FTIR Gas Analysis of Aviator's Breathing Oxygen (ABO): OSCG 2025 Technical Meeting

Jay Roberts, FTIR Gas Product Manager

Thermo Fisher Scientific
Vibrational Spectroscopy Group
Madison, WI (USA)

The world leader in serving science

Aviator Breathing Oxygen (ABO) application

Measuring O_2 purity and contaminants for ABO

- Military jets use small, portable oxygen cylinders for pilot's breathing oxygen
  - Smaller and lighter than air compressors used on larger commercial jets
  - Emergency backup in case of pilot ejection
- The manufacture of liquid oxygen (LOX) can include contaminants in the 100% O2
  - Transfers between different sampling/transport containers
  - Methane and other hydrocarbons pose a potential risk for explosion
    - Acetylene C_2H_2 of particular concern
  - Carbon monoxide CO
  - ChloroFluoro Hydrocarbons (CFC's) used as refrigerants to keep LOX cold, also used as solvents to clean cylinders
  - CFC's are bad greenhouse gases, newer compounds with lower global warming index being phased in

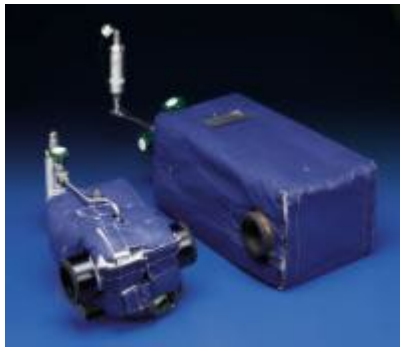
Long history of ABO analysis with US Military & Thermo

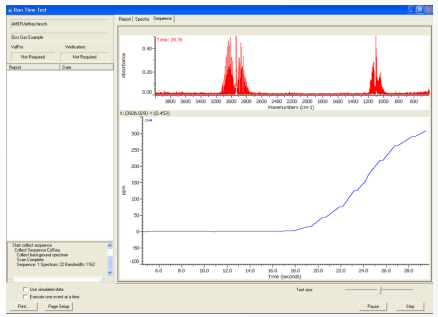
First version of Nicolet FTIR for Navy goes back to early 1990's

- Antaris Industrial Gas System (IGS) designed to analyze contaminants in ABO for Navy
  - Uses gas cell with 10 meter pathlength, 2.0 liter volume
  - Several upgrades over the years, but essentially still doing the same application
  - 62 units currently in use with US Navy
  - Navy group from Lakehurst NJ responsible for worldwide support
- FTIR measures contaminants like CO, CO_2, methane, other hydrocarbons, and some CFC/Freon compounds
- Used together with an Oxygen Analyzer (O_2 is invisible in the IR)
  - ServoMex most common, other O_2 Analyzers also on the market
- Commercial Off the Shelf (COTS) – not restricted to military orders
  - Scuba tanks, Firefighter breathing tanks, Environmental studies

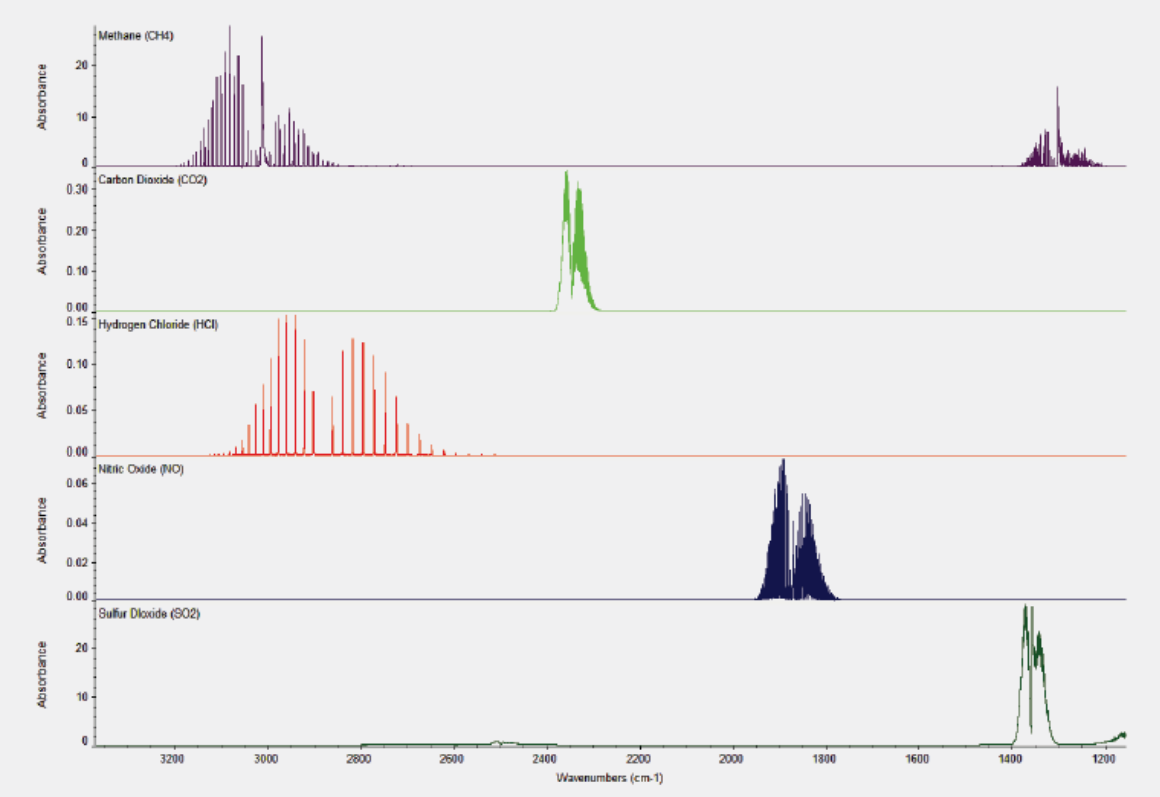
Thermo Antaris Industrial Gas System (IGS)

