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Note 72: An Introduction to Emission Cells and Comparison to Small Chambers for Materials Emissions Testing

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Introduction to emission cells and their application

Emission cells are small portable devices for the determination of volatile organic compounds (VOCs) emitted from indoor materials/products. They differ from small chambers in as much as they have one open wall or 'face' which is placed onto the planar surface of the material under test such that the material surface effectively becomes part of the emission cell. The air inlet of the emission cell is designed such that the flow of air is directed over the entire surface of the test specimen before exiting the cell through a central exhaust point.

The emission cell concept was pioneered in 1990-1991 by a team of Scandinavian scientists. Their objective was to address the need for a small, versatile and easy-to-use tool for both non-destructive on-site (field) measurements and laboratory emissions tests[1,2]. The Field and Laboratory Emission Cell (FLEC®) which resulted from this project is shown in Figure 1. It is constructed of polished, acid-resistant stainless steel. Air enters from a baffle around the perimeter (see inset) and accelerates as it moves towards the exhaust point – eliminating sink effects.

Emission cells can only be used for materials/products with a planar surface. Typical applications include flooring materials (wood-block, carpeting, vinyl flooring, *etc.*),

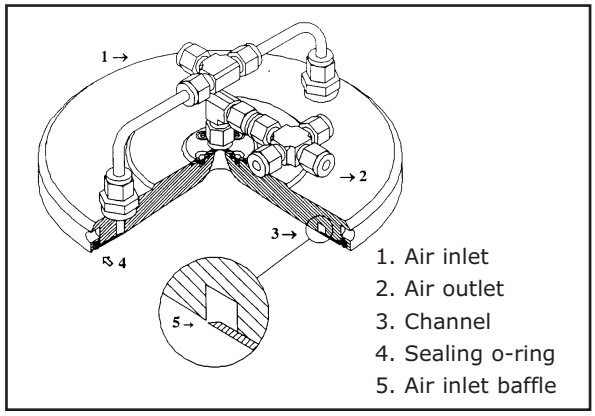

Figure 1: Field and Laboratory Emission Cell - FLEC

wood-based panels, sealants, textiles, adhesives, paints, coatings, plastic beads, concrete levelling compounds, wall paper, plastic sheeting and structural foams. Cells can be placed directly onto rigid products/surfaces and are held in place by the weight of the cell itself compressing the sealing gasket or o-ring. Compressible products are placed into a sample holder, such that the weight of the cell rests on the rim of the sample holder and does not compress the product itself. A planar sample surface can thus be presented to the cell at the right height, without impacting the cell volume or other parameters.

General discussion of emission cells with small chambers

Emission cells like FLEC cannot be used for sculpted or moulded materials nor for whole objects (*e.g.* cell phones). They are limited to planar materials, or to those products which

can be

Parameter	FLEC emission cell	Chamber (<1m^3)	Impact of difference
Air change rate (h^{-1})	~250-2400	Typically 0.5 - 1.0	Not significant. Realistic air velocities
Air supply ($L.min^{-1}$)	0.2 - 1.4	0.5 - 20	>500 L chambers are more expensive to run than cells or smaller chambers
Air velocity ($m.s^{-1}$)	0.007 - 0.05	>0.1 - 0.3	Different air velocities result in different SERs for evaporative emissions
Air distribution	Constant, but uneven distribution	Uneven. Varies with sample orientation	For cells and the smallest chambers: multi tests are needed for mats with point sources
Sample area (cm^2)	177	200 - 1000	Cells more likely to need repeat tests on heterogeneous samples
Loading ($m^2.m^{-3}$)	510	0.5 - 20	Counterbalances different in exchange rate
Volume	35 ml	0.02 to 1 (5) m^3	No still air in cell - minimises sink effects
Equilibration time	Minutes	Hours - days	Cells allow higher experimental throughput

Table 1: Comparison of technical parameters

made to present a relatively planar surface to the cell. Air velocity over the sample surface does vary from point to point[3,4], but this is also the case in small chambers[5]. However, emission rates controlled by internal diffusion are broadly independent of surface velocity, so both cells and small chambers produce meaningful, reproducible and comparable data[4] despite the uneven distribution. The variability of surface air velocity may mean that equilibration times for highly textured surfaces in emission cells need to be extended from 15-20 minutes to ~2 hours, but, again, similar issues also affect small chambers.

The only real concern relating to non-uniform air velocity for internal-diffusion controlled emissions, relates to materials with strong point-source emissions such as knot-holes in wood[3]. In these cases multiple repeat tests would be advised with either small chambers or cells.

Though uneven, the pattern of air velocity distribution within a FLEC cell is reproducible at different flow rates. This allows it to be used for comparing emissions from evaporative controlled systems, but precludes comparison with test data for the same materials obtained using small chambers See later, under 'Performance data'.

The relatively small size of most emission cells (that shown in Figure 1 only allows 177 cm^2 area of sample to be exposed) means that multiple tests are required on inhomogeneous or jointed materials. Depending on size, this is less likely to be an issue with small chambers – especially those that are >100 L.

