# Determination Of Fire Effluents From Products On Railway Vehicles

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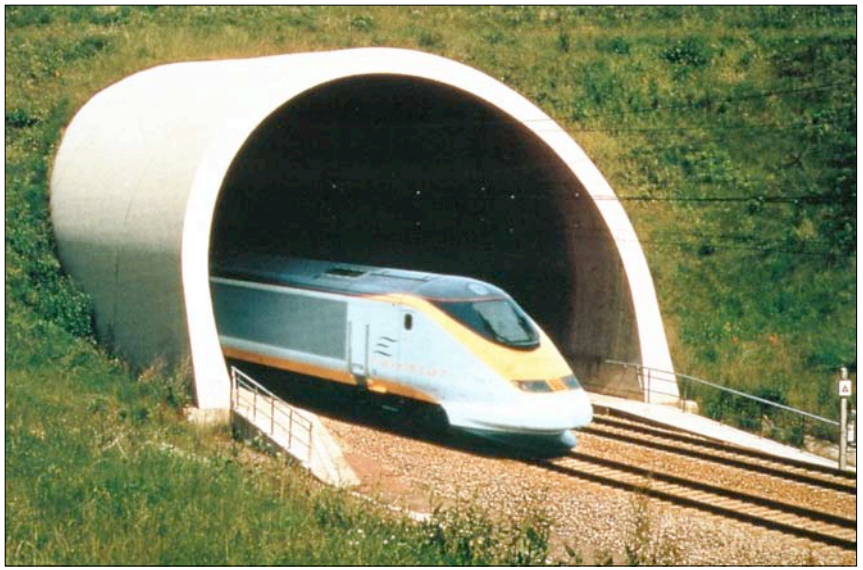
# Introduction

- Since the early 1990s, the European Commission has been developing Directives for the operational and technical harmonisation of the European rail system

- The new Rail Directives should allow train operators and train builders an open market with a standardised rail infra structure and harmonised standards for all products fitted to European trains.



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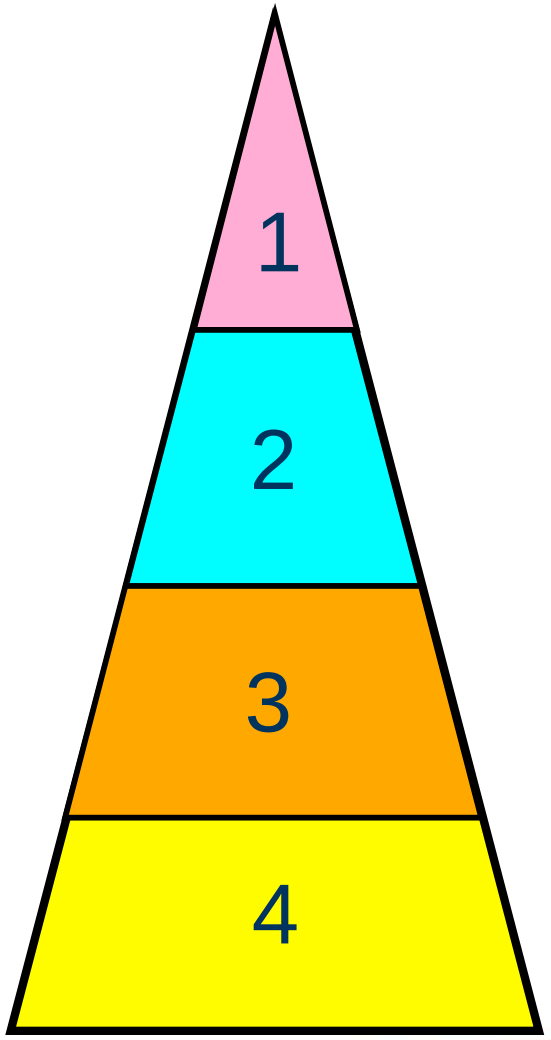
# Introduction: 4 Layer System For Rail Safety In Europe

- Rail Directives – railway legislation that is law.
  Made by European Commission.
- Technical Specification for Interoperability (TSI) that are the regulatory statutes of the law.
  Made by European Commission and European Railway Agency (ERA).
- Standards (ENs) that are the European rules.
  Made by CEN and CENELEC fire committees.
- Local and Regional rules; e.g. London Underground and SNCF/RATP