- Used as deployable ABO analyzer by US Navy
- High-Resolution FTIR Spectrometer
- Rugged Form Factor
- Excellent Performance
- 10M pathlength gas cell for high sensitivity
- Used in conjunction with Oxygen analyzers



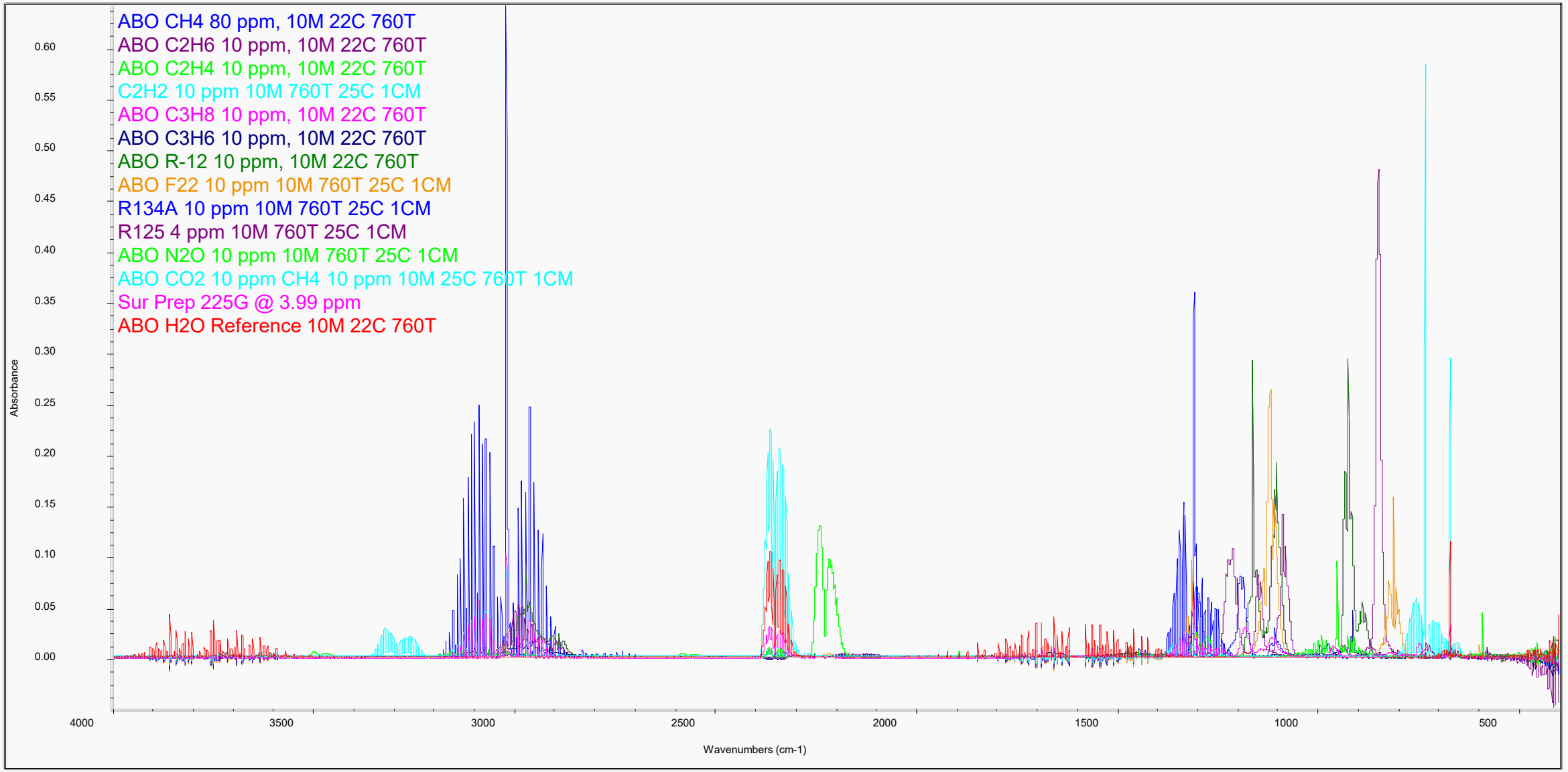


Advantages of FTIR for Gas Analysis

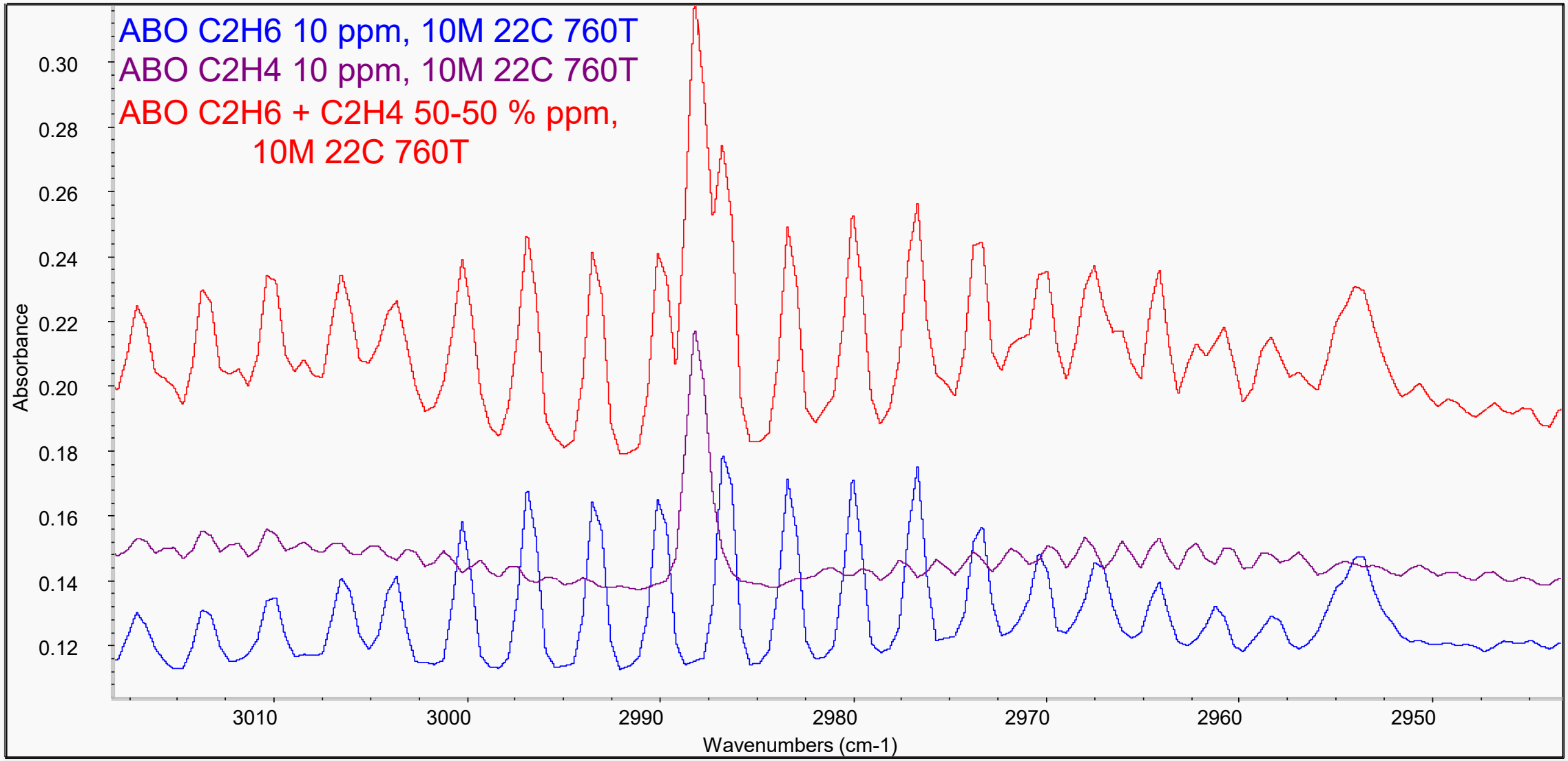


- Realtime analysis of multiple gases
  - Multiple gases advantage vs single component analyzers
  - Time advantage vs GC
- Broad concentration range, from ppb to %
- **Precise and stable** calibrations. No need to recalibrate daily
- Ability to re-analyze saved spectra in case of unusual/unexpected results

