Methods that will be used in EN 45545-2 for the evaluation of the reaction to fire of the products used in Rail- and Surface transport in Europe: maritime and collective on the road.

The use of the Fourier transformation for the dynamic analysis of the toxic gases contained in effluent applied to the chamber ISO 5659-2 in cumulative conditions.

Presentation of the equipment and the test procedures.

Explanation of the indexes CIT and FED / FEC.

C. Baiocchi Senior Developer LSFire
Some signs on the technique of FTIR analysis

What does it mean FTIR?

FTIR is for: Fourier Transform Infrared or Fourier Transform Infrared

What does it represent?

In the context of the infra-red spectroscopy, IR radiation passes through a sample (sample cell gas) where some of the radiation are absorbed from the same sample to other are transmitted. The resulting spectrum represents the absorption (peaks) and the transmission specific molecular that creates a digital fingerprint of the sample. This phenomenon is due to the ability of IR radiation to cause variations in the vibrations of the bonds (stretching & bending) that pass from their state fundamental vibrational to a state vibrational excited. Every single gas molecule then has the property to absorb this energy corresponding to one or more specific regions and notes of the mid-infrared.

Why use this technique?

Infrared spectroscopy has represented one of the techniques from laboratory more credible and used in the analysis of materials for over 70 years. An infrared spectrum represents a fingerprint of the sample. The peaks of spectral absorption correspond to the frequencies of vibration between the bonds of atoms that form the molecular structure of the material. From a moment that each different material has a unique combination of atoms, 2 different substances will never have the same spectrum. As a result, infrared spectroscopy can be adopted as a technique for identification (qualitative analysis) of any type of material. In addition, the size of the peaks in the spectrum provide a direct indication of the quantity of material present is through the use of modern software that process special algorithms, the infrared is an excellent technique for the quantitative analysis.
How works FTIR?

The **IR spectroscopy to Fourier transform**, or in abbreviated form **FT-IR**, is performed by exploiting a **interferometer** that allows the scanning of all the frequencies that are present in IR radiation generated by the source (almost exclusively the globar/thermal radiation) within a few seconds. Scanning is possible thanks to a movable mirror that moving introduces a difference in the optical path, which gives rise to a constructive or destructive interference with the reflected ray by a fixed mirror. In this way it obtains an interferogram that shows the representation of the intensity in the time domain. In this type of instruments and also present a **laser He-Ne** (type of laser: helium-neon source) which emits red light (632.8 nm) and is used to measure the exact position of the mirror and is also used for the sampling of the signal.

By applying Fourier transformation a computer can be used to obtain the infrared spectrum, i.e. the representation of the intensity in the frequency domain.

Among the main advantages of FT-IR, which it delivers more performance, there is the high availability of energy that translates into a report of signals and noises much better compared to the classic infrared spectroscopy. In addition, the analysis times are considerably reduced. Other features are the minimal presence of diffuse light and resolution power that remains constant throughout the IR spectrum.
Example of spectrum in absorption acquired by a FTIR analyzer
The FTIR applied to models of fire

Generic Scheme

The controlled heating of the entire line of sampling and sample cell derives from the need to avoid the presence of points of condensation of hydrogen acid as HCl (hydro chloric acid), HBr (hydro bromic acid) and HF (hydro fluoric acid) that you would not detect in their gas phase at the measuring point (sampling cell). The filtering system of the particulate takes place by PTFE membrane to avoid the possible presence of HF can react with the same.

The sample cell presents within 2 concave mirrors that creates a system of multiple reflection of IR radiation in input. The optical path of this radiation (IR path length) must be as long as possible in a manner to increase the level of detection (sensitivity) of the instrument.

THE peak absorbance (A) is directly proportional to the length of the optical path (path length).
Calibration

The calibration is made using certified cylinders of gas at different concentrations diluted in nitrogen.

Each concentration is translated from the data base in spectrum in absorption and then inserted in a calibration curve in relation to the height or the area of the peak of specific chemical species to determine.

The comparison between this curve and the spectrum purchase of the sample under examination provides the concentration of the specific gas.

<table>
<thead>
<tr>
<th>Gas</th>
<th>Concentrations range (ppm/%)</th>
<th>Number of bottles / concentrations (Min nr. of points) - (LSFIRE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO + CO2 / N2</td>
<td>From 50 ppm + 0.005 % to 5000 ppm + 3.5 %</td>
<td>5 (10)</td>
</tr>
<tr>
<td>HCN / N2</td>
<td>From 10 ppm to 400 ppm</td>
<td>5 (10)</td>
</tr>
<tr>
<td>SO2 / N2</td>
<td>From 20 ppm to 300 ppm</td>
<td>3 (7)</td>
</tr>
<tr>
<td>HCl / N2</td>
<td>From 50 ppm to 5000 ppm</td>
<td>5 (10)</td>
</tr>
<tr>
<td>HF / N2</td>
<td>From 50 ppm to 500 ppm</td>
<td>4 (7)</td>
</tr>
<tr>
<td>HBr / N2</td>
<td>From 50 ppm to 1000 ppm</td>
<td>5 (10)</td>
</tr>
</tbody>
</table>

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<tr>
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<th>Number of bottles / concentrations (Min nr. of points) - (LSFIRE)</th>
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</thead>
<tbody>
<tr>
<td>Acrolein / N2</td>
<td>From 20 ppm to 250 ppm</td>
<td>3 (7)</td>
</tr>
<tr>
<td>Formaldehyde / N2</td>
<td>From 20 ppm to 250 ppm</td>
<td>3 (7)</td>
</tr>
<tr>
<td>NO / N2</td>
<td>From 10 ppm to 200 ppm</td>
<td>3 (7)</td>
</tr>
<tr>
<td>NO2 / N2</td>
<td>From 20 ppm to 750 ppm</td>
<td>3 (7)</td>
</tr>
<tr>
<td>Ammonia / N2</td>
<td>From 20 ppm to 300 ppm</td>
<td>3 (7)</td>
</tr>
</tbody>
</table>
What are the advantages of the FTIR method applied to the analysis of the effluents of the fire?

1. Once we have optimized the most critical part of the system, the sampling line, the measurement of the concentration of the gas can be carried out:
   a. In a discontinuous manner (one or more times during the test at distant intervals of time, well-defined)
   b. In a continuous manner (for the whole test period and relatively short intervals, well-defined)

   In this way one obtains directly the trend of the concentration of specific gas in relation to time: a result of considerable importance in the field of prevention because it is directly usable by modellers to determine the evacuation time linked to a specific scenario of fire.