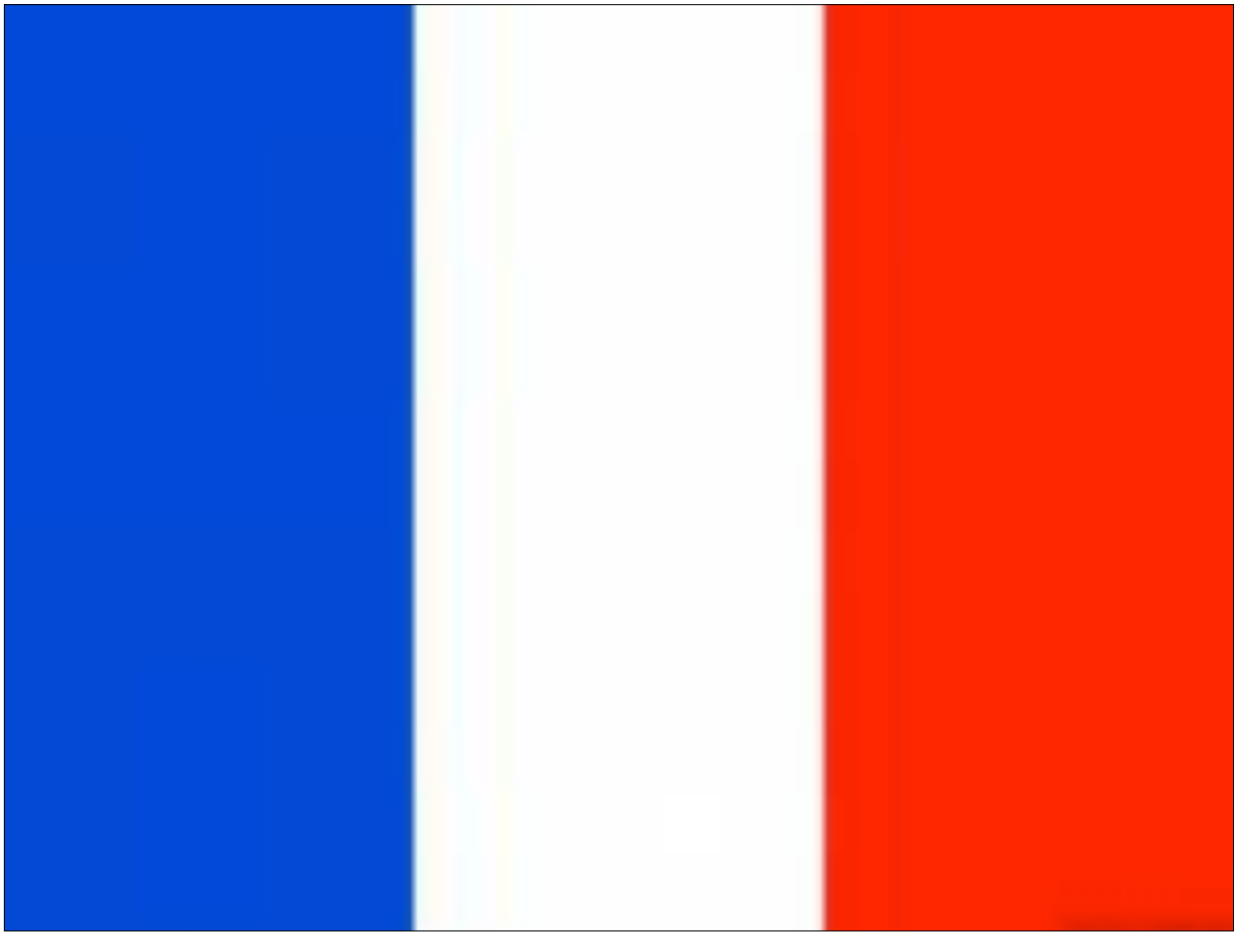


# Now: Current Status?

- Directives written, an essential requirement is that the choice of materials must aim to limit the generation of toxic fumes
- Conventional rolling stock = Existing national requirements
- High speed rolling stock = HS TSI states that pending publication of EN 45545-2, material deemed to be acceptable must meet **one** of five national standards

  National standards recognised:
  - British
  - French
  - German (with toxicity tests)
  - Italian
  - Polish
- The aim is that in the future EN 45545-2 will be used to decide if materials are safe for use in terms of their reaction to fire properties

# Current: French Test Method



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# Current: French Test Method

- NF F 16-101 and NF F 16-102 provides the Reaction To Fire requirements
  - NF X 70-100 details the toxicity test method
    - Part 1 – Analysis methods
    - Part 2 – Burn procedure
  - Gases analysed: CO, $CO_2$, HF, HCl, HBr, $SO_2$ and HCN
  - NB. No requirement to measure $NO_x$
  - Tube furnace technique
- Certifer round robin approval scheme for test laboratories

Laboratory approved by CERTIFER Railway Certification Agency

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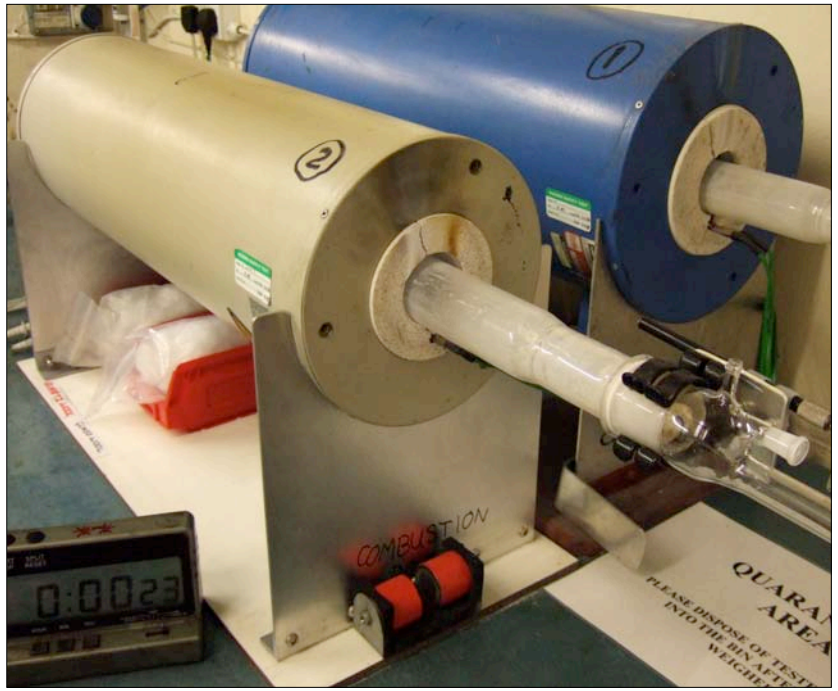
# Current: French Test Method

- 1g specimen
- Tube furnace 800°C for electrical items & 600°C for all other materials
- 2L/min air (well ventilated)
- 20 minutes: specimen in heated zone
- After specimen removed, test continues until tube furnace clear
- All products of combustion collected for analysis
- Triplicate testing for each gas



# Current: French Test Results

- Units of concentration = mg/g

  Total mass of toxic gas emitted (mg) per 1g of product tested
- Calculate **C**onventional **I**ndex of **T**oxicity (CIT)
  - Weighted summation of the species analysed
- Result must be combined with the smoke density results obtained to NF X 10-702 in order to obtain an F rating
- F0 best, F5 worst
- F rating requirement is found in NF X 16-101 and NF X 16-102, dependant upon the products use and the rolling stock operation category

# Current: British Test Methods

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# Current: British Test Methods

- BS 6853 provides the Reaction To Fire requirements
  - Annex B details the toxicity test methods
  - Gases analysed: CO, $CO_2$, $NO_x$, HF, HCl, HBr, $SO_2$ and HCN
    - Annex B.1: NF X 70-100 tube furnace

      Small electrical components, cables and minor usage products

      NB. Annex B.1 burn and analysis procedures identical to NF X 70-100 for French rolling stock
    - Annex B.2: Smoke chamber analysed by a number of methods

      Products with significant surface areas (walls, ceilings, floorings, seat trims, etc.)