High spectral resolution enables separation of overlapping bands

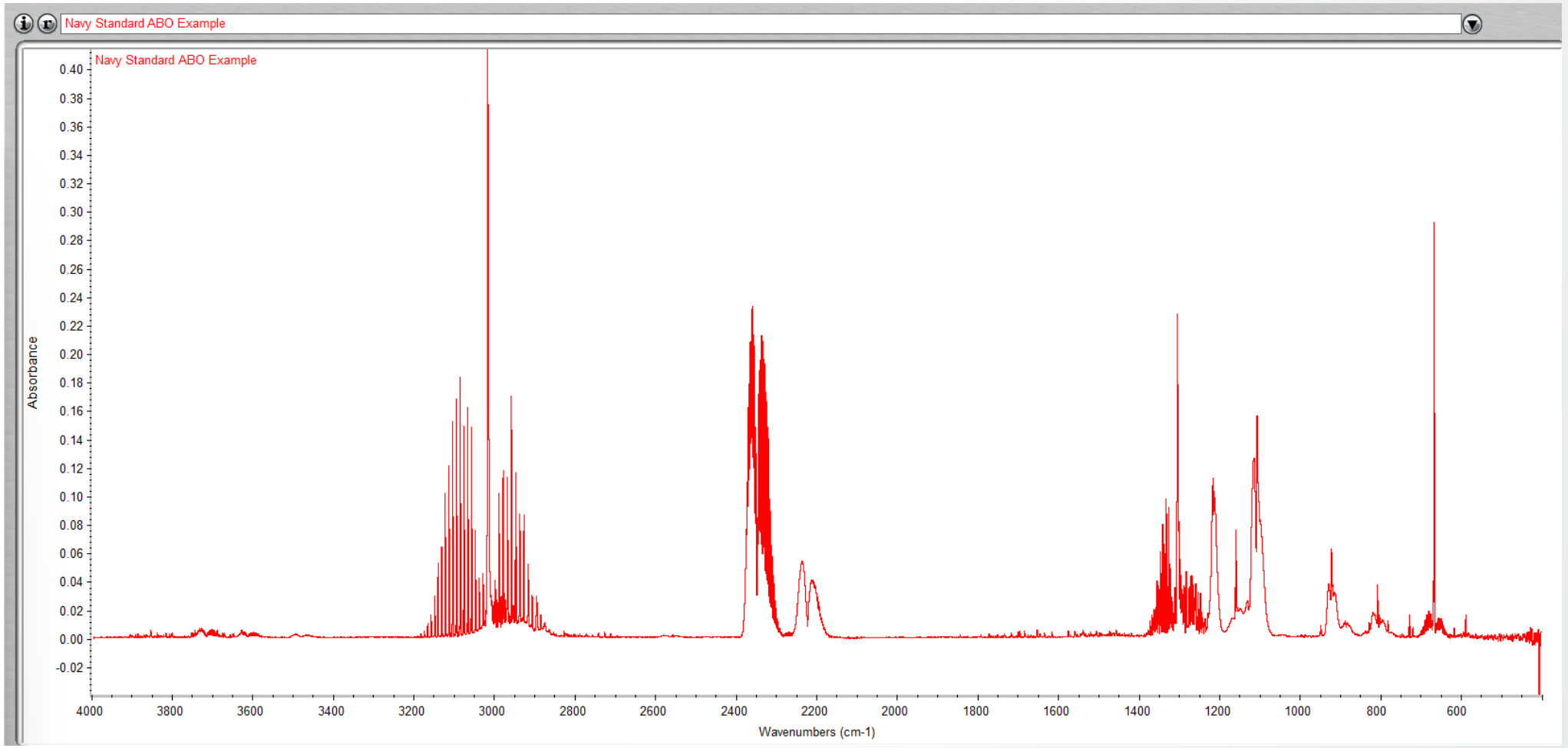


High spectral resolution allows analysis of overlapping bands

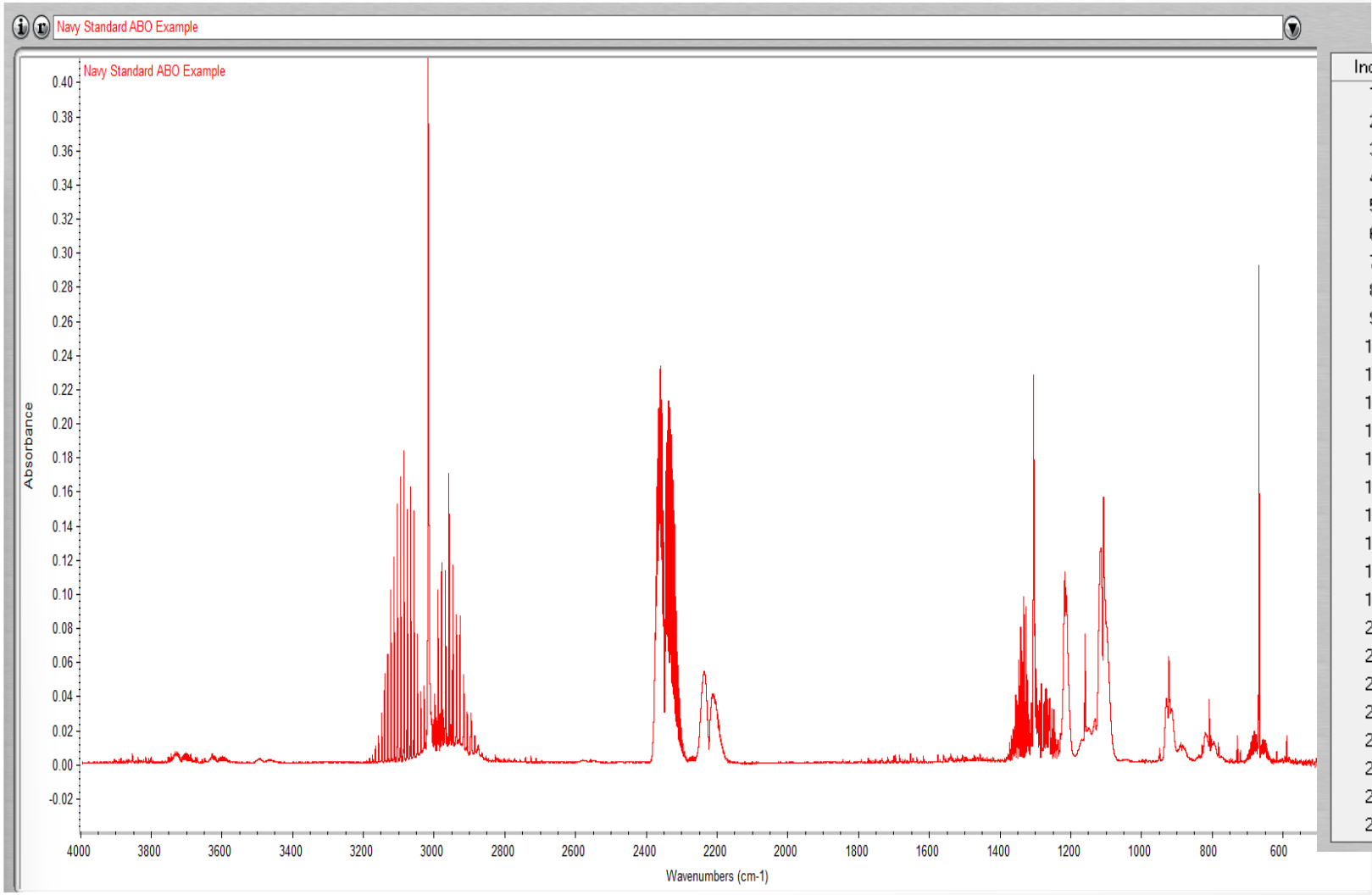


Navy Standard spiked with contaminants at key levels

Round robin gas standard sampled worldwide for statistical analysis, quality control



