REAL-TIME FOURIER TRANSFORM INFRARED ANALYSIS OF COMBUSTION GASES

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OUTLINE OF TALK

- Objectives
- Materials
- Fire Calorimetry Method
- FTIR Sampling System
- Method of Analysis
- Results: Response Times, Gas Histories, Reproducibility, Agreement with NDIR, Error Analysis
- Conclusions

OBJECTIVES

CARGO COMPARTMENT FIRE DETECTION

- Obtain concentration-time profiles of a wide variety of gases produced in early stages of cargo fire development

- Patterns of response will aid in the selection and development of improved cargo smoke and fire detectors

ULTIMATE OBJECTIVES

CARGO COMPARTMENT FIRE DETECTION

- Shorten detection times
- Improve reliability and sensitivity of detectors
- Discriminate between real and spurious signal

FIRE GAS TOXICITY MONITORING

- Develop a method for toxicity monitoring
- Determine at a glance if major interferences are present for each gas

APPROACH

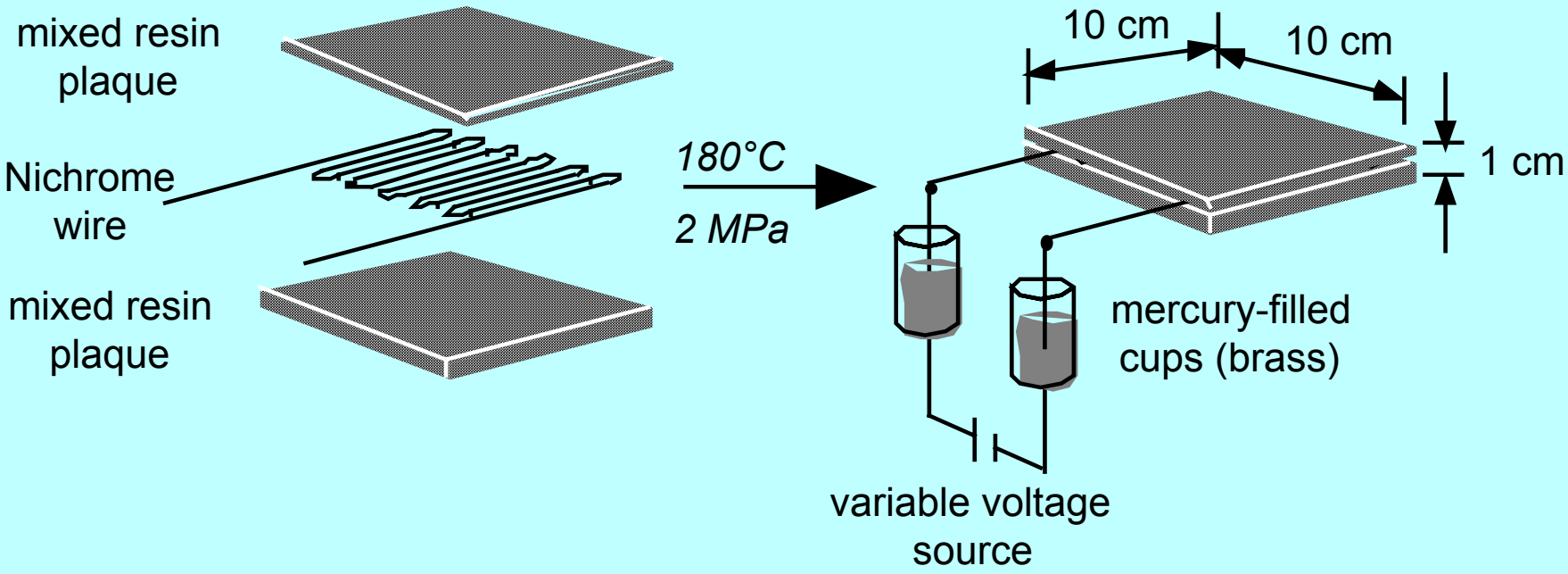
FTIR ANALYSIS OF SMOKE GENERATION SOURCE

- Select a smoke generation source is representative of the composition of combustible materials in luggage
- Determine system response time
- Develop a 16 gas CLS method with low residuals
- Determine reproduciblity of the fire signature for flaming and nonflaming combustion
- Check agreement of FTIR method with NDIR analysers

COMPOSITION OF MIXED RESIN SPECIMEN

Component Material	Trade Name	Parts by Weight
polyamide (nylon 66)	DuPont Zytal 101	1
polyethylene (HDPE)	Dow 08454	1
polystyrene (PS)	HiVal 5308	1
polyvinylchloride, rigid (PVC)	Geon 8700	2
thermoplastic polyurethane (TPU)	Dow 101	1
polybutyleneterephthalate (PBT)	DuPont Crastin 600	1