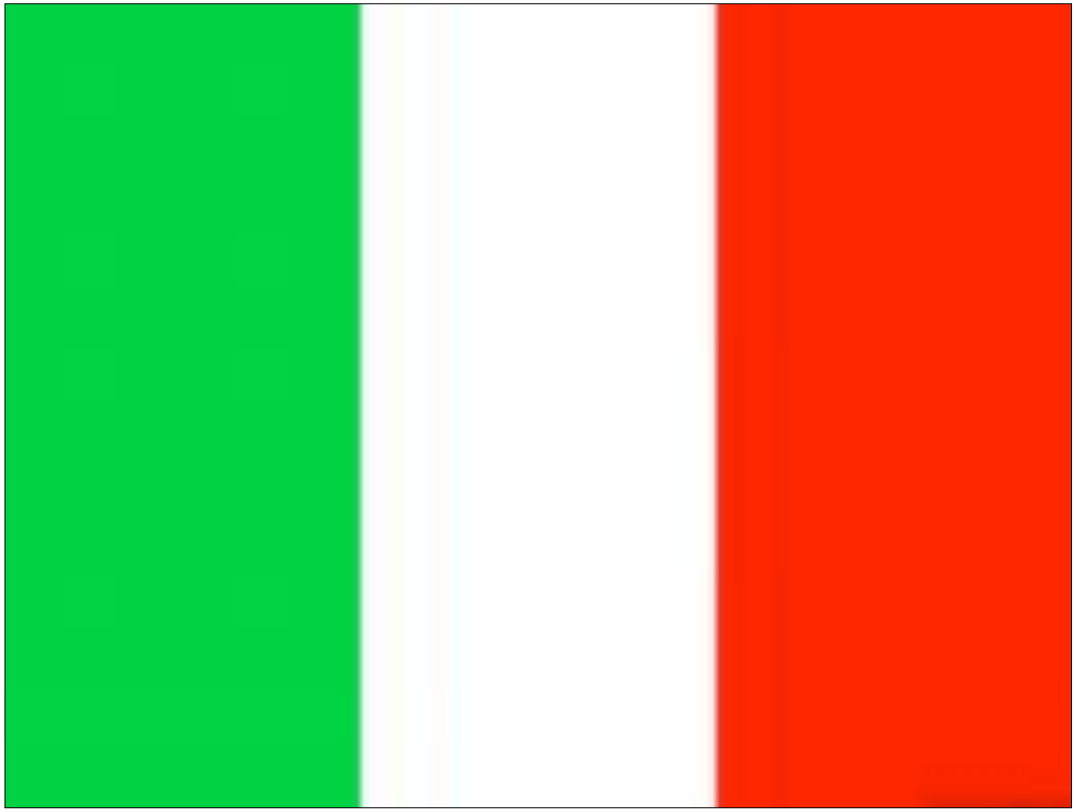
# Current: British Annex B.2 Test Method

- 75mm by 75mm specimen
- Sealed 0.5m$^3$ chamber (ISO 5659-2)
- Test mode: 25kW/m$^2$ with a pilot flame
- First specimen tested to provide smoke density versus time curve
- From curve, determine time products of combustion should be sampled from subsequent three specimens
  - Time at which 85% of the peak smoke emission is reached

# **Current**: British Annex B.2 Test Results

- Units of concentration = $g/m^2$
- Mass of toxic gas emitted (g) per $m^2$ of product tested
- Calculate R value
  - Weighted summation of the species analysed
- Lower the R value the better
- R value requirement is found in BS 6853, dependant upon the products use and the rolling stock operation category

# Current: Italian Test Methods



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# Current: Italian Test Methods

- UNI CEI 11170 provides the Reaction To Fire requirements
  - NF X 70-100 details the main toxicity test method (same as France)
  - CEI 20-37 part 7 details the electrical components toxicity test method
    - Gases analysed: - CO, $CO_2$, $NO_x$, HF, HCl, HBr, $SO_2$, HCN, $H_2S$, $NH_3$, $H_2CO$, $C_3H_3N$
    - Tube furnace technique
    - Tube furnace 800$^oC$
    - Flow rate and test duration same as NF X 70-100
  - EN 50305 details the cable components toxicity test method
    - Gases analysed: - CO & $CO_2$ (plus $SO_2$, HCN & $NO_x$ where appropriate)
    - Must be halogen free (proven to specified fire test methods)

# Current: Italian Test Results

- NF X 70-100
  - Calculations as France
- CEI 20.37 Part 5
  - Units of concentration = mg/g
  - Weighted summation of the species analysed to provide value
- EN 50305
  - CO & $CO_2$ (plus $SO_2$, HCN & $NO_x$ where appropriate)
    - Units of concentration = mg/g
    - Calculate ITC value, weighted summation of the species analysed
  - Halogen free
    - max evolution of HCl = 0.5% to EN 50267-2-1
    - min pH = 4.3 / max conductivity = 10.0µS/mm to EN 50267-2-2
    - max fluorine content = 0.1% to EN 60684-2