Thermo ABO Analysis of Navy Standard Example



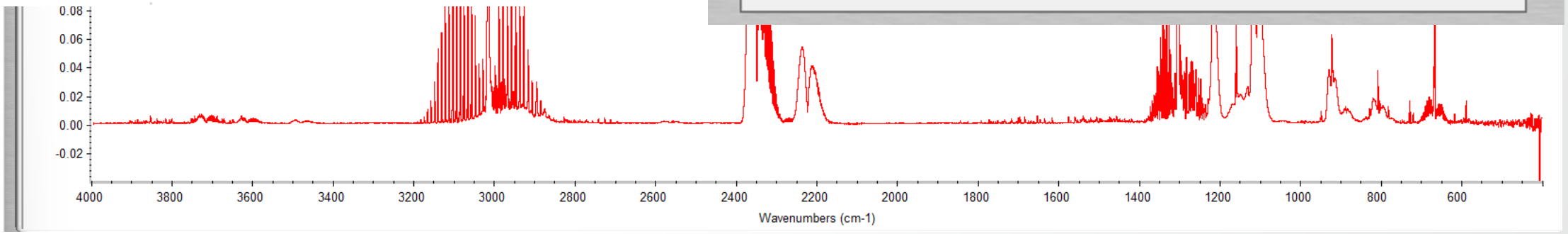
Index	Component	Concentration	Std. error
1	Methane	48.02	0.272
2	Ethane	6.14	0.387
3	Ethylene	0.80	0.095
4	Acetylene	0.17	0.020
5	Propane	0.28	0.279
6	Propene	0.03	0.176
7	Freon-11	0.00	0.021
8	Freon-12	1.86	0.043
9	Freon-13	1.90	0.017
10	Freon-22	2.07	0.063
11	Freon-113	0.26	0.068
12	1_1_1-Trichloroethane	0.26	0.424
13	Trichloroethylene	0.03	0.082
14	Nitrous oxide	3.91	0.015
15	Carbon monoxide	-0.07	0.071
16	Carbon dioxide Low	10.06	0.060
17	Water	2.38	0.182
18	Freon-141b	-0.30	0.148
19	Sulfur hexafluoride	-0.07	0.003
20	Freon-225	-0.23	0.110
21	Carbon Dioxide HIGH	10.31	1.555
22	SurePrep	-0.21	0.152
23	PFBI	-0.08	0.068
24	Freon-134A	-0.11	0.082
25	Freon-125	-0.01	0.039
26	Solstice	-0.05	0.022
27	Carbon Dioxide	10.06	0.060

Example results from Navy Standard analysis

Navy Standard ABO Example

COMPONENT	CONCENTRATION, PPM
Methane	49.4
Ethane	6.2
Ethylene	0.80
Acetylene	0.20
CFC-12	1.99
CFC-13	1.95
CFC-22	2.01
CFC-113	0.19
Nitrous Oxide	3.82
Carbon Dioxide	9.5
Nitrogen	BALANCE

Index	Component	Concentration	Std. error
1	Methane	48.02	0.272
2	Ethane	6.14	0.387
3	Ethylene	0.80	0.095
4	Acetylene	0.17	0.020
5	Freon-12	1.86	0.043
6	Freon-13	1.90	0.017
7	Freon-22	2.07	0.063
8	Freon-113	0.26	0.068
9	Nitrous oxide	3.91	0.015
10	Carbon dioxide Low	10.06	0.060
11	Water	2.38	0.182



Nicolet iS50 used by US Air Force Fuels & Lubricants labs

Nicolet iS50 provides multiple sample pathways and accessories

- 10M gas cell in main sample compartment for ABO analysis
- Liquid ATR crystal accessory to analyze liquids such as fuels and lubricants

New Antaris ABO Oxygen Analyzer configuration

Self-contained, all-in-one system for easy deployment to forward bases

- US Navy has standardized on Antaris IGS with 10m gas cell
  - 62 x IGS units in current use by US Navy worldwide
- Complete system configuration includes
  - FTIR with gas cell + PC with software
  - Gas sampling manifold – oxygen cleaned, kept clean and dry
  - Oxygen analyzer for O2 percentage
  - Vacuum pump
  - Nitrogen/dry air purge to eliminate atmospheric H2O/CO2 interferences
- Antaris IGS units may be deployed to forward combat bases
- US Navy packages pack Antaris IGS FTIR + other components into shipping cases for deployment, which is subject to missing parts, confusing setup, etc.