SMOLDERING SPECIMEN FABRICATION

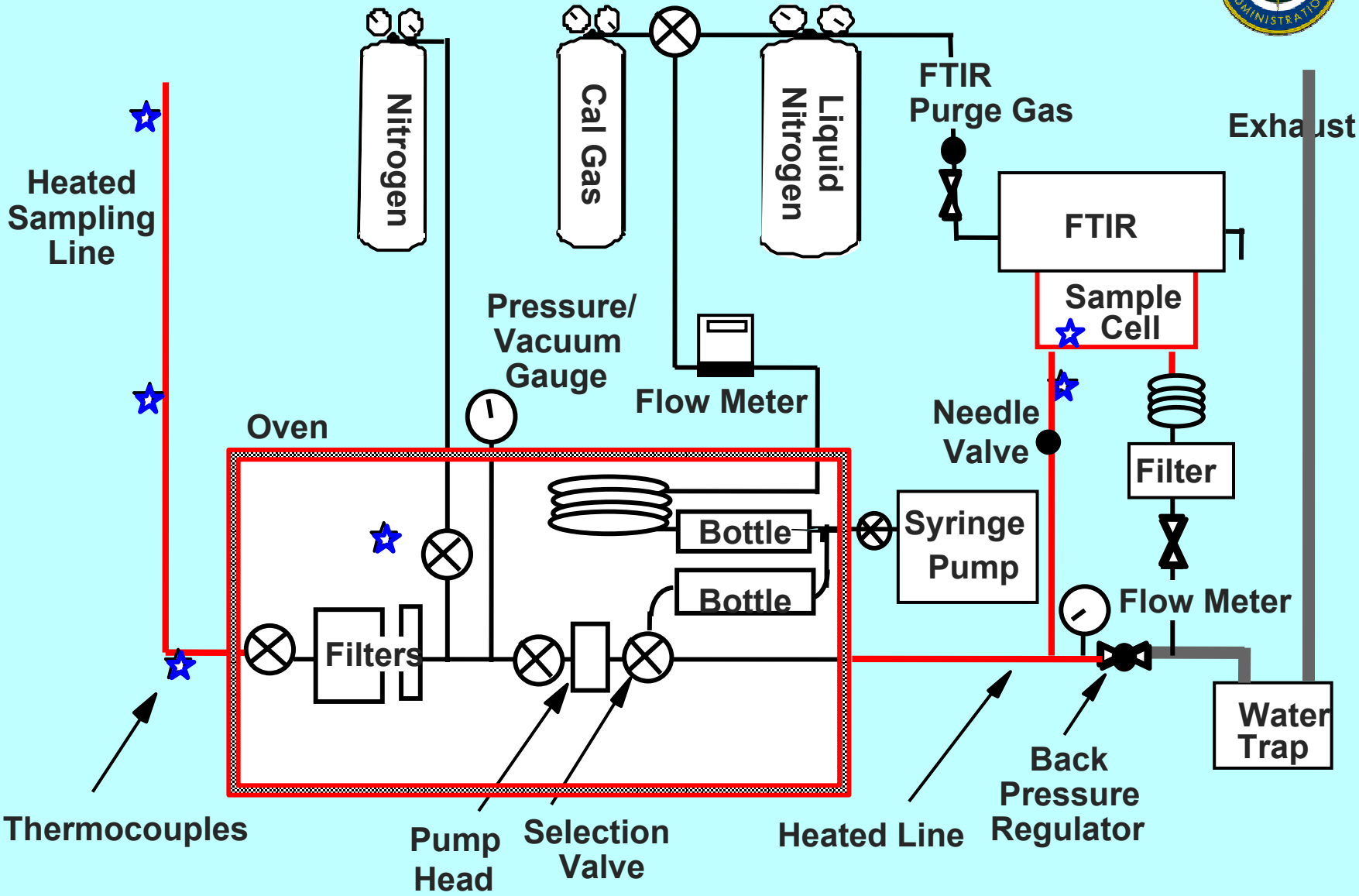


REFERENCE

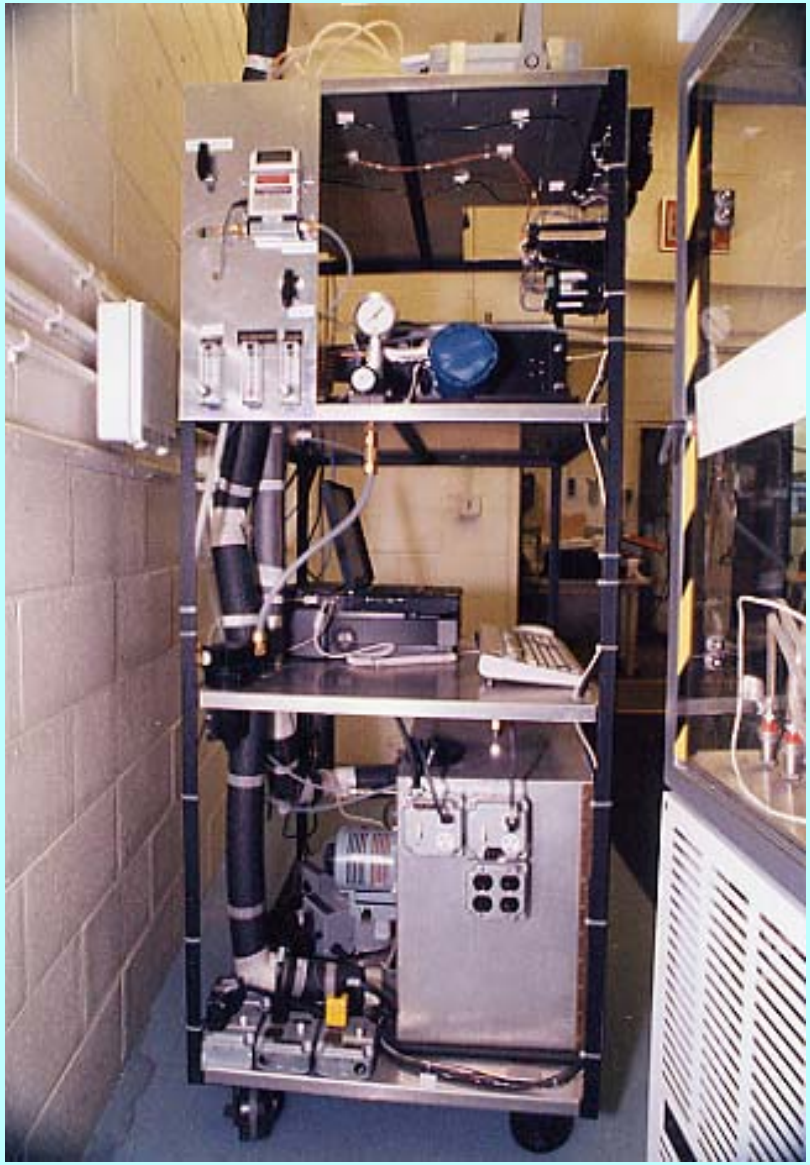
R.A. Filipczak, D. Blake, L. Speitel, R.E. Lyon, J.M. Williams, and W. Gill, “Development and Testing of a Plastic Smoke Generation Source”, Proceedings of the Fire and Materials 2001 Conference, San Francisco, Ca., USA, 22-24 January 2001, Copyright Interscience Communications Ltd., pp. 93-104 (2001).