# Current: Polish Test Method

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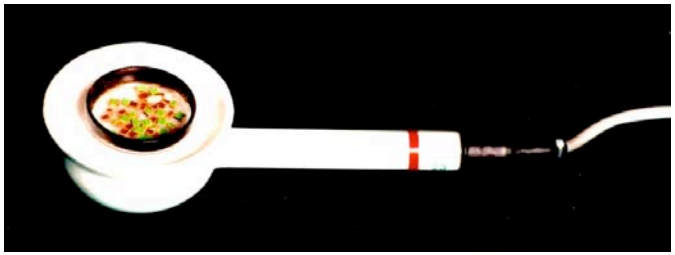
# Current: Polish Test Method

- PN-K-02511 provides the Reaction To Fire requirements
  - PN-K-02505 details the toxicity test method
    - Gases analysed: CO and $CO_2$ only
    - Analysis using colourimetric tubes
    - Sealed $0.5m^3$ chamber (different to ISO 5659-2 chamber)
    - 1g test specimen (in small pieces) in evaporating dish
    - Electric heater = $600^oC$
    - 5 minutes: products of combustion analysed



# Current: Polish Test Results

- Units of concentration = ppm
- Weighted summation of the species analysed
  - 20[CO] + [$CO_2$]
  - Weighted summation < 1200ppm = T1
  - Weighted summation between 1200 and 6000ppm = T2
- Weighted summation >6000ppm = No T classification given
- T classification requirement is found in PN-K-02511, dependant upon the products use and the rolling stock operation category

# Current: German Test Methods

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# Current: German Test Methods

- DIN 5510 provides the Reaction To Fire requirements
  - Current issue of DIN 5510 does not include toxicity test method
    - HS TSI states use internationally recognised method
  - End of 2008, DIN 5510 reissued
  - Gases analysed: CO, $CO_2$, $NO_x$, HF, HCl, HBr, $SO_2$ and HCN
    - Method 1: CEN TS 45545-2 Annex C chamber test method, but
      - Analysis using colourimetric tubes (<80% FED limit) or other listed technique (eg. ion chromatography, FTIR, etc.)
      - Different calculation procedure to CEN TS 45545. Procedure based on fractional effective doses (FED)
    - Method 2: ISO 9705 hood method (seats only)
      - 100g paper cushion fire source
      - Gases collected throughout test duration
      - Total mass of gas produced throughout test duration

# Future: Toxicity Tests To CEN TS 45545-2

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# Future: Toxicity Tests To CEN TS 45545-2

- CEN TS 45545-2 provides the Reaction To Fire requirements
  - Annex C details the toxicity test methods
  - Gases analysed: CO, $CO_2$, $NO_x$, HF, HCl, HBr, $SO_2$ and HCN
    - Method 1: Smoke chamber with FTIR spectrometry

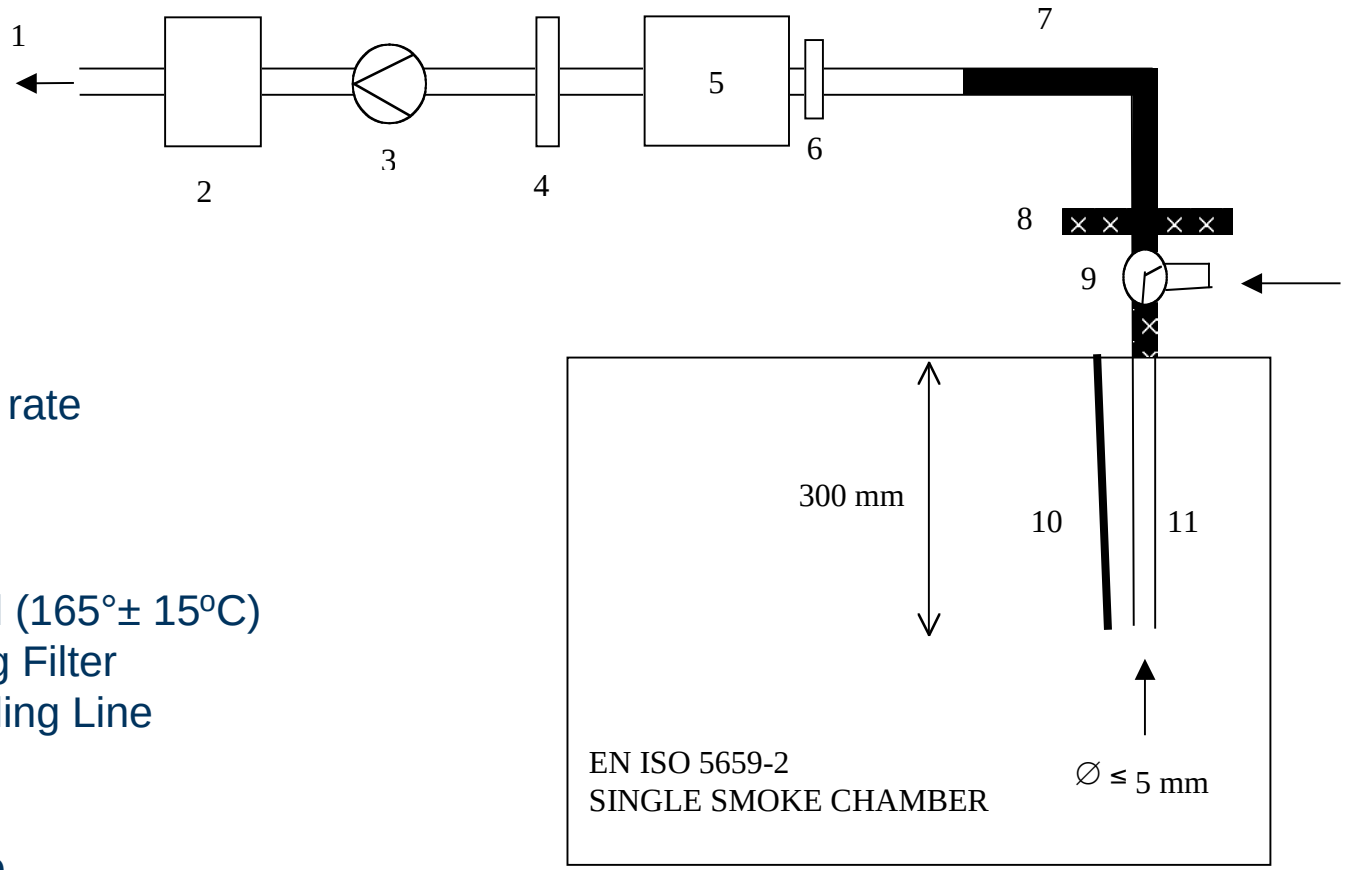
      Products with significant surface areas (walls, ceilings, floorings, seat trims, etc.)
    - Method 2: NF X 70-100 tube furnace (always 600$^{o}$C)