- **Opportunity** – Mount all components into a single package that can be shipped/deployed quickly and easily

Antaris ABO Gas Analyzer

Release sub-modules to build up “ala carte” into final configuration

- Mounting rack with Pelican shipping case
- Sampling Manifold
  - Provides sample to either FTIR or O_2 Analyzer
  - Includes vacuum pump, pressure regulator, flow meters
- Antaris IGS + 10M gas cell + Calibration/software
- Oxygen Analyzer (option)
- Offered in either 120V or 230V configurations
- Battery-backed UPS options (120V and 240V)
- Supporting components, such as
  - Balston Purge Gas Filter options (released, pass through)
  - Gas cylinder regulators option (pass through)
  - Industrial laptop PC option (buy-in)
  - Installation/PV/Training

Combined sample manifold for FTIR and O2 Analyzer

- Multiple inlet connectors
  - ABO, Validation, Zero
- Sample input selector
- Sample Pressure Regulator
- Flow Meter
- FTIR or O2 Analyzer selector valve
- Needle valve control to outlet to vacuum pump
- Vacum pump ON/Off power switch

Backside - Quick connections of purge, vacuum lines

Pre-configured plumbing connections to minimize setup hassle, confusion

- Quick connect to external purge
  - Nitrogen or filtered air
- Flow meters to control purge to different locations, including as sample gas
- Connections of Pressure, Temperature controllers to PC for automatic correction for sampling variance
- Optional UPS to enable orderly shutdown in case of electric glitch/failure

Ability to quickly pack up system for deployment

Pack up Pellican case, move with pallet jack/forklift

- Slide-out rails for access to FTIR and Sampling manifold for service or preparing system for shipping

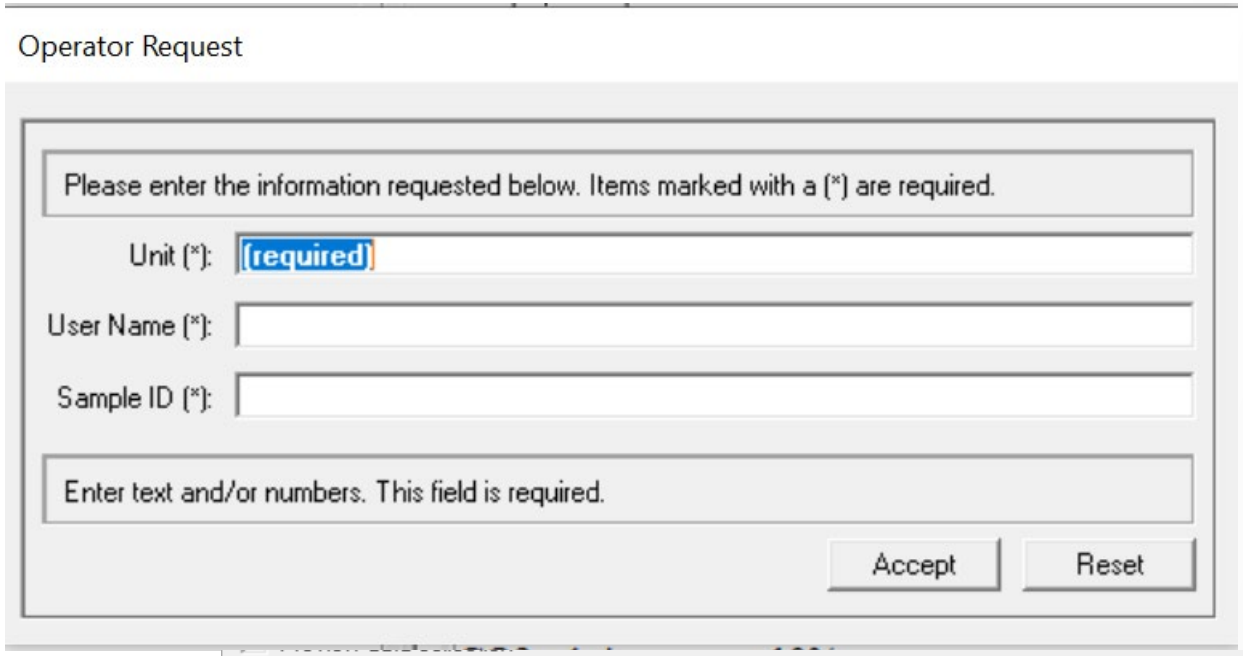
Antaris ABO Test Procedures – turn-key software

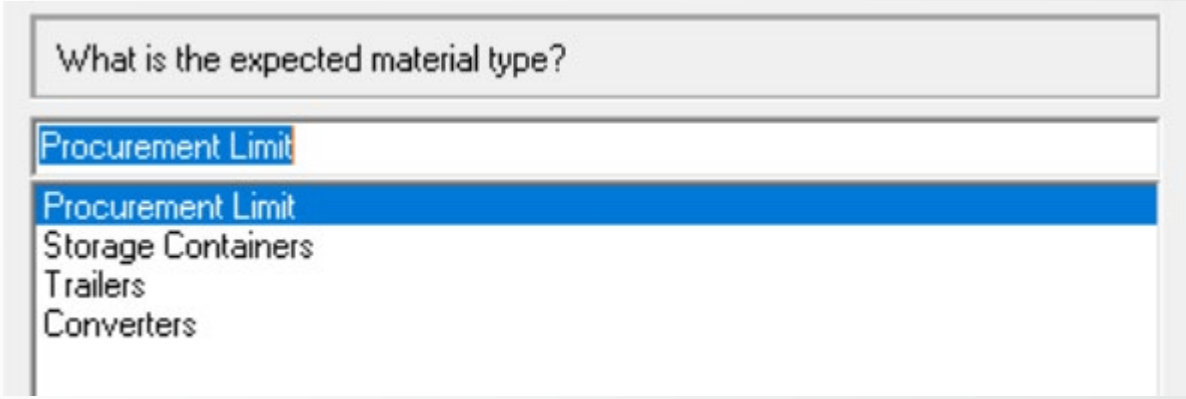
Defined steps to running samples and maintaining the ABO Test System

