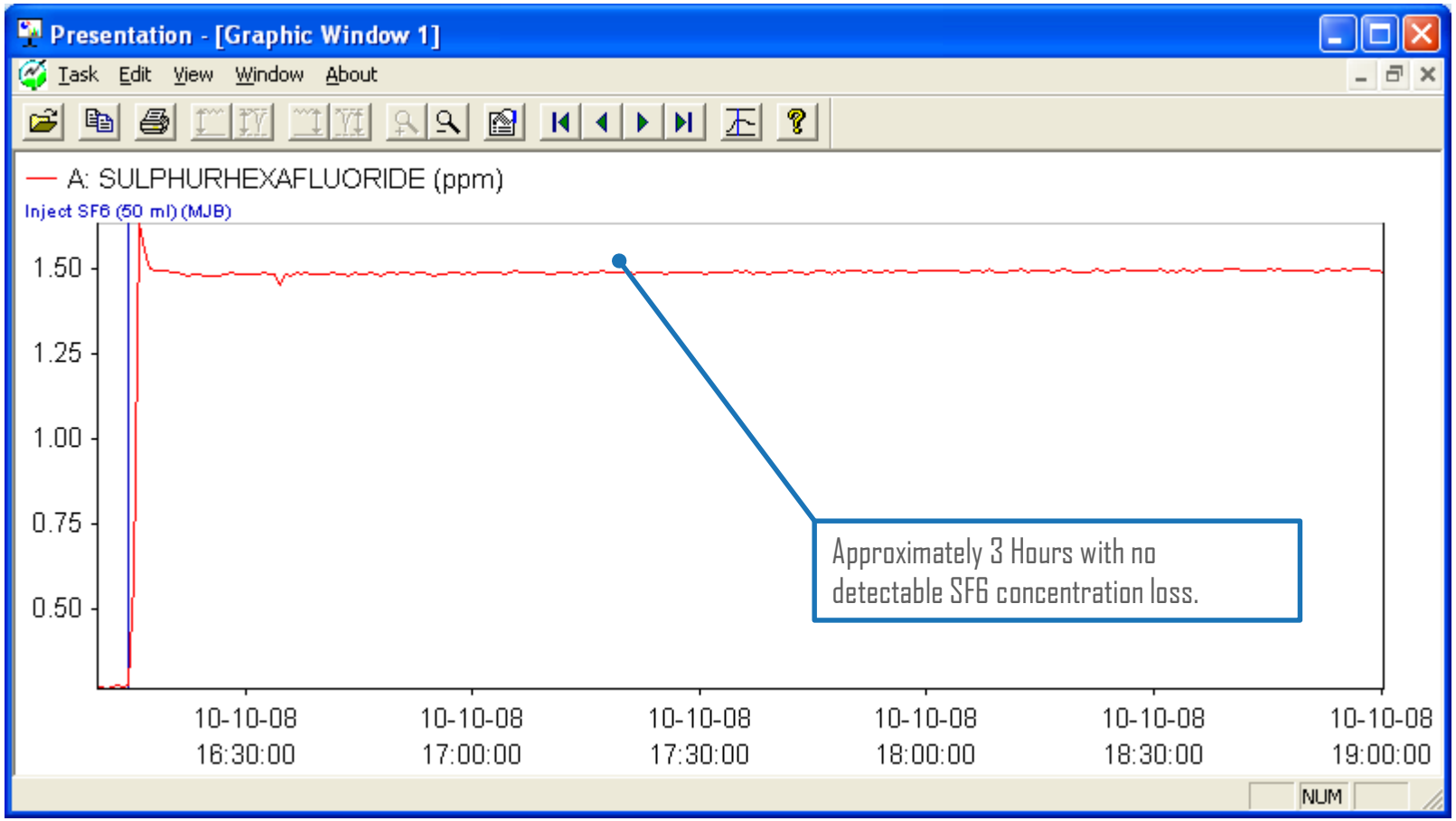


# Test Chamber Integrity Validation

- Pressurized Smoke Test
  - Chamber filled with smoke and pressurized.
    - Utilized smoke cartridges and supply air blower only, exhaust vent sealed.
  - Leaks detectable by smell and sight.
  - Minimal Leaks found and addressed.
  - Also used to verify chamber gas evacuation times.
- Extended Chamber Monitoring
  - Performed with and without a pre-charge of SF6 gas.
    - Performed with a 50 $cm^3$ pre-charge of SF6 to detect SF6 concentration loss to the lower background SF6 gas levels outside of the test chamber.
    - Performed without a pre-charge of SF6 to detect SF6 concentration increase from the higher background SF6 gas levels outside of the test chamber.