FTIR SAMPLING SYSTEM ALONGSIDE THE CONE CALORIMETER

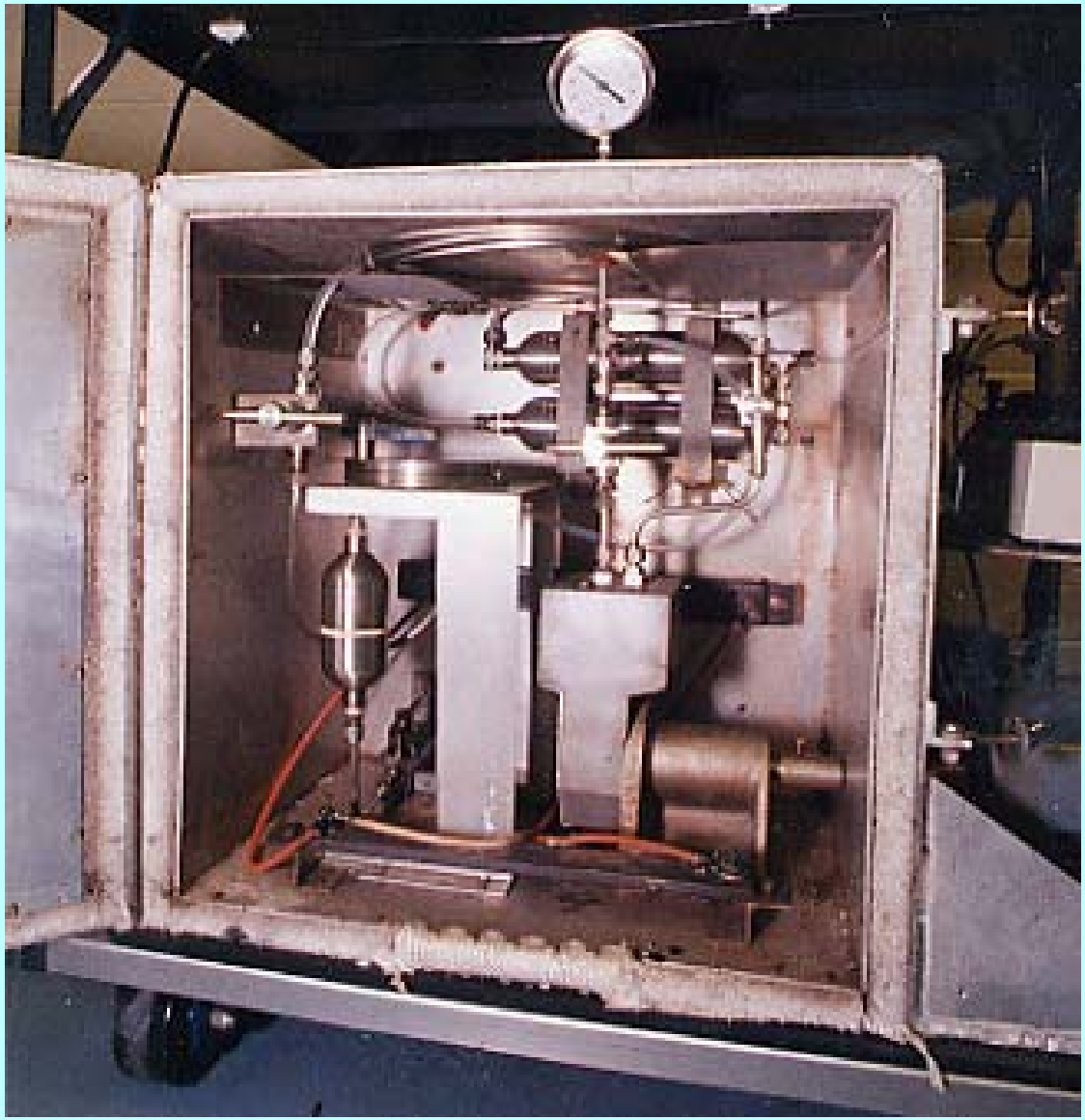
FTIR SAMPLING SYSTEM



FTIR SAMPLING SYSTEM: SIDE VIEW



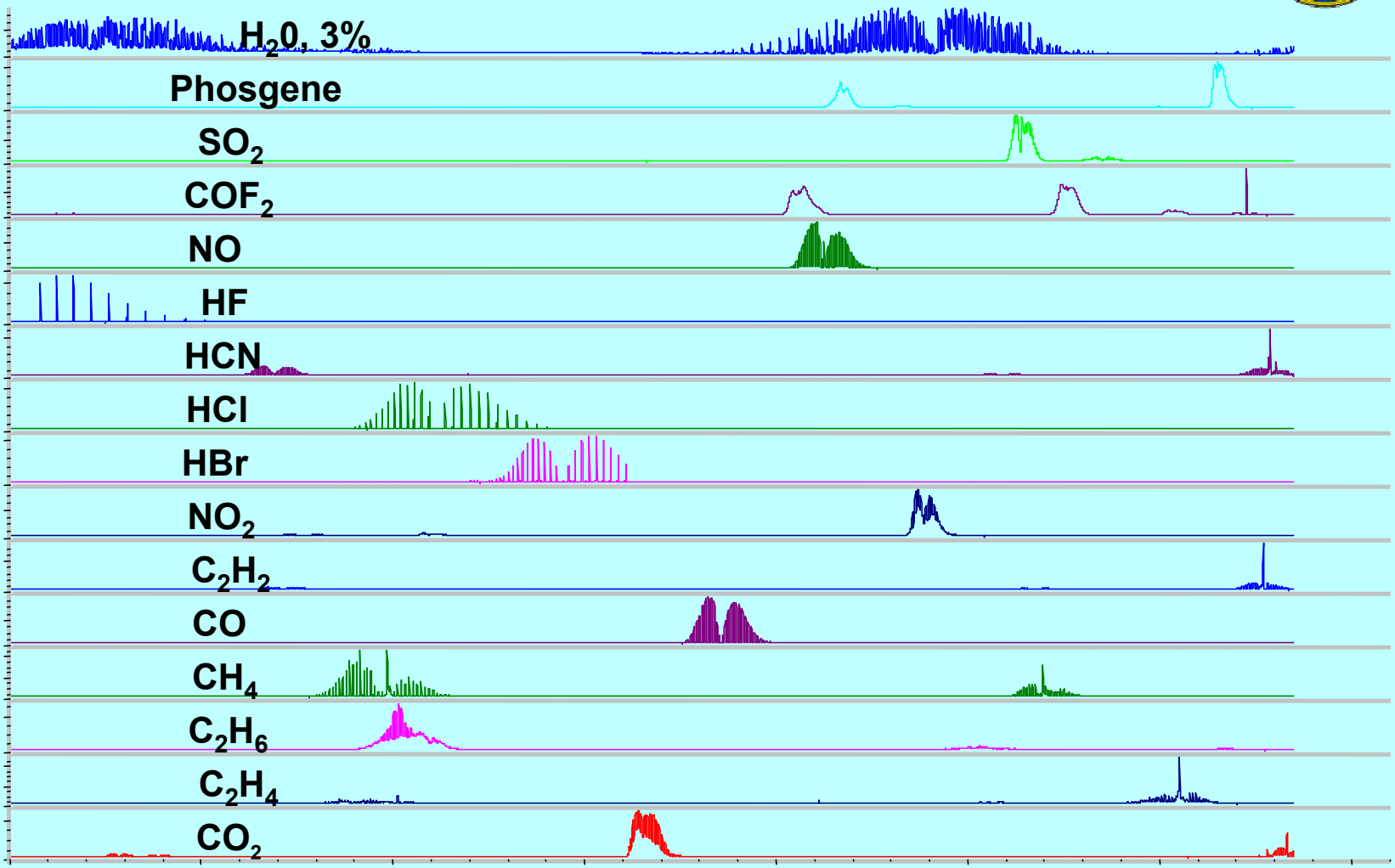
FTIR SAMPLING SYSTEM: OVEN



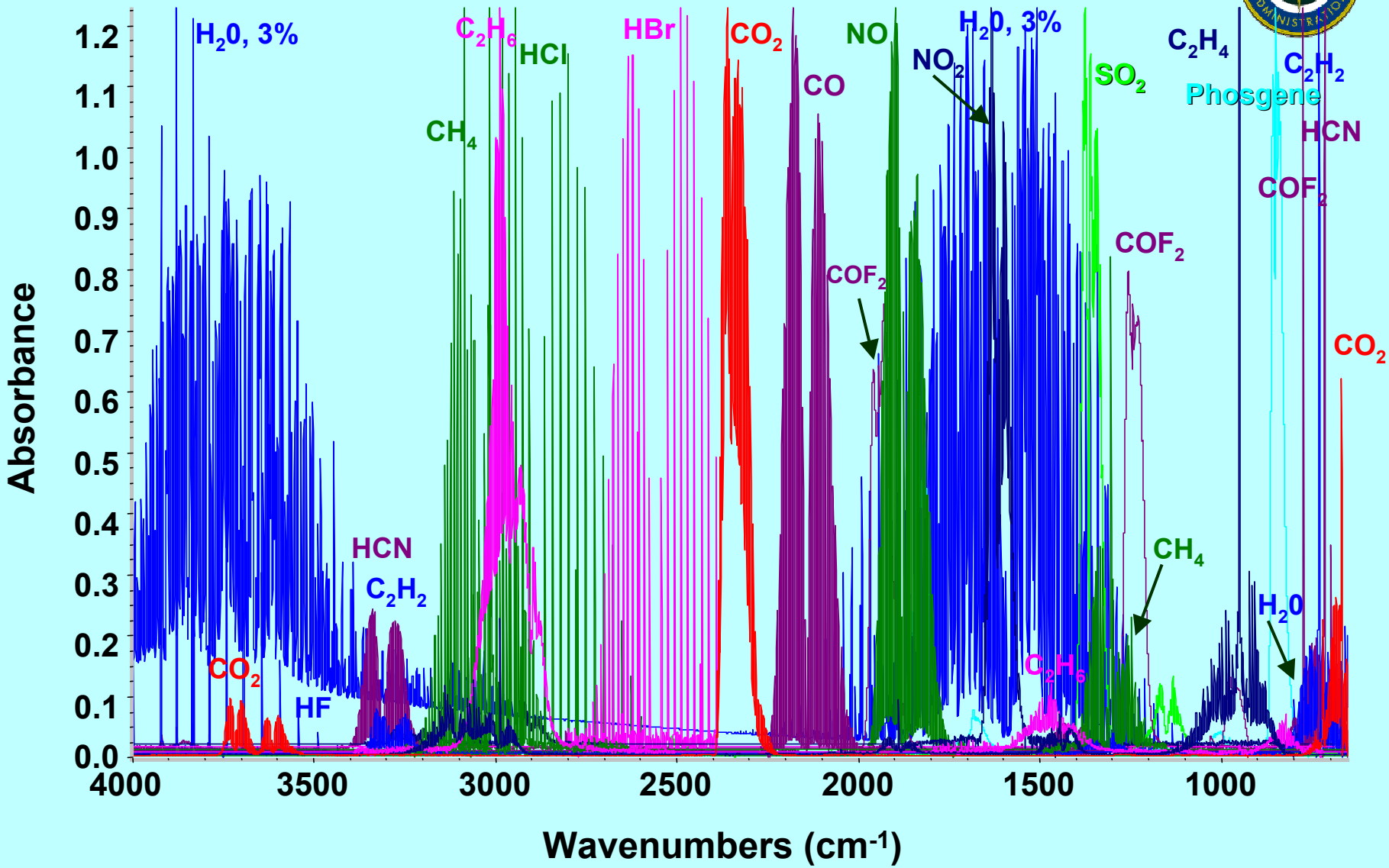
FTIR METHOD

- MCT detector, 4 meter pathlength, 0.5 cm^{-1} resolution
- CLS software selected which allows for the change of the normalized spectral shape with concentration for each of the calibration gases
- Spectral bands selected for each gas that give low residuals for the concentration ranges of the 16 gases to be analysed and the combustion gas samples
- Residuals for each fire test can then be used to determine the validity of the method for each gas

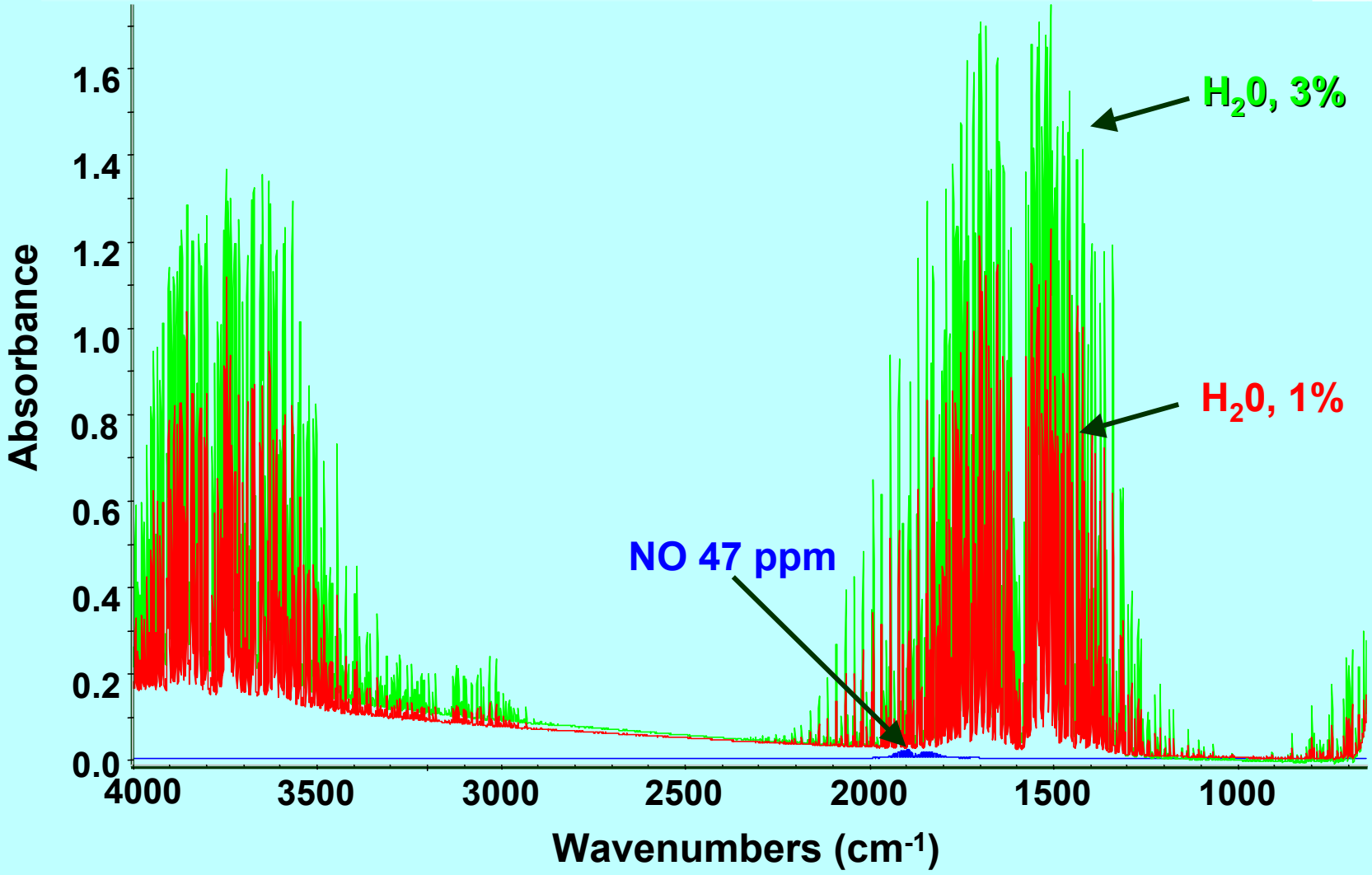
FTIR CALIBRATION SPECTRA OF SIXTEEN GASES AT 170 DEGREES C: FULL-SCALE