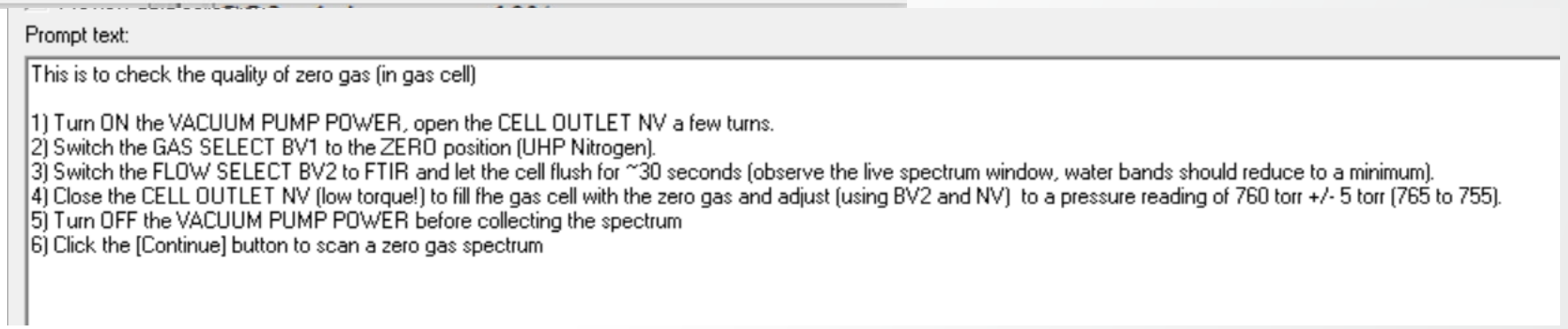
- Performance Validation (PV) – Antaris IGS FTIR System Optics
- Performance Validation (PV) – Complete system test include Gas Cell, Gas Sampling Manifold
- Antaris ABO Purge Test – Confirm that atmospheric moisture/CO_2 is low
- Antaris ABO Zero Gas Test – Confirm that 99.999% N_2 values read near zero
- Antaris ABO Validation Gas Test – Confirm accuracy of results for known gas sample
  - Example, quantify 5.0 ppm CO_2 within defined Pass/Fail parameters
- Antaris ABO samples -
  - Pass/Fail limits may be set for different sample sites
  - Procurement vs Storage Containers vs Trailers vs Containers
- Ability to adjust ABO calibration as necessary after significant optical component replacement

User prompts to guide techs through ABO sampling sequence

Thermo also can provide training via User Guide and training videos



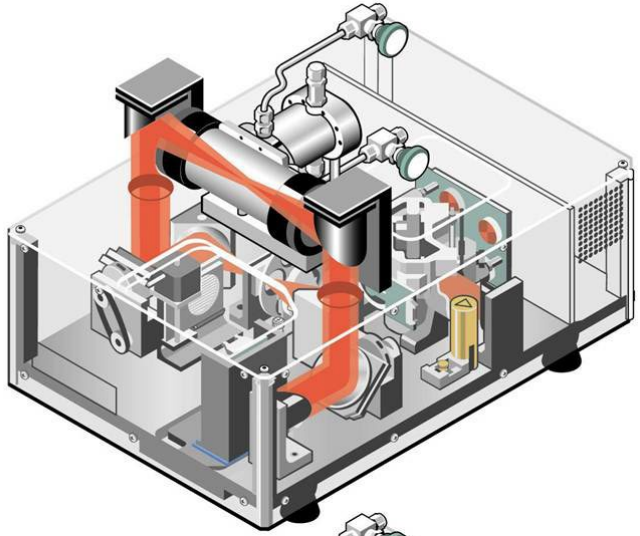


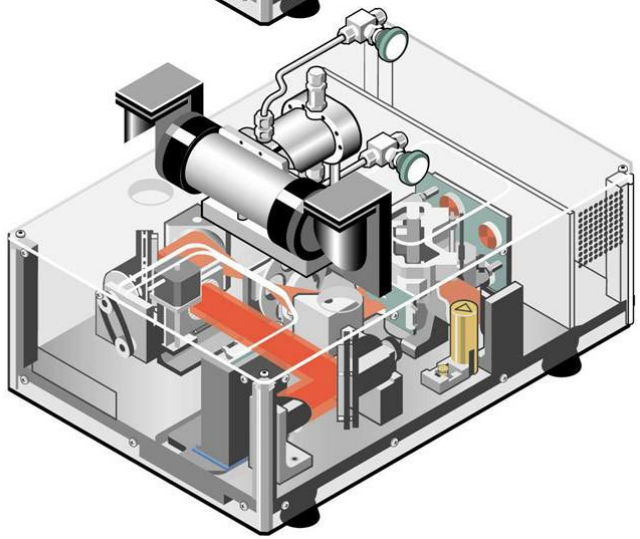


Performance Validation (PV) – Antaris IGS FTIR System Optics

Verify that FTIR system is operating within limits

- Antaris IGS provides dual beampath for diagnostics
  - “Downstairs” light path bypasses gas cell to measure only internal FTIR performance
  - Helps isolate problems in system performance to either FTIR vs gas cell
- Performs automated test via PV wheel with performance standards
  - Open path measurement for IFG beam height, Signal/Noise Ratio
  - NG11 glass for detector linearity
  - 1.5mm Poly standard for wavelength precision
- Bench diagnostics for electrical parameters