      Small electrical components, cables and minor non-listed products – NF X 70-100 tube furnace

      NB. Method 2 burn and analysis procedure identical to NF X 70-100 used for French rolling stock

# Future: CEN TS 45545-2 Annex C

## Method 1




**Key**

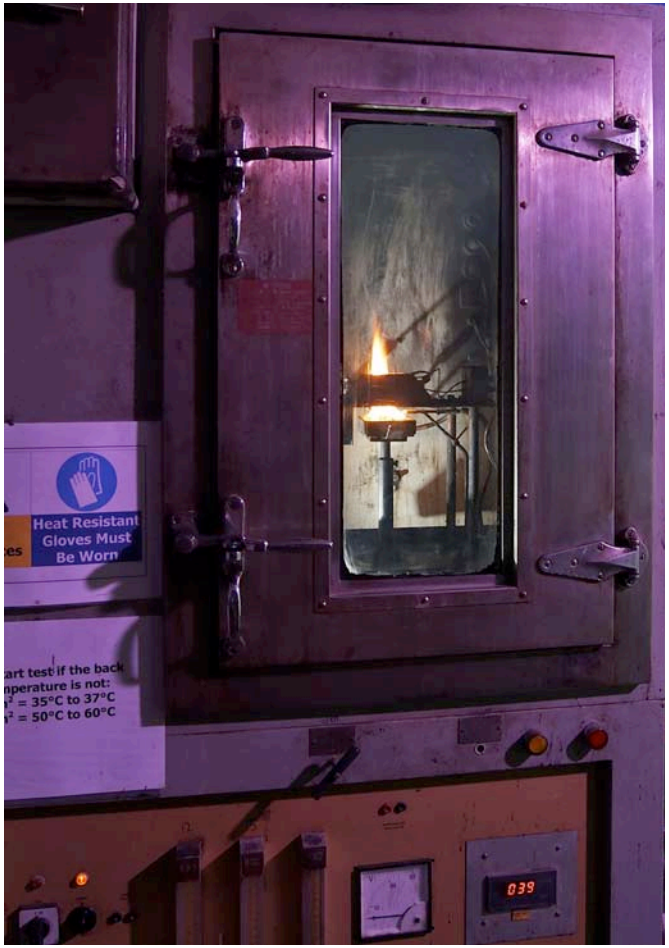
1 Specified flow rate
2 Counter
3 Pump
4 Flow meter
5 FTIR Gas Cell (165°± 15ºC)
6 Cell Protecting Filter
7 Heated Sampling Line
8 Heated Filter
9 Switch
10 Thermocouple
11 Sampling Point

# Future: CEN TS 45545-2 Annex C

## Method 1

- ISO 5659-2 sealed smoke chamber
- Heating mode:
  - 25kW/m$^2$ with a pilot flame

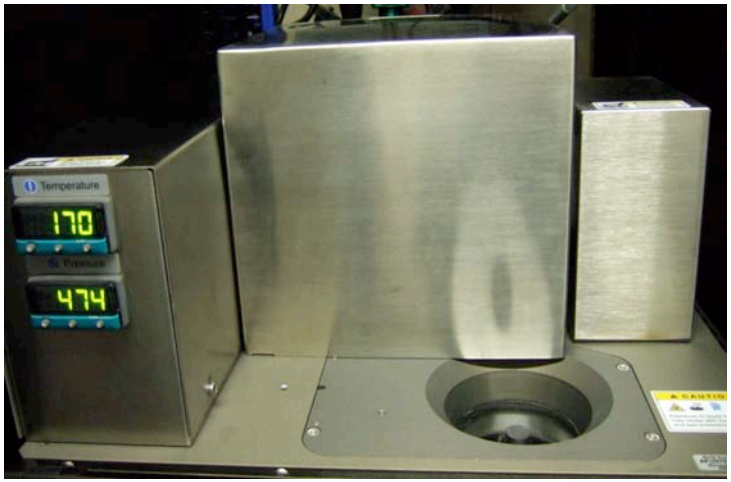
    Or
  - 50kW/m$^2$ without a pilot flame
- Smoke density versus time curve taken throughout test duration using photometric system
- 20 minutes test duration



# Future: CEN TS 45545-2 Annex C

## Method 1

- 4 min and 8 min: concentration of toxic fumes measured using FTIR
- Fumes withdrawn from centre of chamber at 4 L/min
- Through heated filter, heated line, heated filter
- Into FTIR gas cell