# Test Chamber Integrity Validation

## Extended Chamber Monitoring – With SF6 Charge



# Today

## Dual Test Chambers in High Volume Production Test Line

# Implementation

**SAFETY | QUALITY | COST | DELIVERY**

Production Test Lab with Dedicated Mechanical Bays and SF6 Volumetric Tightness Chambers

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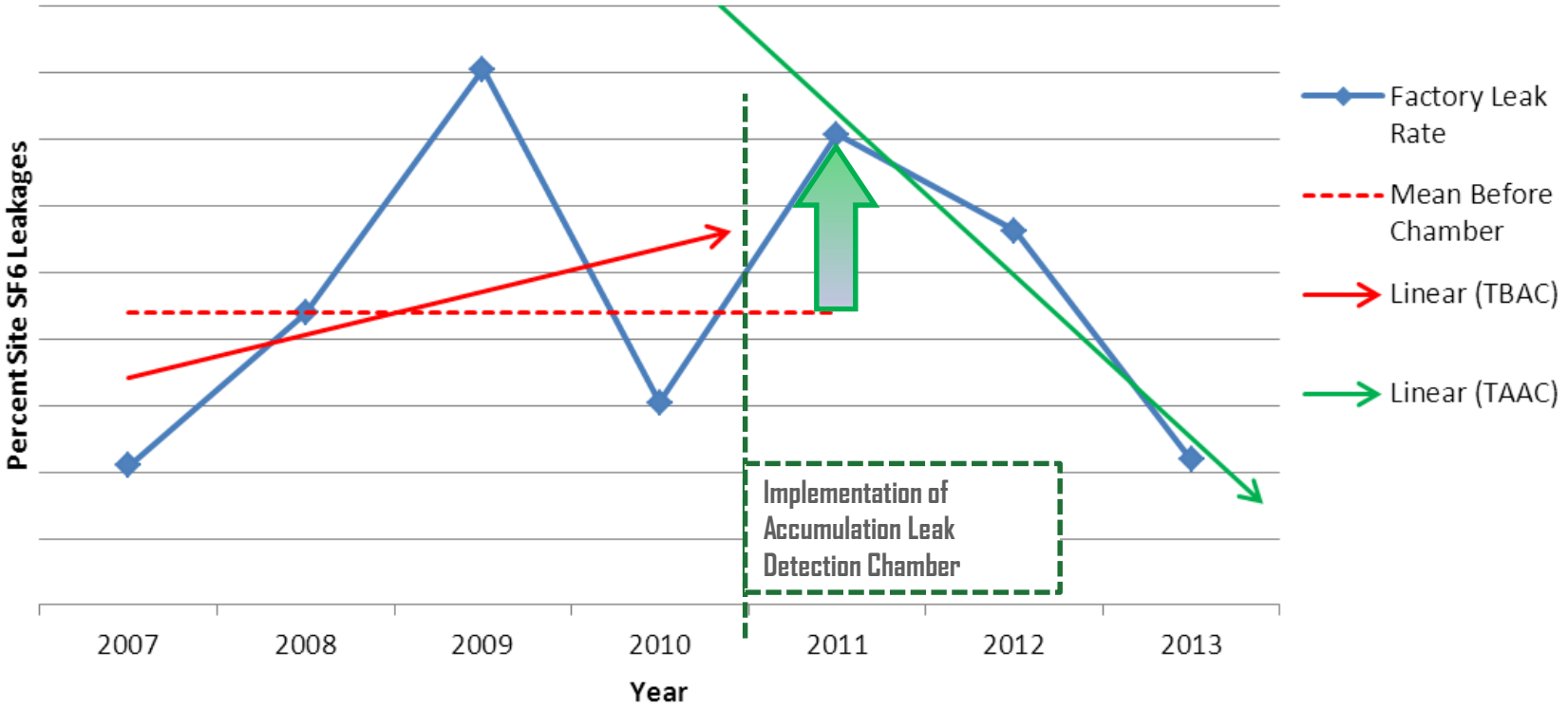
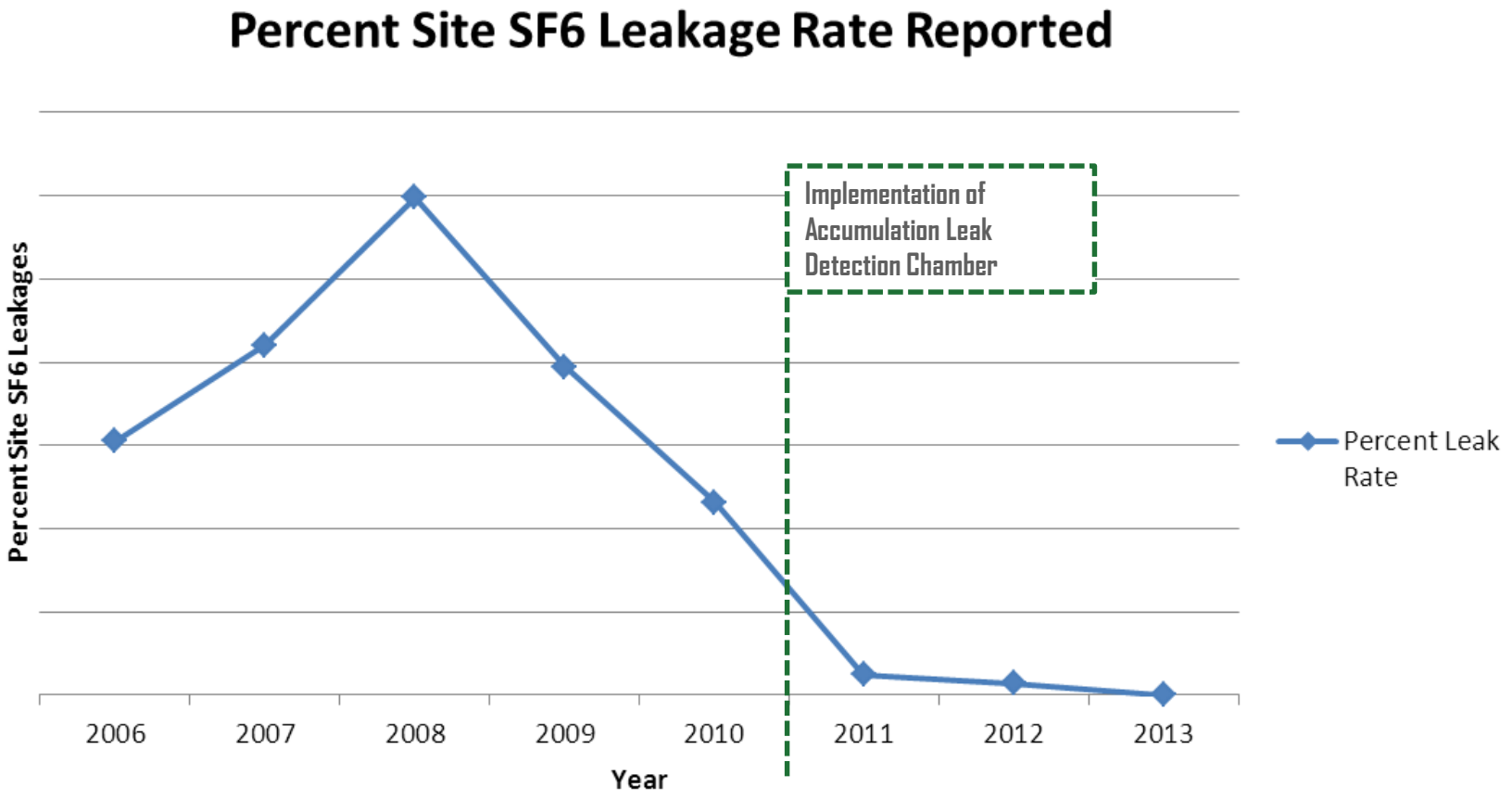
# Benefits

- First installation of Accumulation Chamber (AC) ~ Jan 2011
- Fully assembled breaker tested
- Products tested in original AC
  - DT1 – 38 FK
  - DT1 – 72.5 FK
- Additional AC installation for all product lines
  - 2 new chambers currently to test 38 kV – 170 kV dead tank products
  - Future chambers to test all other products
- Internal and External Improvements

# Benefits



# Benefits



# Benefits

- Historical Mean time to reported site SF6 leakage:

  = Date leakage reported – Manufacture Date

  = 15.2 months (DT1-72.5 FK Product)