2. The measurement of gases takes place by using a single analytical technique and does not require different sampling systems that would lead to the classic wet chemical (bottles of bubbling with different reagents) depending on the type of chemical species to detect.

   It is possible to avoid any possibility of error related to the dexterity of the operator and the utilization of several other analytical chemistry techniques as IC, HPLC, potentiometric titration, UV spectrophotometry and VS.

3. The spectra in absorption captured by the software are storable. If you have the need to measure a gas detected (qualitative analysis) but that has not been the calibration curve (quantitative analysis) it can be calibrated later on and then quantified without losing any information in relation to the test carried out even at a distance of time.
What are the methods of small-scale, that up to now have allowed us to carry out the measures of fumes and/or toxic gases in terms of accumulation?

- NBS chamber
  - Furnace with horizontal radiation
  - Sample Size: 75mm x 75mm x 25mm thick (max)
  - NFX 10-702 (French Standard)
    - Measure of the evolution of opaque fumes with detection of the specific density (Ds)
    - Parameters:
      - VOF4 (increase of the fumes in the first 4min trial)
      - Dm (Ds max detected in 20min test)
  - ATS 1000.001 (Airbus)
    - Measure of the evolution of opaque fumes with detection of the specific density (Ds) and gas concentrations.
    - Parameters:
      - Ds 1.5 min and Ds at 4min (acceptance limits)
      - Conc. Gas at 1.5 min and 4min (acceptance limits)

Both methods with 2 test conditions:
- 25 KW/m² smoldering (without pilot flame)
- 25 KW/m² flaming (with pilot flame)
ISO 5659-2 (Single smoke chamber)

Furnace with vertical radiation

Sample Size: 75mm x 75mm x 25mm thick (max)

IMO FTP Code annex 1 part 2 (naval)

ISO TC 92 SC 1 WG12

Standard ISO-21489 Fire test. Method of measurement of gases using Fourier Transform Infrared spectroscopy (FTIR) by cumulative smoke testing at the preliminary identified maximum smoke density point

Parameters:
**Ds max (Dm)** with acceptance limits depending on the type of application
**Concentration of gases** with levy within **3 min** from the time of reaching the value of Dm with acceptance limits for each gas

3 Test conditions:
- 25 KW/m2 without pilot flame
- 25 KW/m2 with a pilot flame
- 50 KW/m2 without pilot flame
Key
(1) Smoke chamber (ISO 5659-2) (7) Heated soot filter
(2) Sample holder (8) Heated protecting filter at cell entrance
(3) Cone shape radiating heater (9) Pressure indicator
(4) Sampling probe of fire effluents (10) Heated measuring cell of FTIR spectrometer
(5) Heated 3-way Valve (11) Pump for gas extraction (after analyser)
(6) Heated gas sampling line (12) Volume flowmeter

FTP Code

2.6.2 Toxicity

The gas concentration measured at each test condition shall not exceed the following limits:

- CO 1450 ppm
- HBr 600 ppm
- HCl 600 ppm
- HCN 140 ppm
- HF 600 ppm
- SO₂ 120 ppm
- NOₓ 350 ppm
ISO 5659-2 (Single smoke chamber)

Furnace with vertical irradiation

Sample Size: 75mm x 75mm x 25mm thick (max)

Pr EN 45545 part 2 annex C method 1

Railway applications - Fire protection of railway vehicles - Part 2: Requirements for fire behavior of materials and components

*Testing methods for determination of toxic gases from railway products*

Parameters:

- **Dₛₘₐₓ (Dₘ)** with acceptance limits depending on the type of application and requirements
- **Dₛ₄ₘᵢₙ** with acceptance limits depending on the type of application and requirements
- **VOF₄** with acceptance limits depending on the type of application and requirements
- **CＩＴ₄ₘᵢₙ**: Conventional Index of Toxicity at 4min
- **CＩＴ₈ₘᵢₙ**: Conventional Index of Toxicity at 8min

With acceptance limits depending on the type of application and requirements

2 Test conditions

(Depending on the type of application and requirements):

- 25 KW/m² with a pilot flame
- 50 KW/m² without pilot flame
Calculation of the CIT

CIT = [Precursor Term] \times [Summation Term]

CIT_{0} is defined as follows:

\[ CIT_{0} = \frac{0.31 \text{ m}^3 \times 0.1 \text{ m}^3}{150 \text{ m}^3 \times 0.004225 \text{ m}^3} \times \sum \frac{C_{i}}{C_{i-1}} \text{ mg m}^{-3} \]

where

The model is 0.1 \text{ m}^2 material burning and the gaseous effluents disperse into 150 \text{ m}^3.

\( c_{i} \) is the concentration of the \( i \)th gas in the EN ISO 5659-2 smoke chamber;

\( C_{i} \) is the reference concentration of the \( i \)th gas.

This expression simplifies to:

\[ CIT_{0} = 0.0805 \times \sum \frac{C_{i}}{C_{i-1}} \]

The reference concentrations of the gas components for Method 1 are given in Table 1:

<table>
<thead>
<tr>
<th>Gas component</th>
<th>Reference concentration mg/m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO₂</td>
<td>72 000</td>
</tr>
<tr>
<td>CO</td>
<td>1 380</td>
</tr>
<tr>
<td>HBr</td>
<td>99</td>
</tr>
<tr>
<td>HCl</td>
<td>75</td>
</tr>
<tr>
<td>HCN</td>
<td>55</td>
</tr>
<tr>
<td>HF</td>
<td>25</td>
</tr>
<tr>
<td>NO₂</td>
<td>38</td>
</tr>
<tr>
<td>SO₂</td>
<td>262</td>
</tr>
</tbody>
</table>

*NOTE: These reference values are based on IDLH (Immediately Dangerous to Life and Health), recognised as a limit for personal exposure to the gas component by NIOSH (National Institute for Occupational Safety and Health) (1997 version).*

Figure C.1 — Smoke chamber and effluent sampling system for FTIR analysis (Method 1)
For all of these methods the level of the effluents and the determination of the concentration of gas occur in a discontinuous manner, or certain pre-set time intervals.