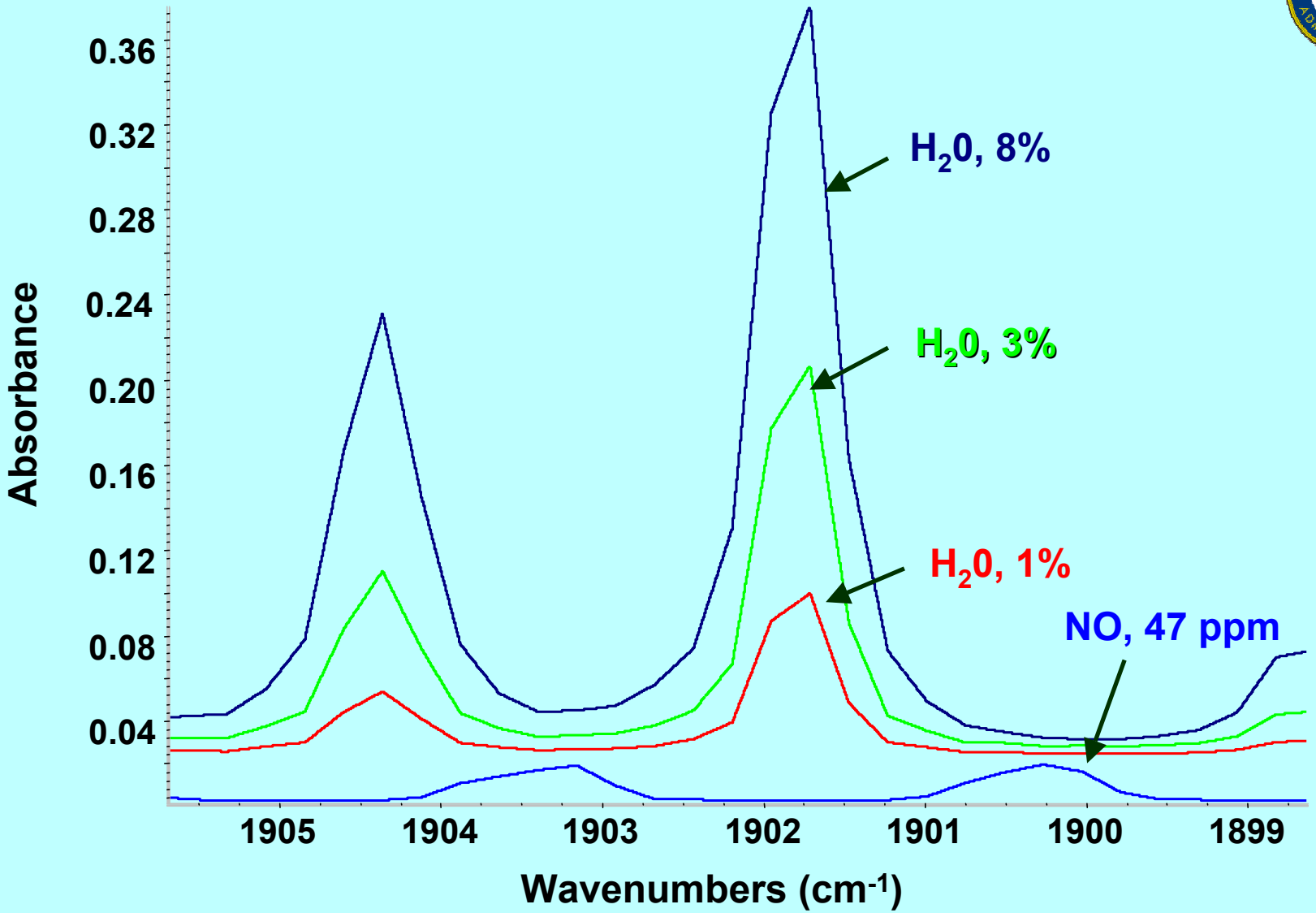
OVERLAID FTIR CALIBRATION SPECTRA OF SIXTEEN GASES AT 170 DEGREES C: FULL SCALE