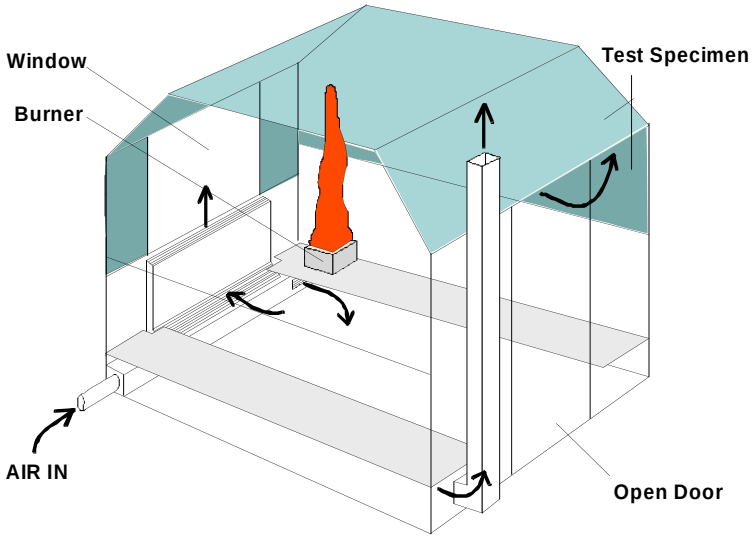
# Future: Hazard Levels

| Op. cat \ Design cat | N | A | D | S |
|---|---|---|---|---|
| | Higher risk (escape time / furnishing) design therefore higher hazard → | | | |
| 1 | HL1 | HL1 | HL1 | HL2 |
| 2 | HL2 | HL2 | HL2 | HL2 |
| 3 | HL2 | HL2 | HL2 | HL3 |
| 4 | HL3 | HL3 | HL3 | HL3 |

Higher risk (escape time) therefore higher hazard ↓

# Future: Toxicity Criteria

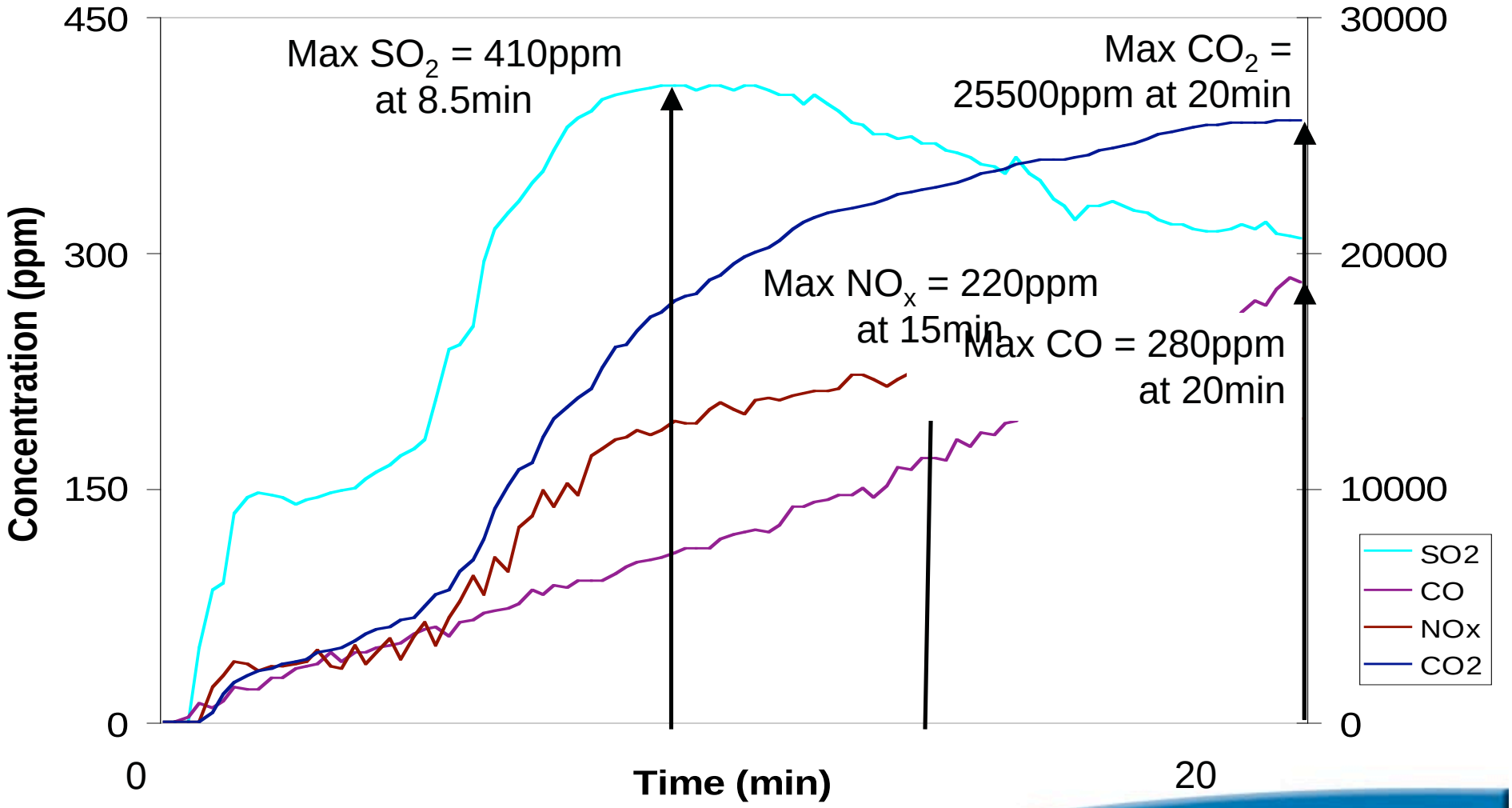
- FIRESTARR – European Commission research project designed to underpin EN 45545-2
- Real-scale tests and small-scale tests on railway products were carried out at Warrington Fire Research Centre.
- FIRESTARR did not include chamber test
- Real-scale test scenario = 150m$^3$ SNCF vehicle
- Toxicity: subsequent zone modelling conducted
  - 8 minute sampling point
  - Limits calculated