One of the main advantages of the FTIR technique and the possibility of making levies continues from the test atmosphere through sampling, in constant flow is calibrated in the cell gas throughout the duration of the test.

The result will be the determination of the dynamic curve of concentration for each gas of interest in relation to the whole test range with scan interval between 2 consecutive data of 15s for 20min.

The range of scanning and direct consequence of the response time of the sampling system, i.e. the minimum time required for the complete renovation of the internal volume of the cell for analysis at a predetermined sampling rate.

This type of development and has been designed, optimized, and at the end applied within the program Transfeu (WP2 - coordination LSFire) and you will arrive at a new and detailed technical procedure for the following test.
Small-scale test for dynamic measurement of smoke and toxic gases produced in a cumulative system
(ISO 5659-2 Smoke chamber)

The experience of LSFire laboratories in the use of FTIR technology applied to models of fire starts in 1992 with the acquisition of the first FTIR spectrometer.

The first collaboration for the development of the analyser was undertaken at the time with the Finnish laboratory of VTT (D. ssa Kallonen) that for some years already had specialized in optimization of this modern technique.

They were then different research programs internal and international take place to which the laboratory LSFire took part both as partners and as coordinator of working groups.
International Research Programms

  - Testing of small scale (cone calorimetric + FTIR)
  - Testing of large scale (furniture calorimeter + FTIR & Room corner test + FTIR)

- **SAFIR (1997 - 1999)** - European research program on the study of the optimization of the use of FTIR in application to models of fire of small and large scale.
  - Testing of small scale (cone calorimetric + FTIR & ISO 5659-2 + FTIR)
  - Calibration and quantitative analysis (software algorithms, PLS, CLS, INLR, etc)

  - Testing of small scale (cone calorimetric + FTIR / ISO 5659-2 + FTIR / NFX 70-100 + FTIR)
  - Test a large-scale and real-life scale (furniture calorimeter + FTIR / railway compartment + FTIR)

- **JWG group CEN TC 256 (2002 - 2006)**: Partners in the preparation of the current text of the PR EN 45545.2 annex C method 1. Execution of validation testing of the method.

- **ISO TC 92 SC1 WG12 (2006-2010)** - Coordinator of the working group for developing new standard ISO-21489 (ISO 5659-2 + FTIR required by the IMO)
  - Drafting text new standard
  - Coordination and participation in the Round Robin of validation

- **Europa cable research program (2002-2004) - toxicity of cables (20 products)**
  - Testing of small scale (ISO5659-2 + FTIR / NFX 70-100 + FTIR/ EN50267-2 -1/ EN50267-2 -2)
  - Test a large-scale and real-life scale (EN 50399 + FTIR)

**Programs of internal research**

- **Alexander VI (1993 - 1996)** - A program of research on the toxicity of effluents of fire test on a small scale in terms of accumulation and full ventilation
  - Testing of small scale (cone calorimetric + FTIR & Dual smoke box/ISO 5924 + FTIR)

- **Roland (1993 - 1998)** - A program of research on the toxicity of effluents of fire on test mid-scale and large scale (ISO 5658-4 + FTIR & ISO 9705 + FTIR)
In the course of the various round robin of the various methods of small scale with the use of FTIR as a technique for the determination of toxic gases and more precisely for the procedures

_Standard ISO-21489 FireTest._

Method of measurement of gases using Fourier Transform Infrared spectroscopy (FTIR) by cumulative smoke testing at the preliminary identified maximum smoke density point

&

_Pr EN 45545 part 2 annex C method 1_

Railway applications - Fire protection of railway vehicles - Part 2:
Requirements for fire behavior of materials and components
Testing methods for determination of toxic gases from railway products

Results were _not very encouraging_ in terms of both, repeatability (r) that of reproducibility (R) and careful analysis of all possible critical factors responsible for the phenomenon, and brought to the conclusion that was not the technique itself to be not suitable but the complex and diverse methods of sampling and spectral acquisition (filters, probes, cells for analysis, resolution, detector type, etc.) adopted by the various laboratories involved.

_It was therefore necessary to initiate an in-depth study of standardisation and validation of a more correct and detailed procedure: what has happened over the course of the project TRANSFEU._
On the occasion of the project, Transfeu LSFire has acquired a second and more modern FTIR spectrometer.

One of the highlights of this new apparatus and the possibility to use a detector much more powerful than classical DTGS (room temperature) used up to now, i.e. the MCT detector (cooling with liquid nitrogen).

This detector allows you to work at scanning speed much higher and to obtain a signal/noise ratio up to 10-20 times greater, with the obvious consequence of being able to obtain detection limits extremely more bass (at least 10 times) and considerable increase of the sensitivity analysis.
RESEARCH TRANSFEU - Small scale test for dynamic measurement of smoke and toxic gases produced in a cumulative system (ISO 5659-2 Smoke chamber)

The WP 2 of the research consortium Transfeu it is busy to study this new procedure by examining in detail all the critical parts relating to:

1. Fire model in examination (single smoke chamber)
2. Pickup Line of the effluents
3. Calibration of the FTIR analyser

MODEL D FIRE (ISO 5659-2 Single smoke chamber)

- Pick-up point of internal probe
- Flow of maximum draw (avoid problems of negative pressure chamber)
- Calibration of the furnace conical radiating
- Calibrating optical unit for measuring the density of smoke (Ds)
- Checking the tightness of the chamber

PICKUP LINE

- Particulate Filtering
- Possible condensation of gas hydrogen halides (thermoregulation at 180 °C)

ANALYSER CALIBRATION

- Cylinders certified concentration
**RESEARCH TRANSFEU - Small scale test for dynamic measurement of smoke and toxic gases produced in a cumulative system (ISO 5659-2 Smoke chamber)**

- **Pick-up point of internal probe**

The study of the ideal placement of the internal probe (probe) in a manner that does not influence the combustion process of the product concerned was executed by VTT.

**Smoke visibility after 344 and 600 seconds**

*The movement of the effluent was obtained by means of a simulation with FDS.*

After 7 min the measurement of the Ds is constant within a distance of 10cm from the line of measurement.

Up to 3min the concentration of gas can have differences of the order max of 10% within 10cm and after the 7min there are no deviations.

