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LARGE SCALE TESTING IN THE INERIS FIRE GALLERY :

A major tool for both assessment and scaling up of industrial fires involving chemicals

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1 The INERIS [1] Fire test facility

The INERIS Fire Gallery is one of the large scale test-rigs being at disposal of INERIS' researchers (and their financial sponsors) to carry out experimental studies in the field of industrial risks and Environmental concerns.

Devoted especially to the fire problem, the Fire Test Gallery (fig. 1) comprises a 50 m long horizontal wind tunnel of about 10 m^2 cross section, ending in a 11 m high 'tower'. This vertical segment is divided into two operating zones : the upward rectangular cross section (6 m2) element, recently refitted with extended measuring facilities, is housing main of the gas sampling equipments connected to the 'mixing point'. The downward (circular cross section) is equipped with a water curtain device acting as a first stage washing unit and air-cooler.

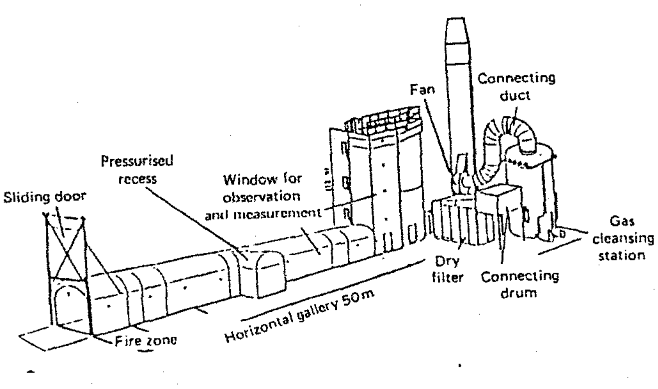

Fig. 1 : The Fire Test Gallery

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[1] *INERIS : Institut National de l'Environnement Industriel et des Risques,, Parc technologique ALATA - F60550 VERNEUIL-en-HALATTE, France*

Beyond the tower the gas stream is crossing a gas cleaning unit (In a series a dust dry filtrer connected to an adjustable water scrubber) which removes gaseous and solid polluants or noxious compounds. This equipment can remove tens of kilogrammes of non desirable compounds such as HCN or HCl potentially emitted in a single fire trial and thus allows experimental scenarios involving products with high toxic potential (as regards their decomposition products).

An adjustable exhaust fan placed between the gas cleaning unit and the stack allows controlled ventilation of the fire zone at flowrates comparable to those observed in industrial premises

Of course, both the horizontal and upward vertical sections walls comprises refractory linings and insulation material layers authorising the users to carry out experiments with hight heat release rates and temperatures (peak thermal power up to 10 MW, temperatures up to 1200 °C)

2 The full scale fire test main features

Among the advantages claimed of the full-scale approach, let us point out the following :

- it is a realistic fire scenario as regards the industrial fire disaster event :

* quantities of products submitted to a fire scenario may typically range between 100 kg and 1000 kg for bulk material or commercially packaged in bags,or liquid products stored in plastic drums

* 1 : 1 scale may be used for fire scenarios related to manufactured industrial apparatus or building materials (electric transformers, other electric devices, rolling stock, insulation panels...),

* significant information are reasonably expected at each stage of a classical fire development [ease of ignition, fire growth mode, eventual self extinguishment tendency, datas related to the flash-over and post-flash-over periods,... (see fig. 2).

* Mass effects generally masked at the laboratory scale (DIN furnace, Tewarson apparatus, cone calorimeter...) may very often be revealed through this large-scale approach

* Extensive qualitative and quantitative information are collected and recorded in real time and may be re-used further for modelling or extrapolation studies purposes thanks to the availability of a wide set of measuring or monitoring instruments i.e. :

- continuous or quasi-continuous control of gaseous effluents performed by gas analysors for numerous species such as CO, CO_2, O_2, SO_2, total HC, NO, NO_2, NH_3, HCl, HCN,N_2O, $COCl_2$, some amines...),

- thermal impact assessed by thermocouples and heat flux-meters or eventually by means of infra-red thermography,
- video camera recorders, allowing full witnessing the fire evolution which may be performed in a play-back mode ,
- additional analytical means (use of impingers or suit collectors for instance) to quantify other chemical impact of the fire (vapors or aerosols, suits, solid residues...).