# Future: Why FTIR?

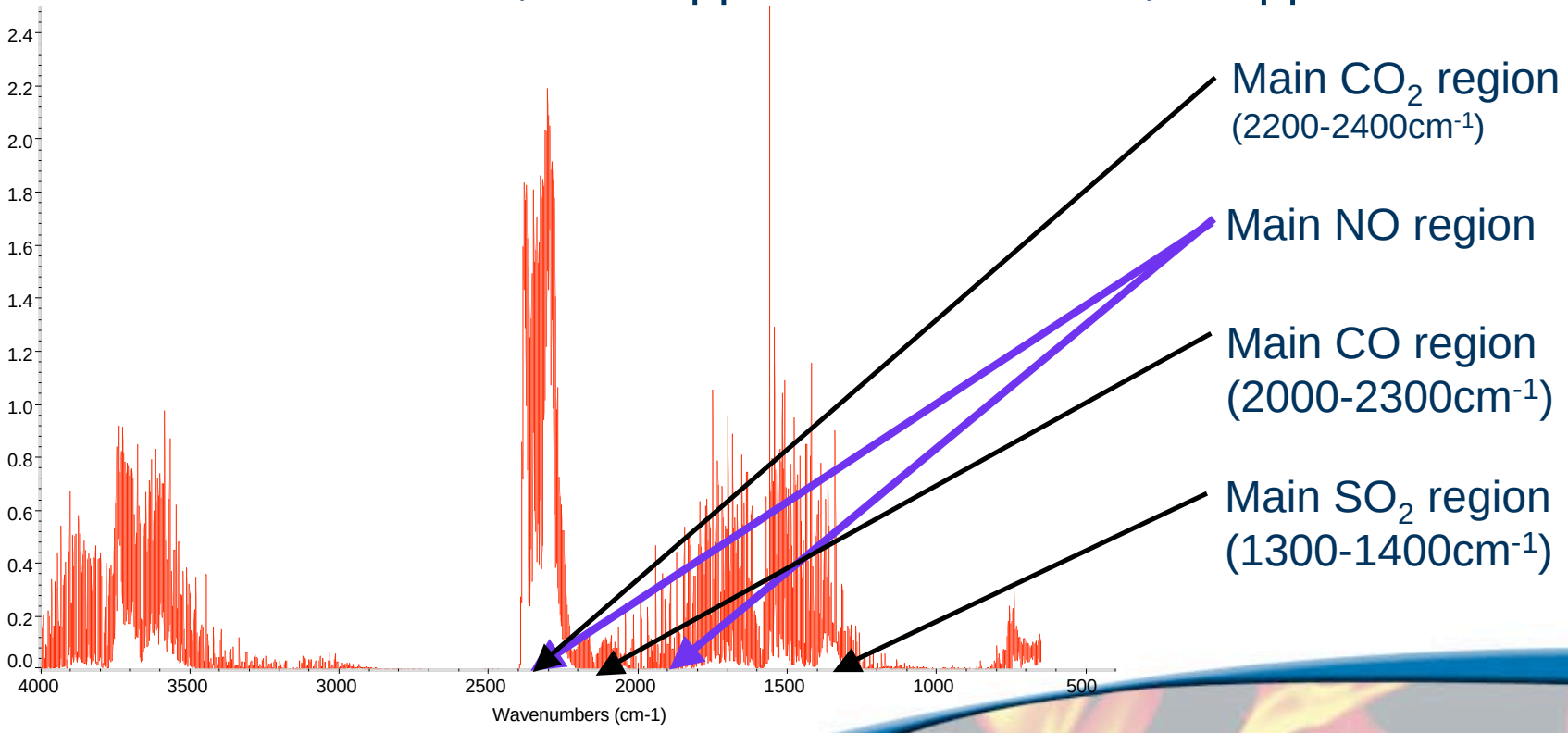
- FTIR
  - One analysis method for all laboratories – remove variable between laboratories
  - Has the ability to measure all gases of interest at one time
  - Possibility for time versus concentration curves for each gas

# Future: Continuous FTIR Analysis Carpet



# Future: FTIR Spectrum Interpretation

- Problems with FTIR
  - Can be difficult to interpret spectra
  - Spectrum shows we have 100ppm sulphur dioxide; 200ppm carbon monoxide; 24000ppm carbon dioxide; 100ppm nitric oxide



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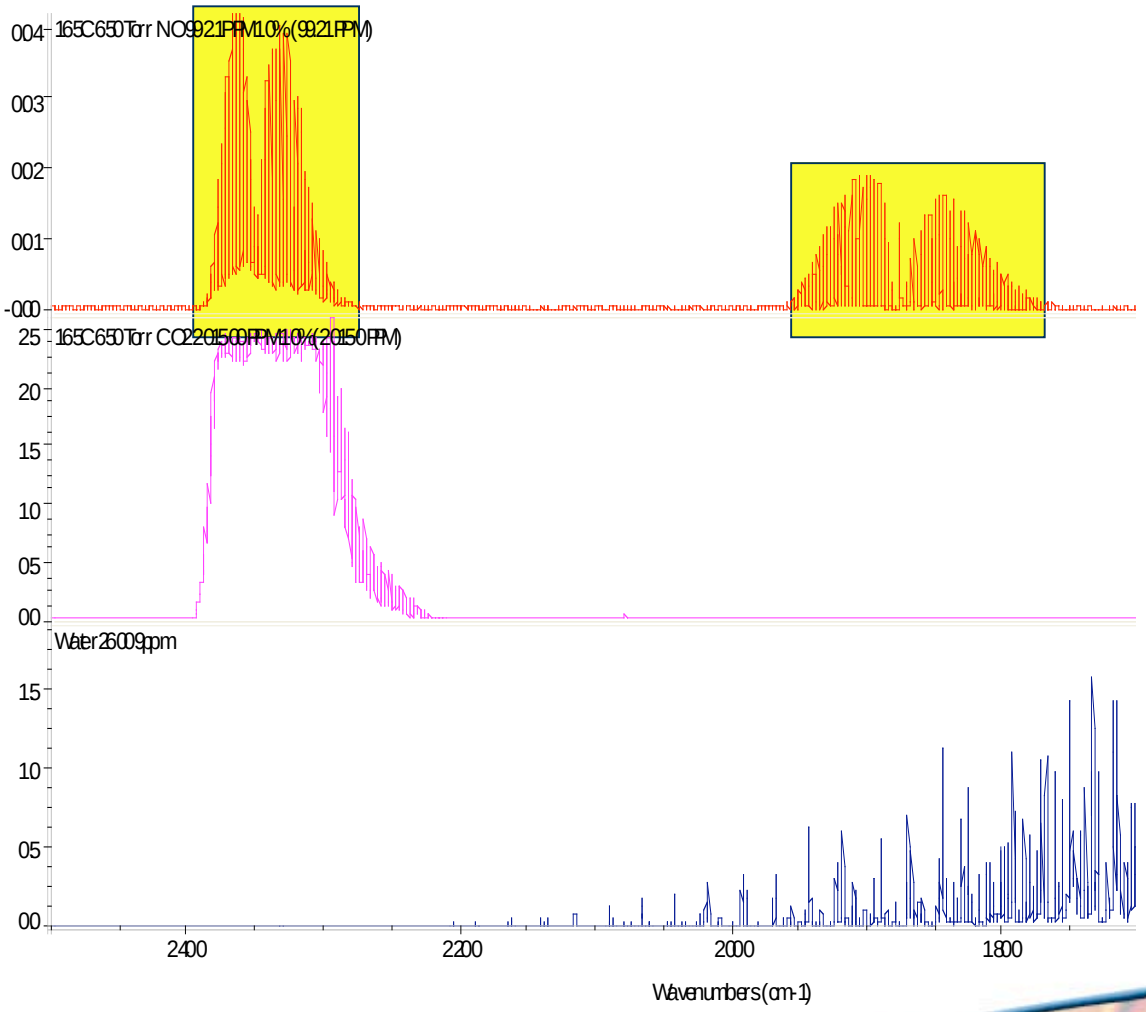