With withdrawals of up to 2l/min, the extent of the fumes and the concentration of the gases can have an offset max of 2-3%.
RESEARCH TRANSFEU - Small scale test for dynamic measurement of smoke and toxic gases produced in a cumulative system (ISO 5659-2 Smoke chamber)

- Flow of maximum draw (avoid problems of negative pressure chamber)

This type of testing has been performed by LSFire

The sampling flow rate used in 20min test was 2l/min. It was monitored the pressure in the chamber without any sample and trying 3 different types of products to all test conditions provided.

In the worst cases the difference in pressure loss from the initial condition in %

-110 Mm H2O / 10130 mm H2O = - 1.1 %

Negative Pressure NEGLIGIBLE
## RESEARCH TRANSFEU - Small scale test for dynamic measurement of smoke and toxic gases produced in a cumulative system (ISO 5659-2 Smoke chamber)

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Calibration of the furnace radiating conical</strong></td>
<td>The calibration was performed using the same radiometer (NEC) circulated in all the 8 laboratories involved in the project.</td>
</tr>
<tr>
<td><strong>Calibrating optical unit for measuring the density of smoke (Ds)</strong></td>
<td>The calibration was carried out using the same set of glass filters with OR certified (LSFire) circulated in all the laboratories involved in the project (8).</td>
</tr>
</tbody>
</table>
| **Checking the tightness of the chamber** | A detailed procedure to test the tightness of the room and has been introduced into the text of the new rule.  

\[0.76 \text{ kPa} \rightarrow 0.50 \text{ kPa} \] < 5 min |

### New procedure

- Calibration of the furnace radiating conical
- Calibrating optical unit for measuring the density of smoke (Ds)
- Checking the tightness of the chamber
**RESEARCH TRANSFEU - Small scale test for dynamic measurement of smoke and toxic gases produced in a cumulative system (ISO 5659-2 Smoke chamber)**

**PICKUP LINE**

- **Particulate Filtering**

  It has been adopted a double filtering system
  Filter 1: at the outlet of the chamber (cylindrical, 2micron, PTFE, 180 °C).
  With respect to planar filter the cylindrical filter ensures greater efficiency in time without incurring a phenomenon of reduction in the sampling flow rate / pressure due to an excessive deposition of particulate.

  2° Filter: at the entrance to the sample cell (planar 47mm dia., 1microns, 130 °C).
  Filter to further safeguard the cell to gas.
  The reduction in temperature is not a cold spot and has been introduced for reasons of dexterity (membrane change after each test).
RESEARCH TRANSFEU - Small scale test for dynamic measurement of smoke and toxic gases produced in a cumulative system (ISO 5659-2 Smoke chamber)

SAMPLING CELL

The sample cell has a volume of 0.375 l and must not be larger in order to allow, by using a sample flow of 1.5 l/min, the time of renewal-sampling (response time) no wider than 15s.

The optical path (IR path-length) and 3m (multireflection)

Interior mirrors in gold and stainless steel body

The operating temperature is 180 °C.

It is equipped with a transducer for monitoring and acquisition of the internal pressure throughout the test because it will serve to correct the phase concentration of quantitative analysis.

The calibration is performed to absolute pressure different (1025mbar) while the test is carried out around the 980mbar.

Since the concentration directly proportional to the pressure, you will have to take account of this correction.
RESEARCH TRANSFEU - Small scale test for dynamic measurement of smoke and toxic gases produced in a cumulative system (ISO 5659-2 Smoke chamber)

ANALYZER CALIBRATION

- Cylinders certified concentration

42 Cylinders certified concentration were circulated within the framework of the 3 reference laboratories (LSFire - Italy, Currenta - Germany and LNE - France) for the implementation of the calibration of the analyzer. The list includes 12 gas.

<table>
<thead>
<tr>
<th>Gas</th>
<th>Concentrations range (PPM/%)</th>
<th>Number of cans / concentrations (Min. number of points)</th>
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<tr>
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<td>From 20 ppm to 750 ppm</td>
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</tr>
<tr>
<td>Ammonia / N2</td>
<td>From 20 ppm to 300 ppm</td>
<td>3 (7)</td>
</tr>
</tbody>
</table>

The number of points (concentrations) is greater than for those gases which have a ratio concentration/absorbance peak area not linear (Eq. Lambert & Beer)
RESEARCH TRANSFEU - Small scale test for dynamic measurement of smoke and toxic gases produced in a cumulative system (ISO 5659-2 Smoke chamber)

General scheme of the new sampling system procedure TRANSFEU

Transfeu WP 2.1.3 Small-scale test method for fire effluents

Main filter contained in heated filter housing (180 °C)

Sampling line (180°C)

Cooler (5 °C)

NEW

Flowmeter (1.5 l/min)

Exhaust

2nd heated filter 130 °C

Gas cell (180 °C)

Cell pressure transducer

Pump MODIFIED

Collection of spectra

FTIR Spectrometer

Fire effluents

Smoke chamber

Probe MODIFIED
RESEARCH TRANSFEU - Small scale test for dynamic measurement of smoke and toxic gases produced in a cumulative system (ISO 5659-2 Smoke chamber)

In the phase of the development of new configuration there were numerous technical meetings held in the laboratory LSFire of Controguerra (TE) on the part of all partner laboratories of the project:

- LSFire (Italy)
- LNE (France)
- RATP (France)
- SNCF (France)
- Currenta (Germany)
- Exova Warrington (UK)
- BRE (UK)
- SP (Sweden)
**RESEARCH TRANSFEU - Small scale test for dynamic measurement of smoke and toxic gases produced in a cumulative system (ISO 5659-2 Smoke chamber)**