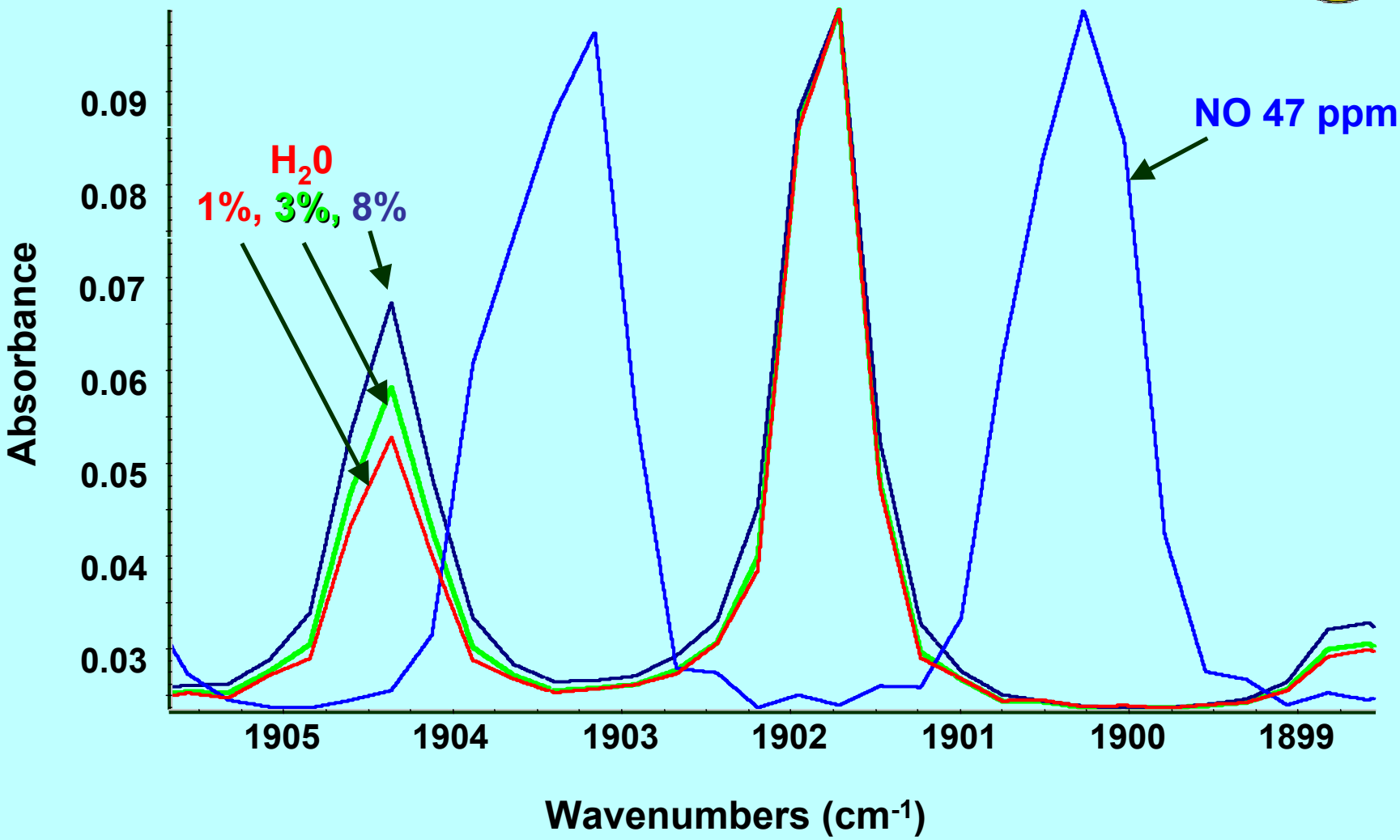
FTIR CALIBRATION SPECTRA OF H_2O AND NO



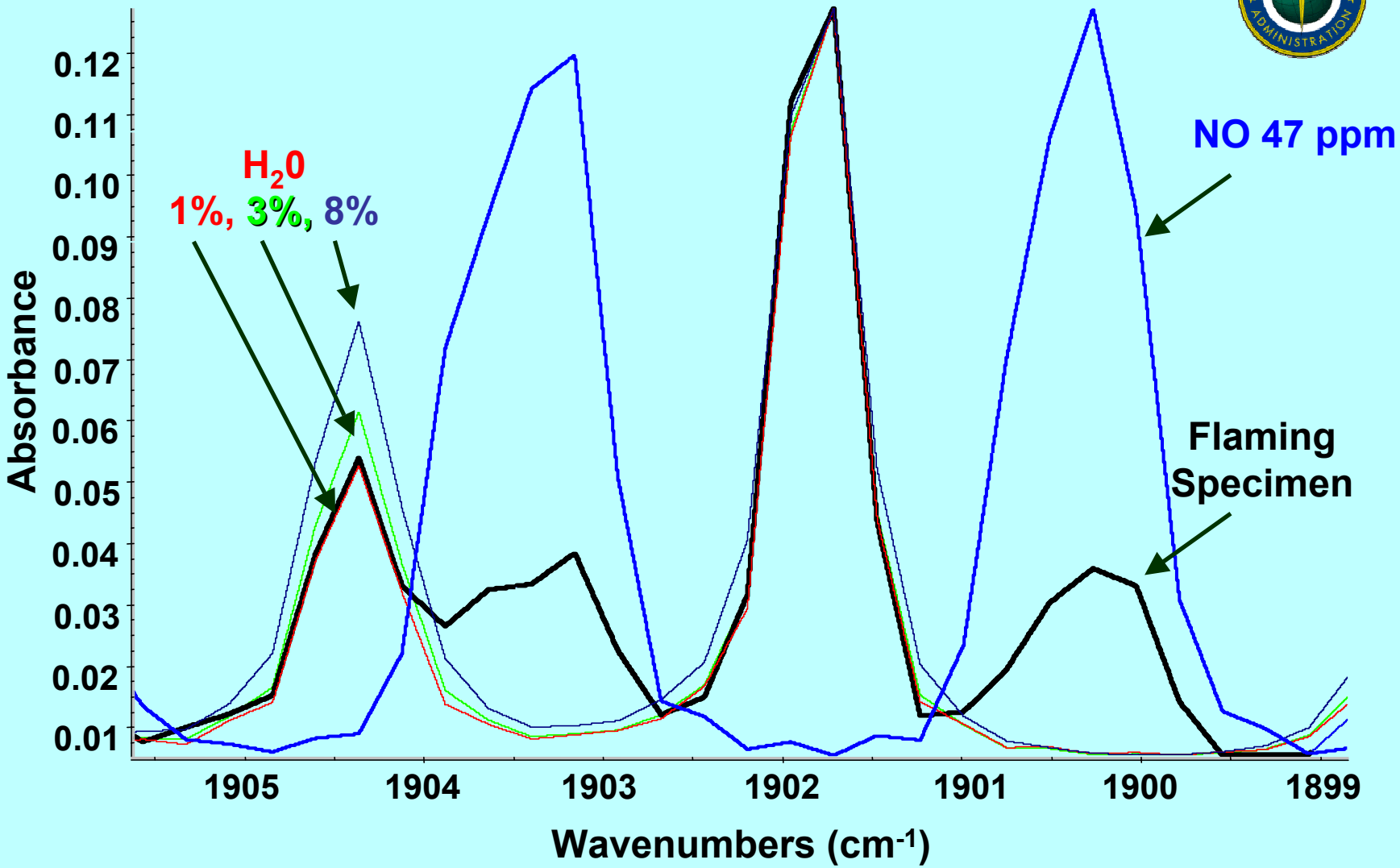
FTIR CALIBRATION SPECTRA OF H_2O AND NO: REGION SELECTED FOR NO ANALYSIS



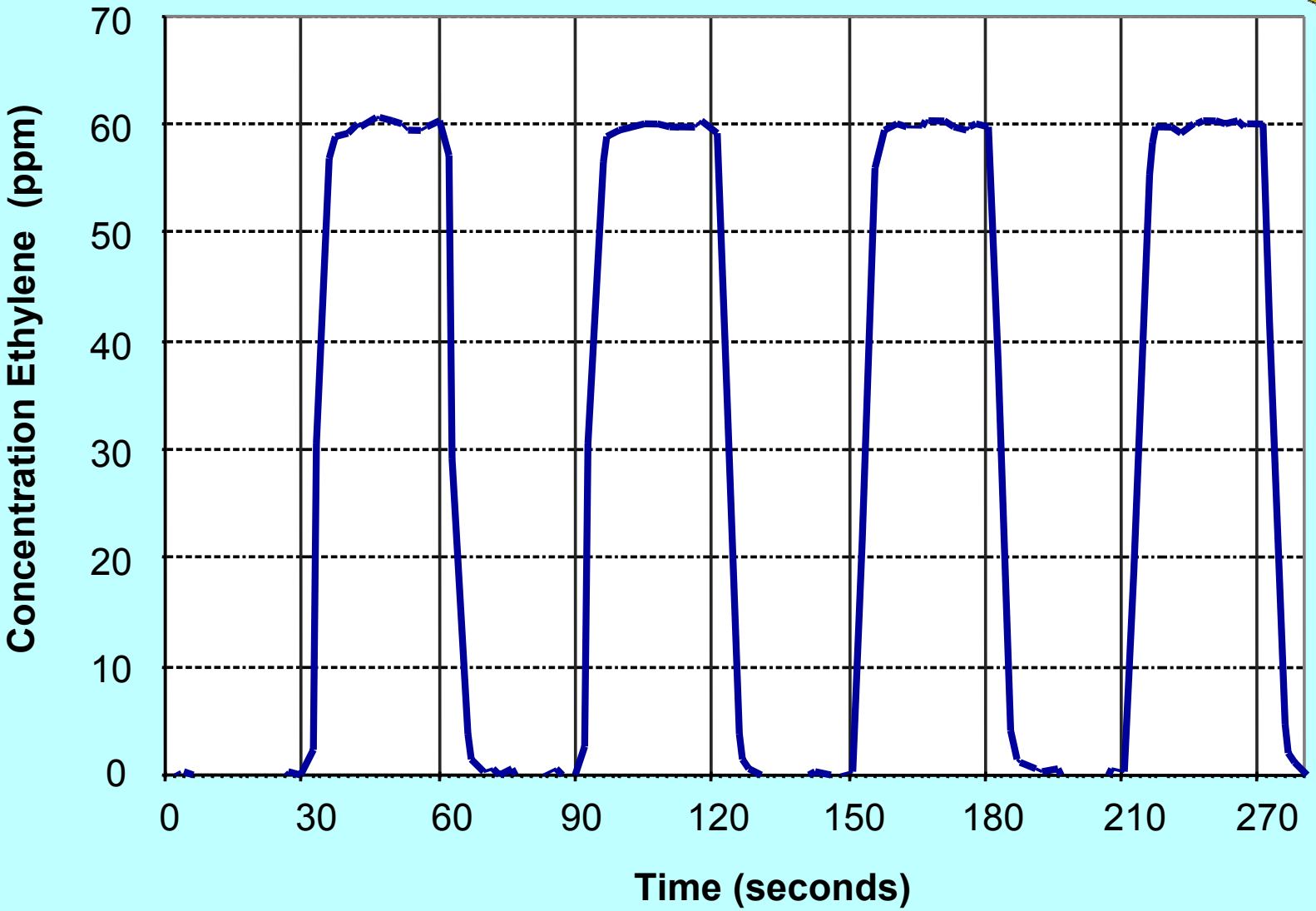
FTIR CALIBRATION SPECTRA OF H_2O AND NO: FULL SCALE