- Reliable Data:

  = ~ Today – 15.2 months

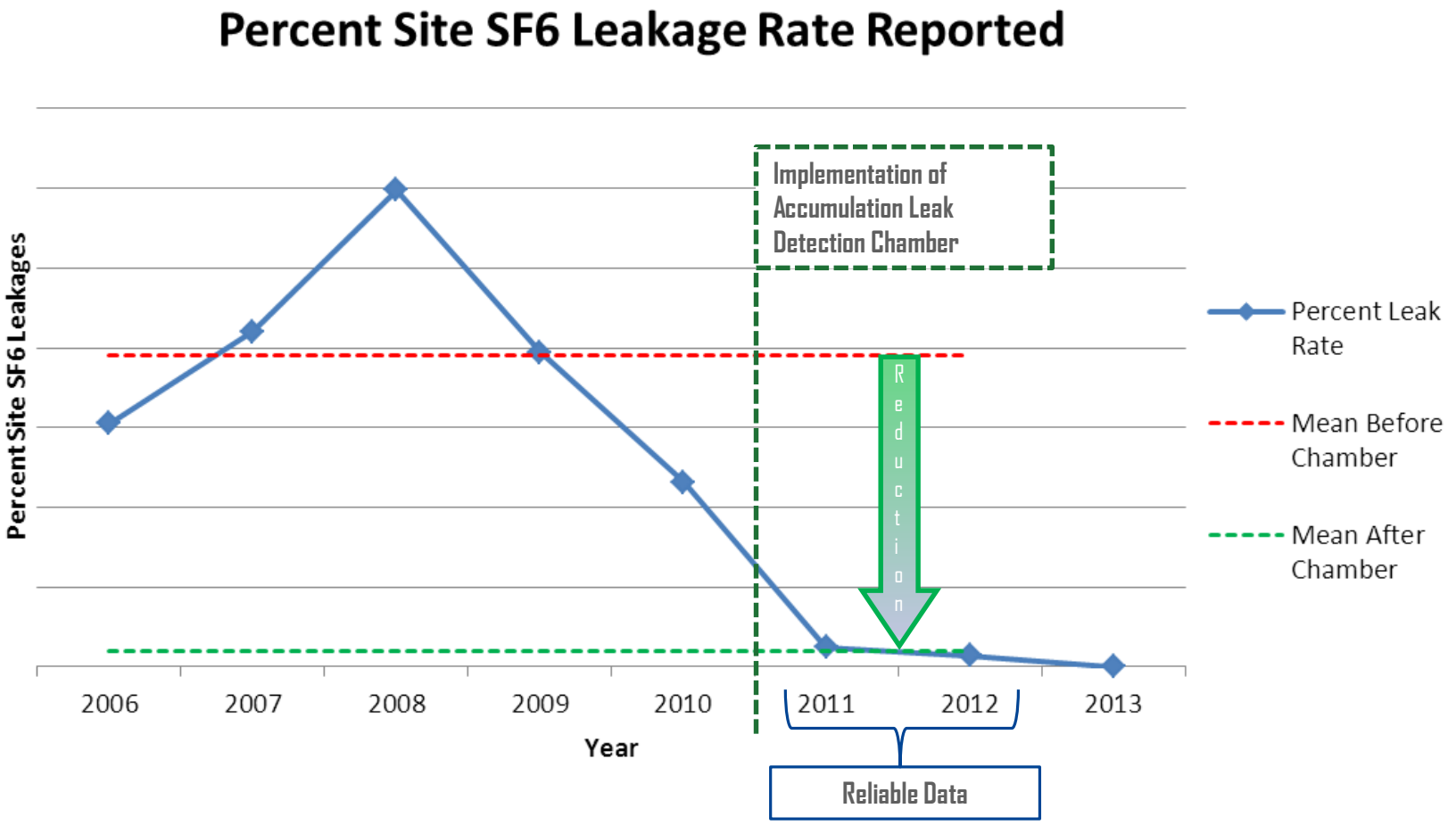
  = January 2013 (any data prior to this date considered reliable)

- Δ Mean % Leak Rate:

  = Mean prior to AC installation = 19.5(X) %

  = Mean after AC installation = X %

# Benefits



# Benefits

- Δ Mean % Leak Rate:

  = Mean prior to AC installation = 19.5(X) %

  = Mean after AC installation = X %

- Reduction:

  - Overall % reduction = 19.5(X) % - X % = **R %**
  - % reduction of existing leakage rate = R% / 19.5(X)% = **94.87%**

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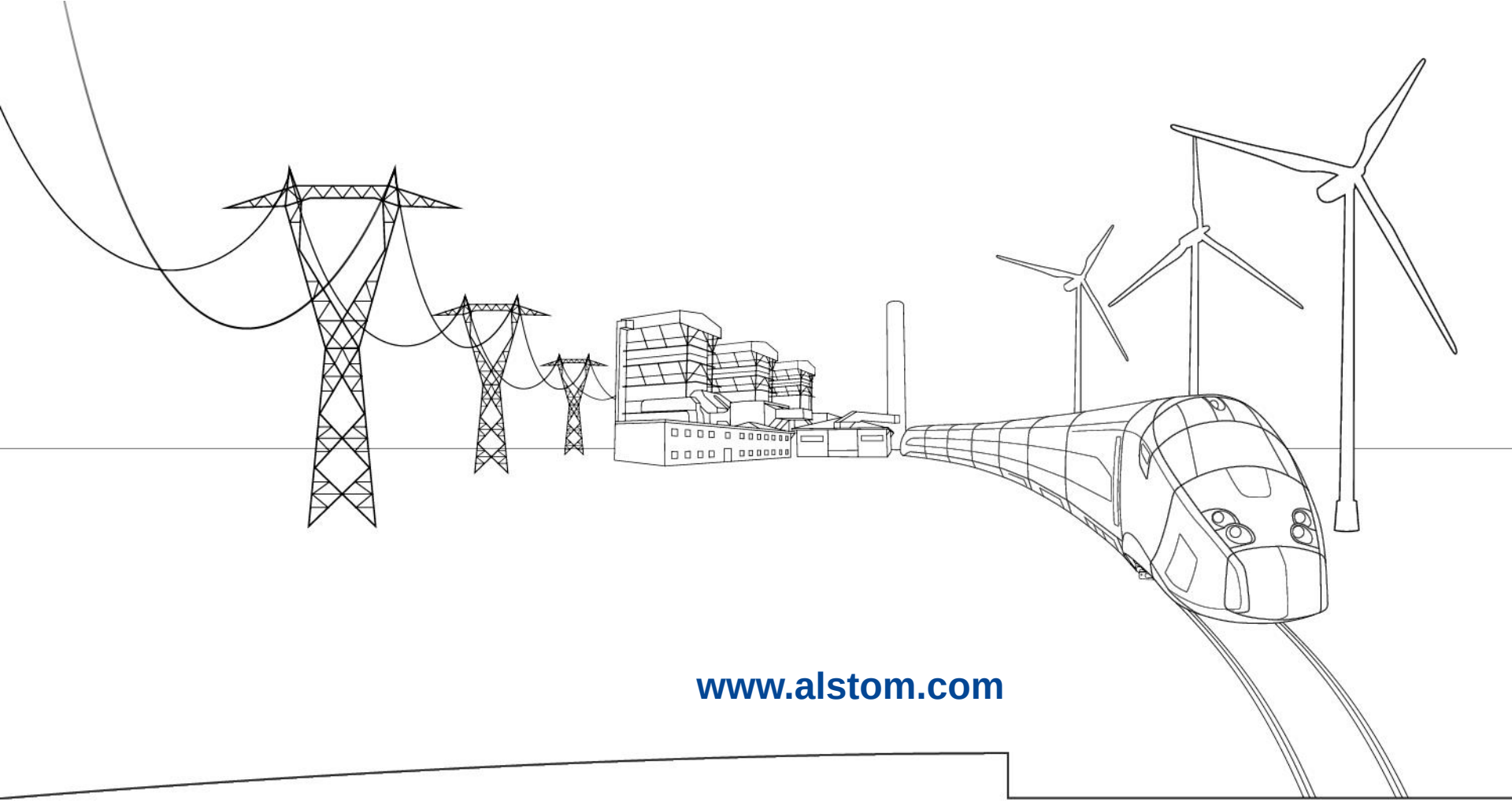
# Conclusions

- ALSTOM has successfully implemented a high accuracy SF6 leak detection test system for use in a production assembly facility.
- The system supports fully-loaded production flow requirements.
- Reliability data indicates this method is immediately effective.
- The volumetric tightness testing system ensures product quality and reliability.
- This testing system reduces product leak emissions …



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