<table>
<thead>
<tr>
<th>Documents TRANSFEU WP2 products</th>
<th>Partners</th>
</tr>
</thead>
<tbody>
<tr>
<td>N01 Transfeu WP2 Subtask 2.1.2 - Smoke chamber modeling</td>
<td>VTT - Finland</td>
</tr>
<tr>
<td>N02 Transfeu WP2 Subtask 2.1.2 - Smoke measurement date</td>
<td>SP - Sweden</td>
</tr>
<tr>
<td>N03 Transfeu WP2 Subtask 2.1.2 - Filtering</td>
<td>LSFire - Italy</td>
</tr>
<tr>
<td>N04 Transfeu WP2 Subtask 2.1.2 - Influence of air extraction from the test chamber of ISO 5659-2 on the related pressure</td>
<td>LSFire - Italy</td>
</tr>
<tr>
<td>N05 Transfeu WP2 subtask 2.1.2 step 2 Report - Influence of 2nd filter on FTIR sampling line to prevent HCl and other halogen gases trapping</td>
<td>LSFire - Italy</td>
</tr>
<tr>
<td>N06 Transfeu WP2 Subtask 2.1.2 - Cone radiator calibration procedures</td>
<td>LSFire - Italy / LNE - France / Currenta - Germany</td>
</tr>
<tr>
<td>N07 Transfeu WP2 subtask 2.1.2 step 5 - Chamber leakage test procedures</td>
<td>LSFire - Italy / LNE - France / Currenta - Germany</td>
</tr>
<tr>
<td>N08 Transfeu WP2 subtask 2.1.2 step 5 - FTIR analyzer calibration using standard gas cans procedures</td>
<td>LSFire - Italy / LNE - France / Currenta - Germany</td>
</tr>
<tr>
<td>N09 Transfeu WP2 subtask 2.1.2 step 5 - Smoke opacity calibration procedures by LSF glass filters</td>
<td>LSFire - Italy / LNE - France / Currenta - Germany</td>
</tr>
<tr>
<td>N10 Transfeu WP2 - Questionnaire on available parts of testing apparatus</td>
<td>(LSFire)</td>
</tr>
<tr>
<td>N11 Transfeu WP2 subtask 2.1.2 step 5 - FTIR Continuous analysis validation by standard liquids combustion</td>
<td>LSFire - Italy / LNE - France / Currenta - Germany</td>
</tr>
</tbody>
</table>
| **N12 Transfeu WP 2.1.3 Small-scale test method for fire effluents**  
Small-scale test for dynamic measurement of smoke and toxic gases produced in a cumulative system  
(ISO 5659-2 Smoke chamber) | **(WP2)** |
RESEARCH TRANSFEU - Small scale test for dynamic measurement of smoke and toxic gases produced in a cumulative system (ISO 5659-2 Smoke chamber)

The verification of the new procedure was carried out initially by 3 reference laboratories

LSFire - LNE - CURRENTA

By means of round robin tests (Round Robin) that for the first time have made use of combustible liquids as reference products in order to check the alignment of the results.

- 4-4 Isocyanate
- Cloroparaffina
- Tetramethyl sulfone
- Mixture (isocyanate + Cloroparaffina + Tetramethyl sulfone)

Detectable Gas: CO, CO2, HCN, NO, HCl, SO2

The new procedure was included in the protocol of verification in the context of all the laboratories TRANSFEU

The tests were performed at 50 kW/m² in the presence of pilot flame.
5 Repetitions

The bottles of liquids were prepared and distributed by LSFire carrying out the sampling from the same container so as to ensure the homogeneity of the reference sample.
RESEARCH TRANSFEU - Small scale test for dynamic measurement of smoke and toxic gases produced in a cumulative system (ISO 5659-2 Smoke chamber)

Liquid mixture

### Smoke Density ave

#### Dsmax

<table>
<thead>
<tr>
<th></th>
<th>Lab 1</th>
<th>Lab 2</th>
<th>Lab 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laboratory mean</td>
<td>600.6</td>
<td>608.4</td>
<td>608.4</td>
</tr>
<tr>
<td>Laboratory standard deviation</td>
<td>10.9</td>
<td>3.9</td>
<td>2.9</td>
</tr>
<tr>
<td>Lab mean / Lab std</td>
<td>1.8 %</td>
<td>0.6 %</td>
<td>0.5 %</td>
</tr>
<tr>
<td>Grand mean</td>
<td>605.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lab std / Grand mean</td>
<td>1.8 %</td>
<td>0.7 %</td>
<td>0.5 %</td>
</tr>
</tbody>
</table>

#### Tdsmax

<table>
<thead>
<tr>
<th></th>
<th>Lab 1</th>
<th>Lab 2</th>
<th>Lab 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laboratory mean</td>
<td>200</td>
<td>168</td>
<td>167</td>
</tr>
<tr>
<td>Laboratory standard deviation</td>
<td>13</td>
<td>6</td>
<td>2.9</td>
</tr>
<tr>
<td>Lab mean / Lab std</td>
<td>6.6 %</td>
<td>3.4 %</td>
<td>1.7 %</td>
</tr>
<tr>
<td>Grand mean</td>
<td>178</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lab std / Grand mean</td>
<td>7.4 %</td>
<td>3.2 %</td>
<td>1.6 %</td>
</tr>
</tbody>
</table>
RESEARCH TRANSFEU - Small scale test for dynamic measurement of smoke and toxic gases produced in a cumulative system (ISO 5659-2 Smoke chamber)

Liquid mixture

- CO ave concentration mg/m³
- CO₂ ave Concentration mg/m³
- HCN mass concentration mg/m³
- NO ave Concentration mg/m³
RESEARCH TRANSFEU - Small scale test for dynamic measurement of smoke and toxic gases produced in a cumulative system (ISO 5659-2 Smoke chamber)

Liquid mixture

**HCl ave concentration mg/m³**

**SO₂ ave concentration mg/m³**
RESEARCH TRANSFEU - Small scale test for dynamic measurement of smoke and toxic gases produced in a cumulative system (ISO 5659-2 Smoke chamber)