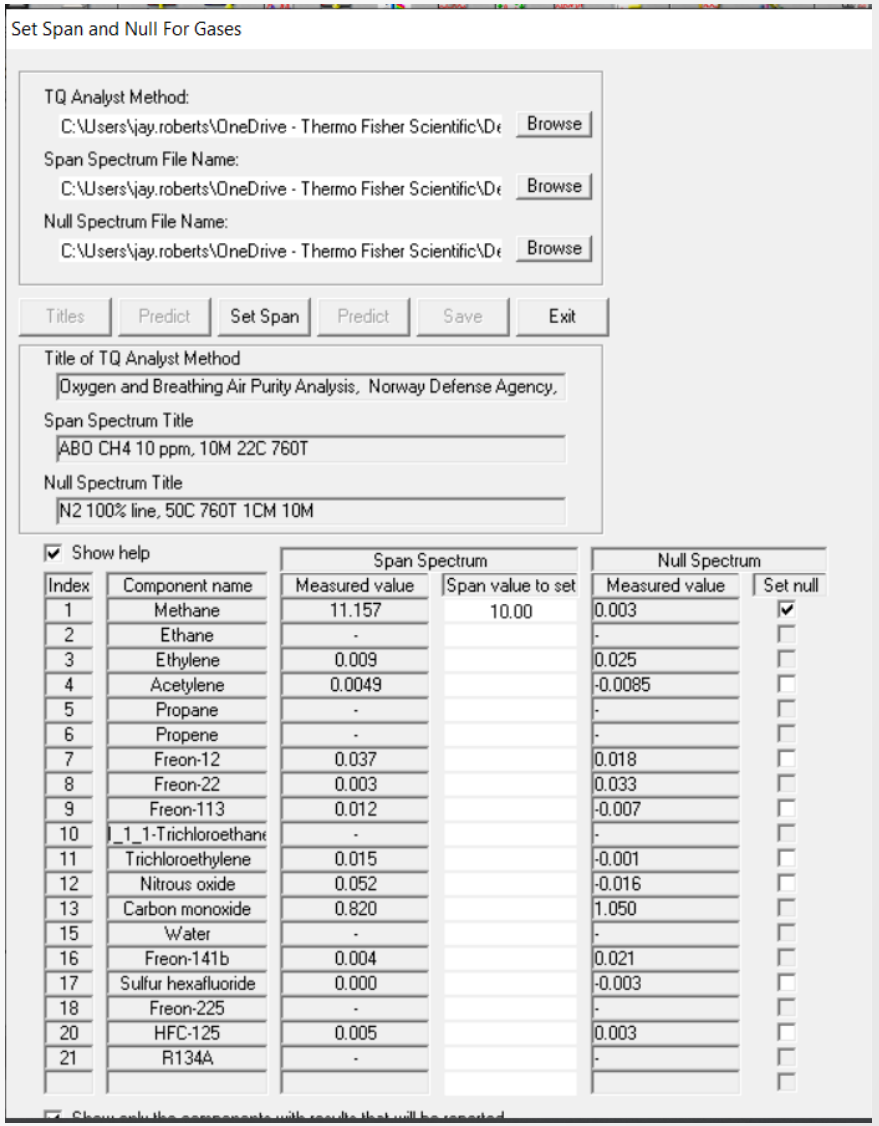


Composite
Interferogram max
+5 volts
+12 volts
-12 volts
Laser X
Laser Y
Laser R
Laser current
Source current
Source power

ReCalibration procedure

Updates TQ method for Slope & Offset values for background, individual components

- Allows user to adjust span/zero values in a TQ method quickly and easily
- Typically used to adjust values after service replacement (example, new beamsplitter)
- Eliminates bias in calculation due to baseline offset
- Available if desired
  - Standard software for US Navy ABO
  - Not used by US Air Force



		Span Spectrum		Null Spectrum	
Index	Component name	Measured value	Span value to set	Measured value	Set null
1	Methane	11.157	10.00	0.003	☑
2	Ethane	-		-	☐
3	Ethylene	0.009		0.025	☐
4	Acetylene	0.0049		-0.0085	☐
5	Propane	-		-	☐
6	Propene	-		-	☐
7	Freon-12	0.037		0.018	☐
8	Freon-22	0.003		0.033	☐
9	Freon-113	0.012		-0.007	☐
10	_1_1-Trichloroethane	-		-	☐
11	Trichloroethylene	0.015		-0.001	☐
12	Nitrous oxide	0.052		-0.016	☐
13	Carbon monoxide	0.820		1.050	☐
15	Water	-		-	☐
16	Freon-141b	0.004		0.021	☐
17	Sulfur hexafluoride	0.000		-0.003	☐
18	Freon-225	-		-	☐
20	HFC-125	0.005		0.003	☐
21	R134A	-		-	☐

Summary

New Antaris ABO configuration simplifies sample handling, deployment

- Thermo has supported US Navy, Air Force, and NATO allies with FTIR analysis of ABO for decades
- Fast, simple, reproducible results
  - Navy Standard provides statistical correlation of results worldwide
- New product offering combines FTIR + Oxygen Analyzer with turn-key sampling manifold
  - 120V and 230V configurations available
- Enables rapid deployment – packaged in Pellican shipping case
- Standardized procedures with turn-key software minimizes sampling/analysis errors between different sites, new users
- Worldwide service and support