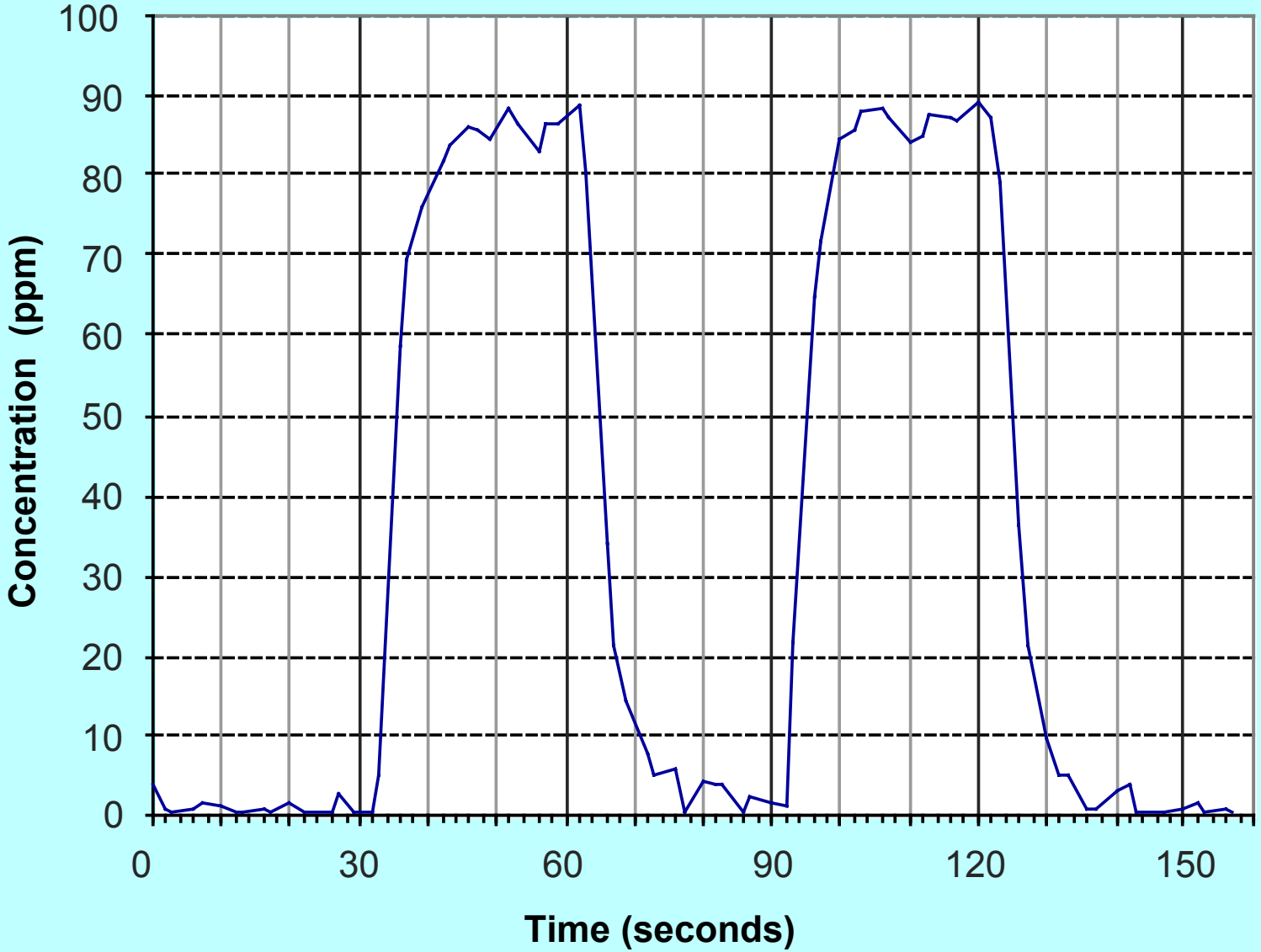
FTIR CALIBRATION SPECTRA OF H_2O AND NO AND FLAMING SPECIMEN SPECTRUM: FULL SCALE



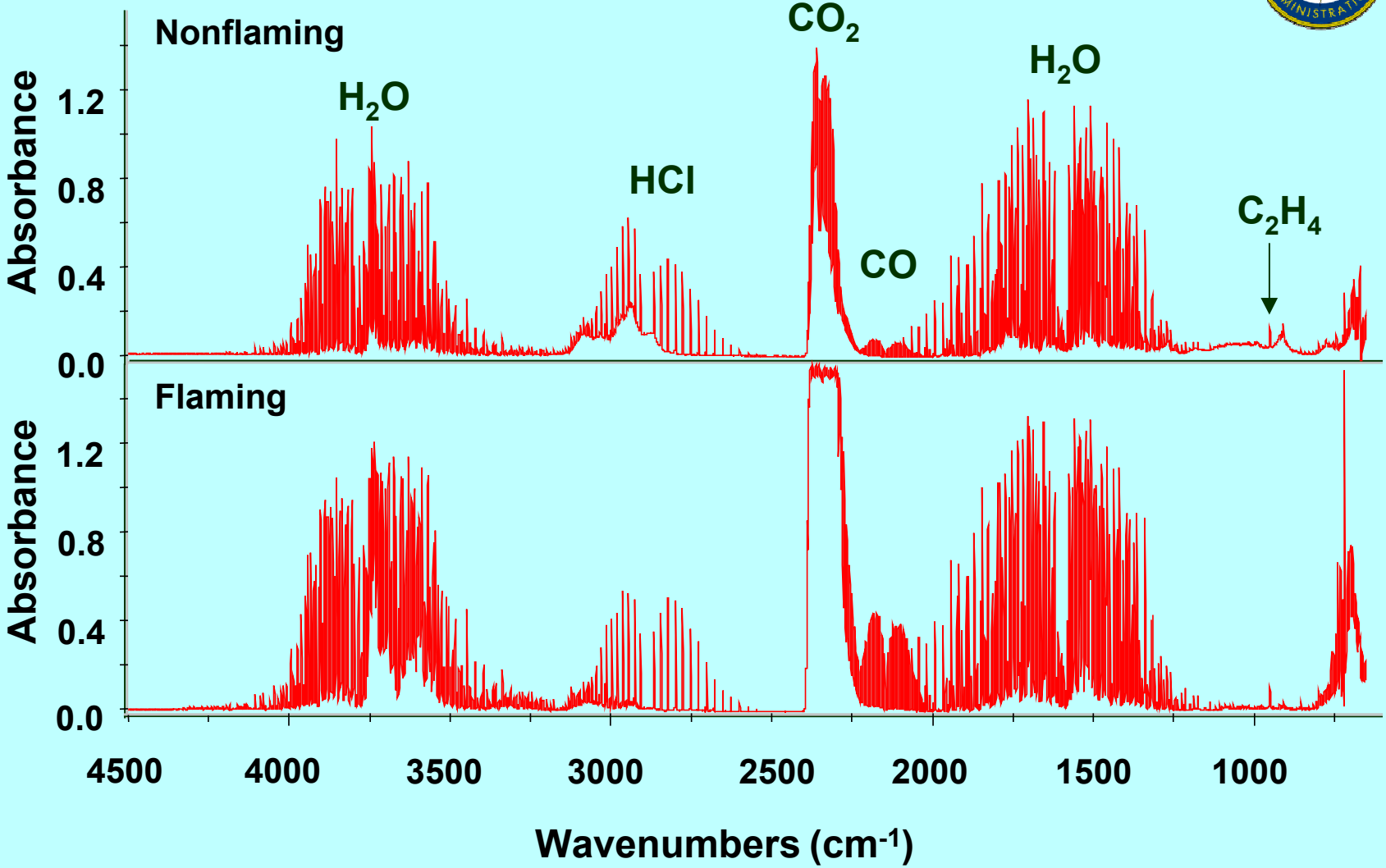
DYNAMIC FTIR SYSTEM RESPONSE WITH GAS INTRODUCED AT HEATED SAMPLE LINE INLET