Liquid mixture

<table>
<thead>
<tr>
<th>CITmax</th>
<th>Lab 1</th>
<th>Lab 2</th>
<th>Lab 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laboratory mean</td>
<td>2,278</td>
<td>2,260</td>
<td>1,908</td>
</tr>
<tr>
<td>Laboratory standard deviation</td>
<td>0,029</td>
<td>0,050</td>
<td>0,059</td>
</tr>
<tr>
<td>Lab mean / Lab std</td>
<td>1.3 %</td>
<td>2.2 %</td>
<td>3.1 %</td>
</tr>
<tr>
<td>Grand mean</td>
<td>2,179</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lab std / Grand mean</td>
<td>1.3 %</td>
<td>2.3 %</td>
<td>2.7 %</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CIT(5)</th>
<th>Lab 1</th>
<th>Lab 2</th>
<th>Lab 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laboratory mean</td>
<td>1,948</td>
<td>1,856</td>
<td>1,723</td>
</tr>
<tr>
<td>Laboratory standard deviation</td>
<td>0,095</td>
<td>0,015</td>
<td>0,091</td>
</tr>
<tr>
<td>Lab mean / Lab std</td>
<td>4.9 %</td>
<td>0.8 %</td>
<td>5.3 %</td>
</tr>
<tr>
<td>Grand mean</td>
<td>1,857</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lab std / Grand mean</td>
<td>5.1 %</td>
<td>0.8 %</td>
<td>4.9 %</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CIT(10)</th>
<th>Lab 1</th>
<th>Lab 2</th>
<th>Lab 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laboratory mean</td>
<td>1,580</td>
<td>1,730</td>
<td>1,591</td>
</tr>
<tr>
<td>Laboratory standard deviation</td>
<td>0,051</td>
<td>0,056</td>
<td>0,114</td>
</tr>
<tr>
<td>Lab mean / Lab std</td>
<td>3.3 %</td>
<td>3.2 %</td>
<td>7.2 %</td>
</tr>
<tr>
<td>Grand mean</td>
<td>1,639</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lab std / Grand mean</td>
<td>3.1 %</td>
<td>3.4 %</td>
<td>6.9 %</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CIT(20)</th>
<th>Lab 1</th>
<th>Lab 2</th>
<th>Lab 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laboratory mean</td>
<td>1,298</td>
<td>1,561</td>
<td>1,424</td>
</tr>
<tr>
<td>Laboratory standard deviation</td>
<td>0,017</td>
<td>0,029</td>
<td>0,163</td>
</tr>
<tr>
<td>Lab mean / Lab std</td>
<td>1.3 %</td>
<td>1.8 %</td>
<td>11.4 %</td>
</tr>
<tr>
<td>Grand mean</td>
<td>1,428</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lab std / Grand mean</td>
<td>1.2 %</td>
<td>2.0 %</td>
<td>11.4 %</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tcit=0.3</th>
<th>Lab 1</th>
<th>Lab 2</th>
<th>Lab 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laboratory mean</td>
<td>55</td>
<td>85</td>
<td>68</td>
</tr>
<tr>
<td>Laboratory standard deviation</td>
<td>9</td>
<td>9</td>
<td>10.6</td>
</tr>
<tr>
<td>Lab mean / Lab std</td>
<td>15.7 %</td>
<td>10.2 %</td>
<td>15.7 %</td>
</tr>
<tr>
<td>Grand mean</td>
<td>69</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lab std / Grand mean</td>
<td>12.5 %</td>
<td>12.5 %</td>
<td>15.3 %</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tcit=1.0</th>
<th>Lab 1</th>
<th>Lab 2</th>
<th>Lab 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laboratory mean</td>
<td>85</td>
<td>105</td>
<td>105</td>
</tr>
<tr>
<td>Laboratory standard deviation</td>
<td>9</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>Lab mean / Lab std</td>
<td>10.2 %</td>
<td>0.0 %</td>
<td>0.0 %</td>
</tr>
<tr>
<td>Grand mean</td>
<td>98</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lab std / Grand mean</td>
<td>8.9 %</td>
<td>0.0 %</td>
<td>0.0 %</td>
</tr>
</tbody>
</table>
RESEARCH TRANSFEU - Small scale test for dynamic measurement of smoke and toxic gases produced in a cumulative system (ISO 5659-2 Smoke chamber)

It was then proceeded to perform a round robin (RR) on 3 reference materials included in the list of 60 products to be assessed in the research program.

1. Synthetic rubber glued on plywood (IN 16-6) at 25 kW/m² with pilot flame
2. GFK laminated (IN 1-5) to 50 kW/m² no pilot flame
3. Upholstery for passenger seats and head rest (mat F1A-1-2) on 25 kW/m² with pilot flame

Is currently being further round robin which includes all 8 laboratories involved in the project and who will take part in the test both on combustible liquids and that on 3 reference materials.
RESEARCH TRANSFEU - Small scale test for dynamic measurement of smoke and toxic gases produced in a cumulative system (ISO 5659-2 Smoke chamber)

During this first experimental stage a speech was reserved to the field of electrical applications and more precisely to the cables.

A series of types of cables (10 type halogen-free) were tested simultaneously

- Small scale (ISO 5659-2 + FTIR Transfeu procedure)
- Large scale (IEC 60336-2 -3-10)

The testing was intended to establish the existence of a possible correlation between the two models as regards the quality and quantity of toxic gases emitted from the effluents.

With regard to the small scale was defined as a condition of heat attack that sampling so as to standardize as much as possible the two different models of a fire in regard to the relationship between the level of heat emission to amount of material.

<table>
<thead>
<tr>
<th>Thermal Attack small scale: 50 kW/m² without pilot flame</th>
</tr>
</thead>
<tbody>
<tr>
<td>![Image of small scale thermal attack setup]</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Thermal Attack large scale: flame burner incident with attack measured heat corresponding about 50 kW/m².</th>
</tr>
</thead>
<tbody>
<tr>
<td>![Image of large scale thermal attack setup]</td>
</tr>
</tbody>
</table>

LSFire Testing Institute srl
RESEARCH TRANSFEU - Small scale test for dynamic measurement of smoke and toxic gases produced in a cumulative system (ISO 5659-2 Smoke chamber)

The results clearly aroused a great debate species for the systematic difference in the phase of qualitative analysis of fire effluents.

- In the large scale cables "halogen free" did not produce, in addition to CO & CO2, chemical species of particular relevance from a toxicological point of view.
- In the small scale, for the same type of cable, was obtained systematically significant production of formaldehyde.

The need to better understand the phenomenon, have been performed additional tests on a small scale in an attempt to succeed in improving this first result.