* Heat Release Rates measurements based on oxygen consumption [2] may now be applied with a good accuracy in the same way it is systematically operated on the cone calorimeters or Tewarson apparatus. Correlations studies are thus expected to get the best chances of succes, since this parameter is now believed to be of prime importance in the laws governing the fire conditions

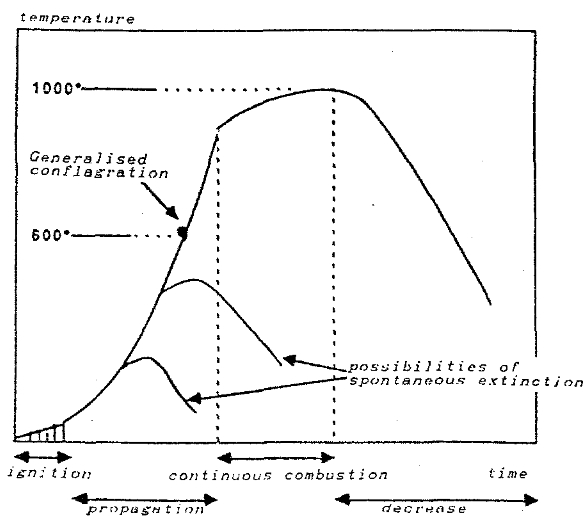

Fig. 2 : typical curve of fire development

* moreover, as concerns the chemical point of view, where the scientific community is still largely lacking of crucial information, there is no actual equivalent for the assessment of the plume fire source term generally required in the framework of the safety studies demanded now by national as well as international regulations (Seveso Directive, EPA new regulation on the storage of chemicals)

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[2] *M. JANSSENS, " Measuring Rate of Heat Release by Oxygen Consumption", Fire Technology, August 1991*

We do not deny that the method suffers from some drawbacks : such experimentations are known to be rather costly and besides they only reveal quantitative information on aimed physical or chemical parameters. To cope with the fact, one must carefully prepare the testing programme, and eventually use complementory tools prior to the full-scale experimentation in order to enlarge the expected benefit.

3 Qualification and experience achieved

Since the commissioning of the unit, over 10 years of fruitful experience has been gathered, leading to several fully controlled large-scale procedures suitable for various purposes :

- home-standard procedure for palletised solid products (powders, granules...) with various ignition systems (gas burners, radiant panels, solvant pool-fire)

- pool-fire test procedures (with management of a constant liquid layer in trays) for more or less flammable liquids (size ranges easily between 0,25 m2 and 2 m2 in fully controlled ventilation conditions)

- use of a calibrated wood-crib as ignition procedure (mining equipment or tunnel linings)

The following tests results could be made partially available to our future 'MISTRAL' partners (especially for the modelling validation steps of FLAMME 2 or 3) as a manner to join scientific efforts on related topics even if at the moment no European partnership with CEA has yet been contracted :

- thermal and chemical datas on various pesticides (Diuron, Dimethoate, other commercially important agro-chemicals of various types (organo-phosphorous, carbamates, ...) and fertilisers (NPK type)[3]

- equivalent information on basic chemicals of PUR manufactoring (di-isocyanates)[4]

- detailed quantitative information (mostly thermal) on the impact of a calibrated wood crib (300 kg and 450 kg), obtained in the framefork of European Research contracts[5]

- sets of chemical datas on nitrogen containing gaseous compounds issuing from chemicals involved in industrial fires.

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[3] *C. CWIKLINSKI, " Incendie dans les entrepôts de produits phytosanitaires. Les apports de l'essai en grand", R.G.S journal, n° 110, febr. 1992 (in French).*

[4] *G. MARLAIR, H. SAND, "Assessment of the fire hazard of a burning pool of Toluene di-isocyanate (TDI)", Journal of Cellular Polymers, vol 11 n° 1, 1992*

[5] *ECSC Research contracts n° 7262 31 223 03 & 7262 01 31 225*

Besides, qualification work on both the Fire test Gallery and the applied test methodologies have been fairly largely undertaken at both national and international levels :

- The INERIS pool-fire testing procedure has been chosen by the I.I.I[6]. (a trade society grouping main isocyanates world producers) for the assessment of the fire behaviour of two of the main di-isocyanates available on the market The procedure was also successfully applied in the framework of the European EUREKA 499 "Firetun" project related to fire safety into traffic tunnels,

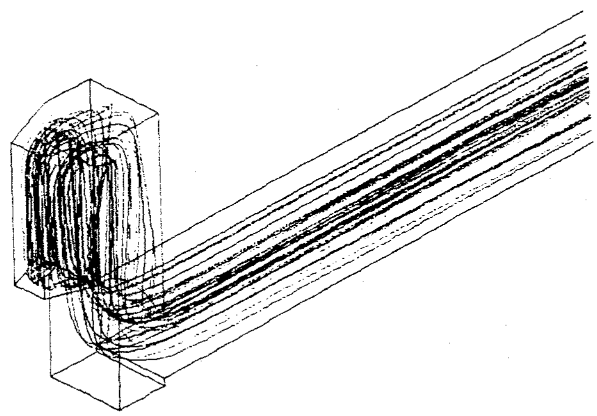

fig. 3 : 3 D modelling of flowlines inside the INERIS Gallery at jonction of horizontal and vertical sections (induced by a wood crib) computed with the Phœnics code.