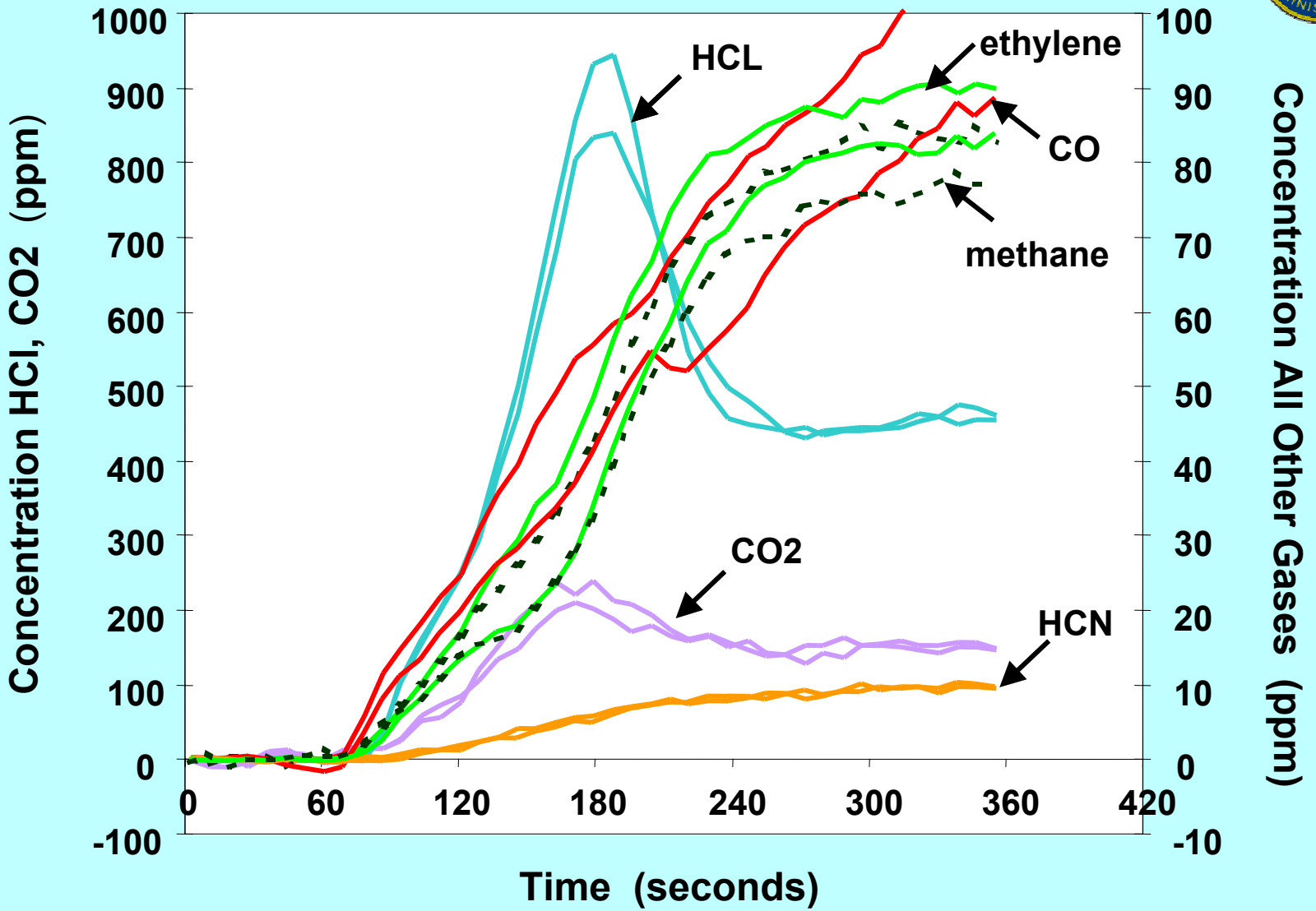
DYNAMIC FTIR SYSTEM RESPONSE WITH GAS INTRODUCED AT CENTER OF CONE