1. We have changed the amount of cable (reduced) so as to increase the ratio of the necessary oxygen and the combustible part in order to increase the efficiency of combustion and thus prevent the onset of intermediate products such as formaldehyde
2. We proceeded to change the condition of heat attack with the introduction of the pilot flame (50 kw/m2 in the presence of pilot flame)

In the first case, there has been no progress since the formaldehyde continued to form.
In the second case, the formaldehyde is no longer detected.
The production of formaldehyde and exclusively derived from the condition of smouldering on the model of fire adopted.
RESEARCH TRANSFEU - Small scale test for dynamic measurement of smoke and toxic gases produced in a cumulative system (ISO 5659-2 Smoke chamber)

ISO 5659.2 Single smoke chamber + FTIR. Cable 937 - CO concentration comparison

ISO 5659.2 Single smoke chamber + FTIR. Cable 937 - CO$_2$ NOEC comparison

ISO 5659.2 Single smoke chamber + FTIR. Cable 937 - CH$_2$OR concentration comparison

ISO 5659.2 Single smoke chamber + FTIR. Cable 937 - CIT comparison
RESEARCH TRANSFEU - Small scale test for dynamic measurement of smoke and toxic gases produced in a cumulative system (ISO 5659-2 Smoke chamber)

Currently in EN 45545-2 are provided 2 attack conditions thermal relating to test small-scale:

- 25 KW/m² with a pilot flame
- 50 KW/m² without pilot flame

The possibility of being able to adapt the test requirements of all other types of existing applications on the basis of the conclusions obtained in the study on the cables and adapting them to the real and specific scenarios of fire is currently under discussion in the "Scientific Panel" of the project Transfeu.

(Consider then also the 50 kW/m² with the presence of pilot flame)
**TRANSFEU WP3**
Development of conventional pragmatic classification system for the toxicity of fire effluents released from products on trains

**IN THE EVENT OF A FIRE ON A TRAIN**

\[ RSET = \text{time required to reach the first place of safety} \]

\[ ASET = \text{time available to achieve the first place of safety} \]

There are the 2 parameters that the consortium Transfeu has identified as time of reaching the CIT (Conventional Index of Toxicity) = 1

This should be determined for each category of train.

The new procedure for the determination of toxic gases present in the effluents of fire provides for the dynamic analysis of their development and thus the possibility of calculating the value of the CIT in time and also the consequence of the ASET/RSET

When the calculation of the RSET will be associated with the categories of level of hazards of trains (HL) the classification system will be completed and valid for all types of products/applications.
TRANSFEU WP3
Development of conventional pragmatic classification system for the toxicity of fire effluents released from products on trains

In general, the value of the CIT is defined (EN 45545-2 annexes C) from 2 essential modules:

\[ \text{CIT} = [\text{Precursor Term}] \times [\text{Summation Term}] \]

The [Precursor Term] identifies the scenario of the fire in its main parameters such as:

- Volume
- Extension of the burned area

In the current version of the pr EN 45545-2

- \( V = 150 \text{m}^3 \)
- The area burned estimated = 0.1 m\(^2\).

The [Summation term] is closely connected to the measurement obtained in the experimental part:

\[ \text{Summation Term} = \sum_{i=1}^{s} \frac{c_i \text{ (mg.m}^{-3})}{C_i \text{ (mg.m}^{-3})} \]

where

- \( c_i \) concentration of the \( i^{th} \) gas in the EN ISO 5659-2 smoke chamber at 4 min and 8 min
- \( C_i \) reference concentration of the \( i^{th} \) gas
**TRANSFEU WP3**

Development of conventional pragmatic classification system for the toxicity of fire effluents released from products on trains

The precursor term is, in this case, based on 1 individual model corresponding to the single carriage at 1 level with instantaneous and homogeneous development of gas for an area burned of 0.1 m² with 150 m³ volume (corresponding to some of the carriages to wide use in Europe).

\[
Precursor = \frac{0.51 \text{ (m}^3\text{)} \times 0.1 \text{ (m}^2\text{)}}{150 \text{ (m}^3\text{)} \times 0.004225 \text{ (m}^2\text{)}}
\]

\[
\text{Summation Term} = \sum_{i=1}^{8} \frac{c_i \text{ (mg.m}^{-3}\text{)}}{C_i \text{ (mg.m}^{-3}\text{)}}
\]

\[
\text{CIT}_G = \text{[Precursor Term]} \times \text{[Summation Term]}
\]

<table>
<thead>
<tr>
<th>Gas component</th>
<th>Reference concentration mg/m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO₂</td>
<td>72 000</td>
</tr>
<tr>
<td>CO</td>
<td>1 380</td>
</tr>
<tr>
<td>HBr</td>
<td>99</td>
</tr>
<tr>
<td>HCl</td>
<td>75</td>
</tr>
<tr>
<td>HCN</td>
<td>66</td>
</tr>
<tr>
<td>HF</td>
<td>25</td>
</tr>
<tr>
<td>NO₂</td>
<td>38</td>
</tr>
<tr>
<td>SO₂</td>
<td>282</td>
</tr>
</tbody>
</table>

Table 1 — Reference concentrations of the gas components

**NOTE**: These reference values are based on IDLH (Immediately Dangerous to Life and Health), recognized as a limit for personal exposure to the gas component by NIOSH (National Institute for Occupational Safety and Health) (1997 version).
**TRANSFEU WP3**  
Development of conventional pragmatic classification system for the toxicity of fire effluents released from products on trains

In WP3 project Transfeu were identified 3 different product families based on their applications:

<table>
<thead>
<tr>
<th>Type</th>
<th>Products</th>
</tr>
</thead>
</table>
| Type A | Wall coverings and ceiling  
Floor coatings  
Interior Lights  
Intercommunicating Membranes internal  
External bodywork |
| Type B | Hangings in the area of personnel  
Seats and head restraints in the passenger area  
Sitting of the body of the passenger seat  
Back of the body of the passenger seat  
Armrests of the passenger seat |
| Type C | Products with limited surface (stickers, seals)  
Parts not listed (Not listed items)  
Electrotechnical Products  
Cables |
**TRANSFEU WP3**

Development of conventional pragmatic classification system for the toxicity of fire effluents released from products on trains

<table>
<thead>
<tr>
<th>Type A</th>
</tr>
</thead>
<tbody>
<tr>
<td>V coach : 150m³ (single deck) and 190m³ (double deck)</td>
</tr>
<tr>
<td>Q air : 0 m³/s (air conditioning turned off) and 0.42 m³/s (trains urban and suburban)</td>
</tr>
</tbody>
</table>

\[
CIT_{G,t+\Delta t} = CIT_{G,t} \times \left( \frac{V_{coach} - Q_{air} \Delta t}{V_{coach}} \right) + \frac{0.51 m^3 \times 0.1 m^2}{V_{coach} \times 0.004225 m^2} \sum_{i=1}^{8} \frac{c_i(t) \times \Delta t}{C_i}
\]

<table>
<thead>
<tr>
<th>Type B</th>
</tr>
</thead>
<tbody>
<tr>
<td>V coach : 150m³ (single deck) and 190m³ (double deck)</td>
</tr>
<tr>
<td>Q air : 0 m³/s (air conditioning turned off) and 0.42 m³/s (trains urban and suburban)</td>
</tr>
</tbody>
</table>