← **100ppm NO gas**

- 1st region: highest intensity
- Plus 2nd region

← **24000ppm $CO_2$ gas**

← **24000ppm $H_2O$ vapour**

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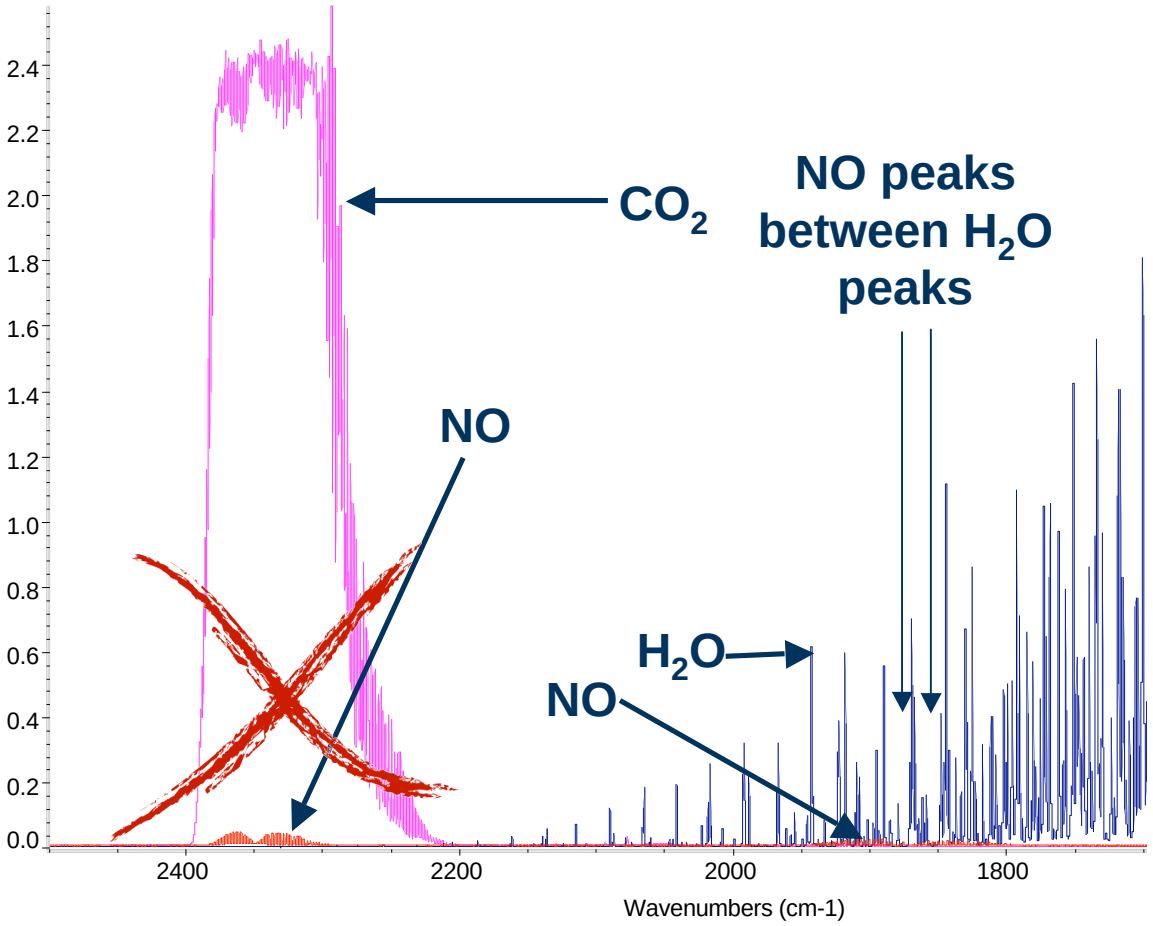
# Future: FTIR Spectrum Interpretation




## 1st region:

Carbon dioxide peaks at typical concentration swamps the first region of nitric oxide peaks

## 2nd region:

Need to see if any nitric oxide peaks are between the water peaks

# Future: FTIR Toxicity Summary

- Toxicity testing is an important and regulated topic
- FTIR offers opportunities for improvement for the future
- Further FTIR research is required
  - Flow rates
  - Filtering considerations
  - Recycling of fumes upon analysis
  - Selection of regions for analysis
  - Intra-laboratory and inter-laboratory accuracy and precision checks