- Several studies were carried out with an important experimental phase taking place in the fire test gallery in the recent past as experimental supports of ECSC research projects,

- besides, as often as needed, INERIS applies to home-made softwares under constant development named *Bigexp* or *Jehinc* (which could be at last a useful link with MISTRAL modelling tasks) or conventional 3D fluid dynamic modelling packages (see fig. 3).

4 Draft view of some recent INERIS results issuing full scale experimentations

Work has been performed with both following purposes :

- focused on accurate targets in the framework of commercial services
- more general aims leading to better scientific knowledge of behaviour of materials submitted to fire conditions

[6] *International Isocyanate Institute Inc.*

41 fertilisers

* Following the Nantes NPK fertilisers warehouse fire which in France induced the Authorities' decision to evacuate 30,000 people out of the town, duplicating the accident at a realistic scale inside the Fire test gallery was decided.
We reproduced a bulk storage capacity inside the gallery ; the ignition procedure was arranged in relation with the presumed cause of the accident ("hot point" induced by electrical failure)

Fig. 4 gives an overview of the chemical characterisation of the plume fire obtained through the experimentation (1000 kg submitted to thermal decomposition leaving 512 kg of solid residue).

identified compound	mass (kg)	volume (m3 at 0°C)
CO	7,2	5,7
CO_2	7,35	3,7
HCl	8,0	4,9
Cl_2	9,0	2,8
NH_4Cl	87,7	36,7
N_2O	39	19,9
NO_2	2,15	1,0
HNO_3	36	12,8
N_2	57,6/76,5	46,1/61,2
H_2O	238/215	291/268
total	488	420

<u>Fig. 4 : global composition of fumes issuing a NPK ternary fertiliser "fire"</u>

42 Pesticides

* The fire behaviour of dimethoate, $C_5H_{12}NO_3PS_2$ (concentrated solution), belonging to the organo-phosphorous pesticides family was analysed in various fire scenarios (impact of the solvant alone, use of full-commercial packaged product...).

Fig. 5 presents main chemical figures obtained from a fire scenario involving 120 l of dimethoate (60 bottles of 1 liter and 60 liters burning initially as a pool), disposed on a pallet.

identified compound	mass (kg)	volume (m3 at 0°C)
CO_2	220	112
CO	11,7	9,3
HCN	0,4	0,3
NOx (as NO_2)	0,1	0,05
Σ (isocyanates)	<0,01	-
SO_2	8,4	2,9
Σ (mercaptans)	4,2	12,96
Σ (aldhehydes)	$\leq$ 0,02	-
soots	5	-
condensables	40, water, dimethoate (traces)...	-
phosphorated products	not determined	-

Fig. 5 : chemical characterisation of the fire plume from the dimethoate fire (120 l at 400 g/l)

43 Burning pools of TDI[7]

On behalf of the International Isocyanate Institute, we carried out a series of experiments on TDI pools with the aim of evaluating the fire hazard. Fig. 6 presents some of the results.

test ID #	1	2
Quantity of TDI[8] (kg)	25	75
pool area (m^2)	0,25	1,00
air flow rate (m^3)	≈ 10000	≈ 10000
burning rate ($kgm^{-2}min^{-1}$)	1,38	2,0
effective HRR (kW)	122	560
gas concentrations :		
CO_2 (%)	0,25	1,05
CO (%)	70 - 80	350
NOx (ppm)	10 - 12	10 - 12
HCN (ppm)	(2)	40
TDI (mg/m3)	10 -15	8 - 10
gas yields (mg/g) :		
- CO_2	2090	1620
- CO	41,1	36
- HCN	(1,2)	4
- NOx (as NO_2)	10,4 - 12,5	1,7 - 2
- TDI	5 - 7,5	0,7 - 0,9
molar ratio CO_2/CO	32	29

Fig. 6 : characterisation of burning pools of TDI

[7] *G. MARLAIR, P.H. PRAGER, H. SAND ; "The behaviour of commercially important di-isocyanates in fire conditions" - Part I : toluene di-isocyanate (TDI) ; submitted to Fire and Materials*

[8] *commercial mixture 80/20 of the two isomers*