Note: for each of the products evaluated the calculation will take account of the exposed area (0.1 m² and/or 0.7 m²) and the source of the trigger used in relation to the type of fire of reference:

Type 1 (EN 50553) : that does not require the "running capability"

Type 2 (EN 50553) : that requires the "running capability"
**TRANSFEU WP3**

Development of conventional pragmatic classification system for the toxicity of fire effluents

Released from products on trains

<table>
<thead>
<tr>
<th>Type C</th>
<th>Products with limited surface (stickers, seals)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Parts not listed (Not listed items)</td>
</tr>
<tr>
<td></td>
<td>Electrotechnical Products</td>
</tr>
</tbody>
</table>

As parts not listed

\[
CIT_{G,t+\Delta t} = CIT_{G,t} \times \left( \frac{V_{coach} - Q_{air} \cdot \Delta t}{V_{coach}} \right) + \frac{0.51m^3 \times 0.1m^2}{V_{coach} \times 0.001225m^2} \sum_{i=1}^{8} \frac{\dot{c}_i(t)}{C_i} \times \Delta t
\]

\[
CIT_{NLP,t+\Delta t} = CIT_{NLP,t} \times \left( \frac{V_{coach} - Q_{air} \cdot \Delta t}{V_{coach}} \right) + \frac{0.51m^3 \times w_a}{V_{coach} \times w_s} \sum_{i=1}^{8} \frac{\dot{c}_i(t)}{C_i} \times \Delta t
\]

where:

- \( w_a \) is the estimated mass of the product present in 0.1m² exposed area in the coach (g)
- \( w_s \) is the mass of the specimen tested in the ISO 5659-2 smoke chamber (g)
**TRANSFEU WP3**
Development of conventional pragmatic classification system for the toxicity of fire effluents
Released from products on trains

Type C

- Cables
  - a) With test data of small scale (ISO 5659-2 + FTIR)

\[
CIT_{C,T,A} = CIT_{C,T} \times \left( \frac{V_{coach} - Q_{air} \Delta t}{V_{coach}} \right) + 0.5 \frac{m_a}{m_s} \sum_{i=1}^{8} \frac{c_i(t)}{C_i} \times \Delta t
\]

where:
- \( m_a \) is the estimated mass exposed on representative area in a real coach\(^*\) (g)
- \( m_s \) is the combustible part of the specimen mass (=total mass - mass of conductors) tested in the ISO 5659-2 smoke chamber\(^**\) (g)

\(^*\) Defined based on the specimen mass in the smoke chamber test according to the following options:
- \( m_a \) = mass loss of the specimen in the smoke chamber test
- \( m_a = m_s \)
- \( m_a \) = representative value to be determined in the project.

\(^**\) Test specimen consisting of one layer of cables installed adjacent to each other

- b) With test data of large scale (EN 50399)

Instead the sampling point will be in the flow of exhaust gas. The mass production rate of one of the toxic gases can be calculated as

\[ m_i(t) = c_i(t) \times \dot{V}(t) \]

where
- \( \dot{V}(t) \) is the flow of exhaust gases at the sampling point in the prEN 50399 test apparatus (m\(^3\)/s)
- \( c_i(t) \) is the concentration of gas i (mg/m\(^3\))

The equation for the one zone model considered in WP3.3 will, for this case, be as follows:

\[
CIT_{C,T,A} = CIT_{C,T} \times \left( \frac{V_{coach} - Q_{air} \Delta t}{V_{coach}} \right) + \frac{\dot{V}(t)}{V_{coach}} \sum_{i=1}^{8} \frac{c_i(t)}{C_i} \times \Delta t
\]
TRANSFEU WP3
Development of conventional pragmatic classification system for the toxicity of fire effluents released from products on trains

As an alternative to the use of the index is CITG is currently considering the possibility to use also two different indexes which are distinguished by the effects of toxicological, that cause on the human physical.

These indices are designed in the context of the ISO TC 92 SC3 "Fire threat to people and environment" documents AND described in the reference document ISO TS 13571 "Life-threatening components on fire - Guidelines for the estimation of time available for escape using fire date"

• FED (Fractional effective dose) is calculated by taking into account dose limits for exposure to poison gas (CO and HCN) capable of producing "incapacitation" on a subject of average susceptibility (cumulative effect)

• FEC (Fractional effective concentration) is calculated by taking into account limit concentrations of exposure to irritant gases (HCl, HBr, SO2, NOx, acrolein and Formaldehyde, ...) capable of producing "irritation" on a subject of average susceptibility (instantaneous effect)
TRANSFEU WP3
Development of conventional pragmatic classification system for the toxicity of fire effluents released from products on trains

\[\text{FEC} = \frac{[\text{HCl}]}{F_{\text{HCl}}} + \frac{[\text{HBr}]}{F_{\text{HBr}}} + \frac{[\text{HF}]}{F_{\text{HF}}} + \frac{[\text{SO}_2]}{F_{\text{SO}_2}} + \frac{[\text{NO}_2]}{F_{\text{NO}_2}} + \frac{\text{[Acrolein]}}{F_{\text{Acrolein}}} + \frac{\text{[Formaldehyde]}}{F_{\text{Formaldehyde}}} + \sum_i \frac{\text{[irritant]}}{F_{C_i}}\]

\[\text{FED} = \sum_{i=1}^{i=2} \frac{[\text{CO}]}{35000 \text{ ppm} \times \text{min}} \Delta t + \sum_{t=1}^{t=2} \exp\left(\frac{[\text{HCN}]}{43}\right) \frac{220 \text{ min}}{\Delta t}\]

\[= \exp\left(\frac{[\%\text{CO}_2]}{5}\right)\]
**TRANSFEU WP3**

**Reasons taking account this method of calculation instead of the CIT?**

- *The effect of incapacitation is much more important than the "lethality" in terms of prevention and safety*

- *You could use the time of reaching the limit value of 0.3 for feds and FEC (and not 1) that takes into account the different level of susceptibility by human (in relation to many components: sex, size, age, presence of a disease, different ability ...etc.)*

- *In the future experts in toxicology can update the information about the types of chemical species to be considered more important and expanding the list by entering their critical concentrations.*