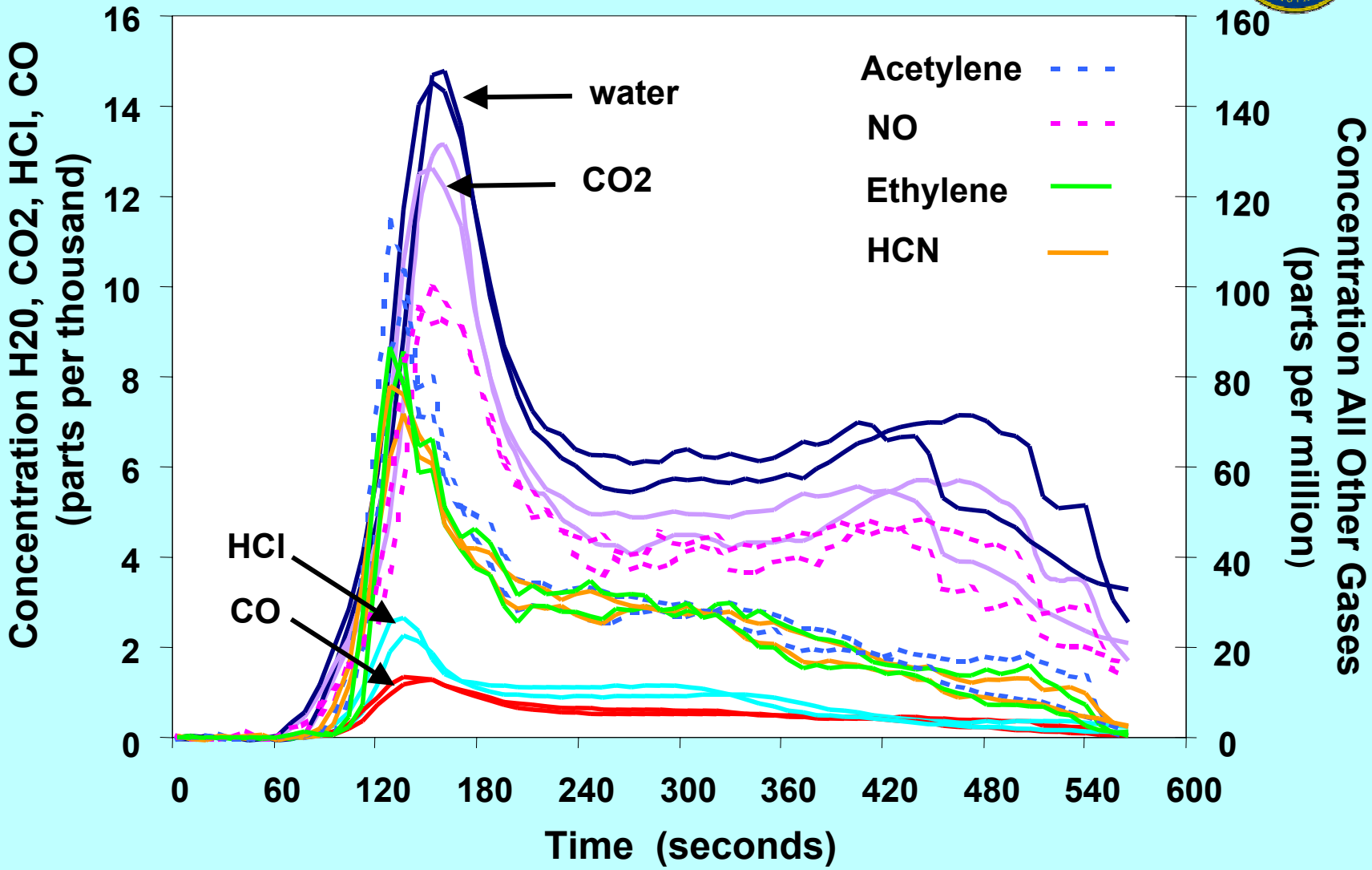
FTIR SPECTRA OF MIXED PLASTIC SPECIMENS



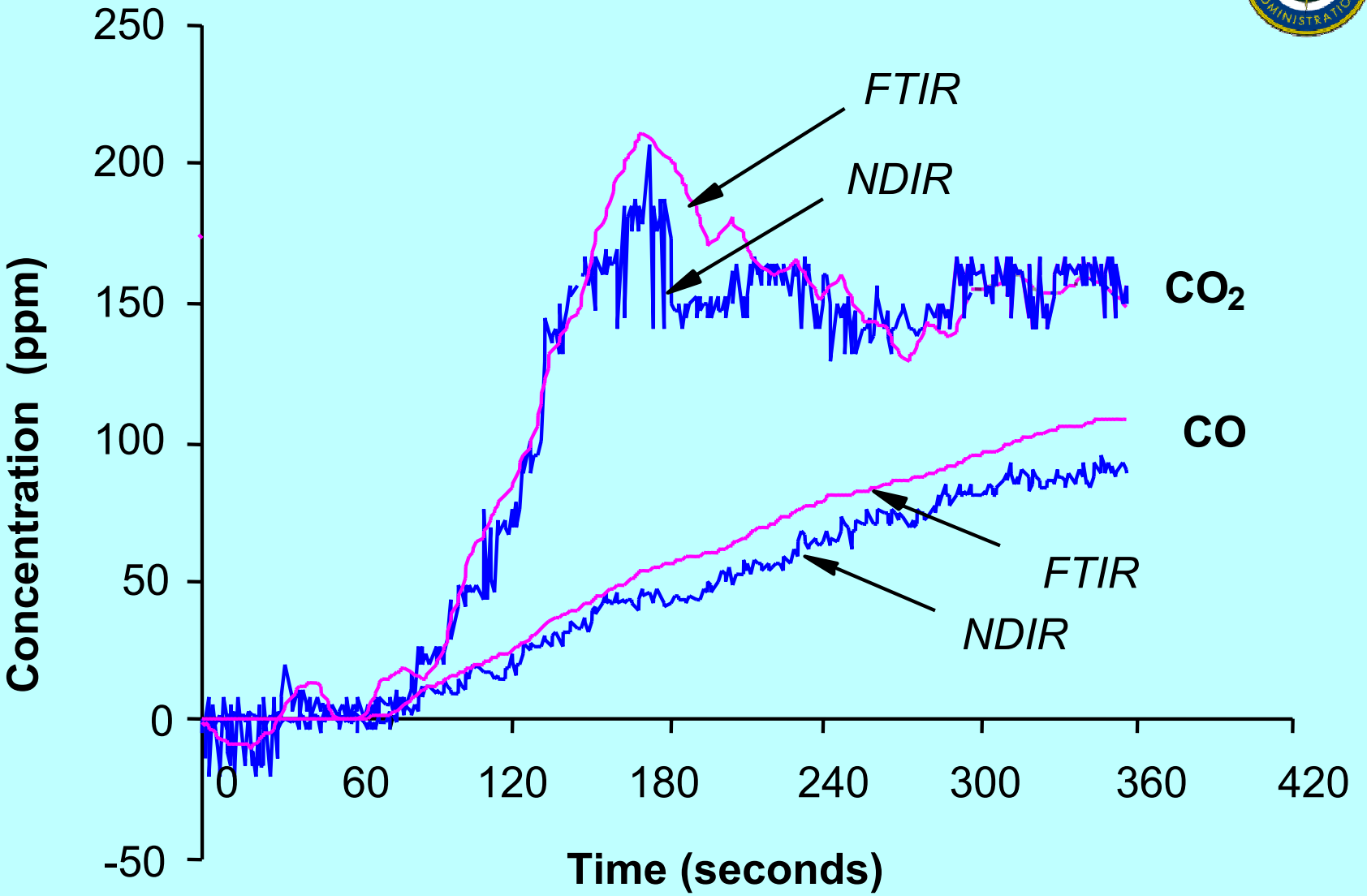
FIRE GAS HISTORIES FOR DUPLICATE NONFLAMING TESTS OF MIXED PLASTIC SPECIMEN



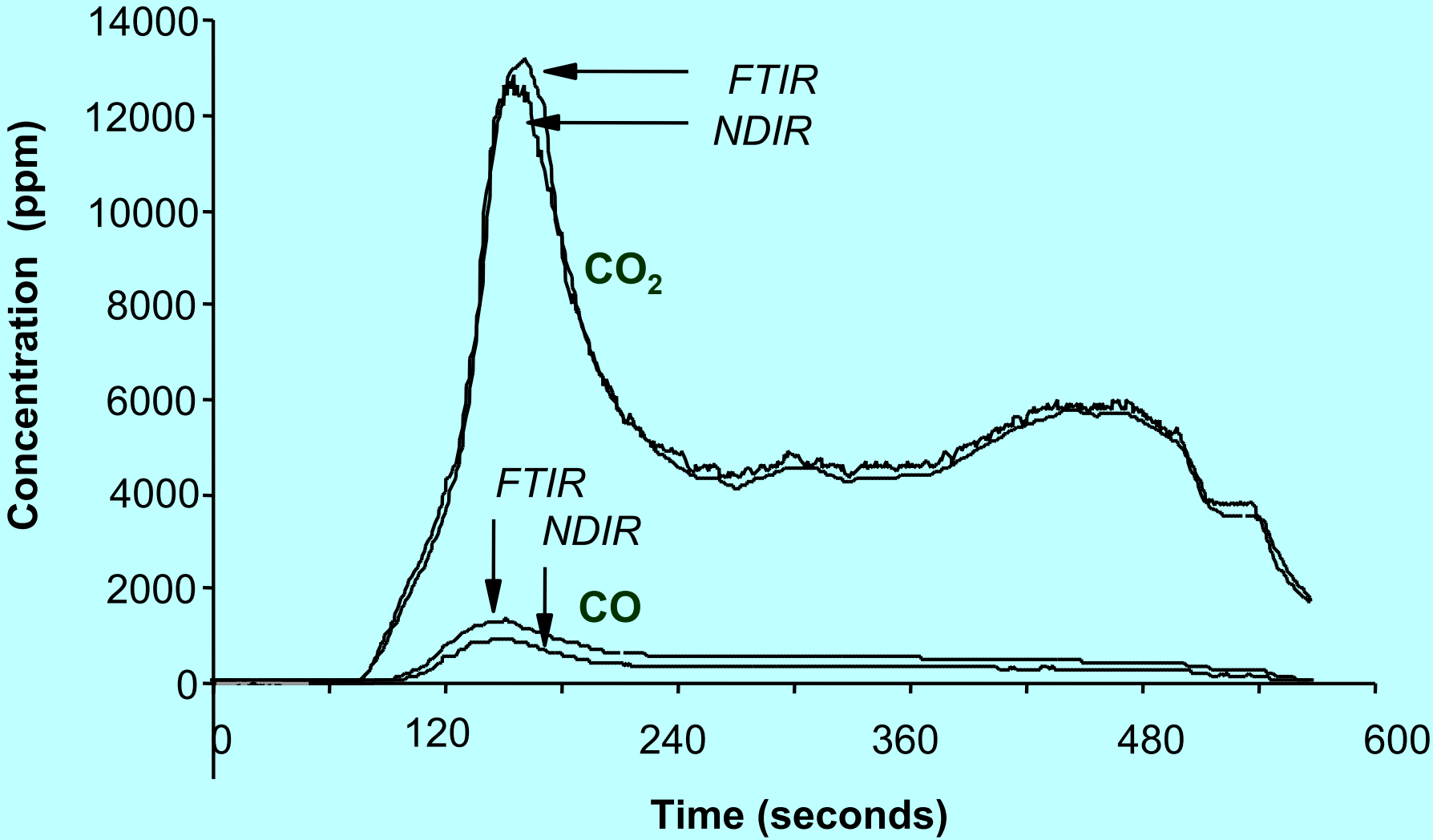
FIRE GAS HISTORIES FOR DUPLICATE FLAMING TESTS OF MIXED PLASTIC SPECIMEN



COMPARISON OF FTIR AND NDIR NONFLAMING PROFILES



COMPARISON OF FTIR AND NDIR FLAMING PROFILES



RESIDUALS FOR NONFLAMING SPECIMEN AT 171 SECONDS

Gas	Concentration (ppm)	+/- Error (ppm)	Error (%)
CO	53.6	0.7	1.3
CO_2	210.5	39.2	18.6
$COCl_2$	-0.1	0.1	
COF_2	8.3	2.2	26.5*
HBr	-0.2	1.2	
HCl	805.3	14.4	1.8
HCN	5.6	0.9	16.1
HF	0.0	1.3	
NO	-0.3	-6.5	
NO_2	-0.0	-6.5	
SO_2	6.4	3.3	51.6*
CH_4	37.6	0.4	1.1
C_2H_2	-1.0	0.2	
C_2H_4	42.9	0.4	0.9
C_2H_6	0.0	2.7	
Water	267.2	572.7	214.0*

RESIDUALS FOR FLAMING SPECIMEN AT 171 SECONDS

Gas	Concentration (ppm)	+/- Error (ppm)	Error (%)
CO	1025.9	5.5	0.5
CO_2	12182.3	1031.8	8.5
$COCl_2$	0.1	0.1	
COF_2	-0.4	1.3	
HBr	0.0	1.0	
HCl	1236.9	24.6	2.0
HCN	43.8	1.3	3.0
HF	0	1.7	
NO	90.9	11.2	12.4
NO_2	-0.1	11.2	
SO_2	2.5	4.8	192.0*
CH_4	40.6	32.7	80.5*
C_2H_2	50.1	0.5	1.0
C_2H_4	41.6	0.5	1.2
C_2H_6	-1.0	4.6	
Water	13578.6	203.6	1.5

RESULTS

- Quick system response
- Excellent agreement for replicate tests in both flaming and nonflaming mode
- Low residuals in flaming and nonflaming mode for 16 gases
- Accuracy confirmed by reasonable agreement of the FTIR method and NDIR CO and CO_2 gas analysers

CONCLUSIONS

- The patterns of response will aid in the selection and development of improved cargo smoke and fire detectors

- This FTIR method may be useful for toxic gas monitoring for fire toxicity tests.