Within the restrictions/limitations described above, emission cells do provide a simple and effective tool for testing emissions from many common materials/products. For example; because the emission cell is simply placed directly onto most products, it eliminates sample orientation and edge sealing issues. This makes it significantly easier for routine industrial labs to obtain meaningful data for production quality control. The features of emission cells are well documented in the literature and include:

- Minimal sink effects and >90% recovery of VOCs[2] (While there are little specific data on recoveries from small chambers in the published literature, chambers are

typically expected to offer >80% recovery of VOCs. The internal geometry of emission cells means that there are no volumes of still air which helps minimize sink effects and optimize recovery.)

• Tests are more rapid – typically 15-30 minute equilibration for smooth surfaces and 15-20 minute vapour collection – compared with several (up to 24) hours for small chambers and days for each large chamber test

• The relatively small size and low air flow (<1 L/min) of emission cells mean that parameters are easy to control or change (*e.g.* temperature, humidity). They are also readily reproduced and convenient to monitor. In this respect emission cells are not dissimilar to the smallest test chambers, but larger chambers (>100 L) do require more careful control

• Minimal cleaning is required between tests and cells are easy-to-clean when needed

• Cells also facilitate field use, testing of composite sample testing and testing at elevated temperatures.

Emission cell: small chamber – comparison of technical parameters and discussion of performance data

Table 2 presents a summary of the results from inter-laboratory (round robin type) studies of emissions for a range of material types. Correlation between data from chambers and cells are generally satisfactory (*i.e.* within 25% difference), especially for dry products where the primary emission process is internal diffusion. Some discrepancies are observed, but this is true of all inter-laboratory studies of emissions testing (whether carried out using emission cells, small chambers, or a mixture of the two) and is not primarily caused by differences in chamber/cell design. Laboratory performance and material heterogeneity currently appear to be the most significant factors[6,7].

Emissions controlled by internal diffusion (dry products/materials) are largely independent of surface air velocity, provided the rate is fast enough to prevent build up of contaminants at the sample surface. In these cases, data from emission cells and from different types of chambers correlate satisfactorily. However, in the case of drying or curing products, the primary emission process is normally evaporation (external diffusion), which is significantly affected by both surface air velocity and the sample loading factor ($m^2.m^{-3}$) (and associated vapour concentration within the chamber/cell). Emissions data for wet (drying or curing) materials will thus depend strongly on emission test parameters, and will correlate well unless identical test conditions and equipment have been used for all measurements. The exact timing of emissions testing and selection of sample storage conditions prior to testing are also critical for wet samples. Although emission test data for wet samples obtained using an emission cell such as FLEC or any one given type of chamber can thus be made to be reproducible by applying rigorous control of all parameters prior to and during testing[8], the extreme sensitivity of the results to such a multitude of variables, does call into the question the validity of testing wet samples during the curing or drying stage.

Conclusions

Experience gained during the inter laboratory studies described and in routine use, has shown the FLEC emission cell to be suitable for many emissions testing applications and to be a useful supplement to small chambers. Acceptance of emission cells is now reflected by their inclusion by CEN in ENV 13419-2 as a 'horizontal' standard (multi-product/ application), for use by industry and service laboratories in compliance with the European Construction Products Directive. Similar draft standards are currently proceeding through the balloting process in both ASTM (Work Item WK3368) and ISO (DIS 16000-10). However, additional, well-regulated intercomparative testing of various small chambers and test cells, under controlled/harmonized conditions of analytical method, VOC recovery and specified homogeneity of the test sample would make an important contribution and should be strongly supported.

Chamber size/type - Duration/time of testing	Building product	Compound	Comments
250 L stainless steel[1] - 3 weeks	PVC flooring	Cyclohexanone, phenol, TXIB	Satisfactory correlation between emission cells and one chamber - some apparent material heterogeneity
50 L stainless steel[8] - 2 weeks	Paint, wax	Ethylene glycol, Texanol, TVOC	Satisfactory correlations, especially after 50 h. *N.B.* Emission cell SERs generally higher (possibly due to min. sink effects)
1 m^3 stainless steel or glass[9] - 1 week	Wood	Terpenes	Satisfactory correlation with glass chamber in one test. Apparent heterogeneity in another test and/or domination of evaporative emission (velocity dependent). *N.B.* emission cell SERs generally high
34 m^3 wood walls, PVC floor[10] - 20 h	Floor polish	2-(2-ethoxyethoxy) ethanol	Satisfactory comparison (<2x). Modelled and measured peak concentration appear after 30 and 100 min. respectively
1 m^3, 187 L stainless steel - months[11] + office air - months	Linoleum floor	Hexanal	Unsatisfactory correlation. Higher SER in chambers partly assigned to edge effects. Satisfactory correlation between measured hexanal SER in office and emission cell
1 m^3 stainless steel[12] - /*ca* 13 d	Wood based products	Formaldehyde	Satisfactory correlation (R = 0.98)
European round robin (18 labs)[6]. Up to 1 m^3 stainless steel/glass-/48 h	Carpet, PVC, paint	VOCs	Main causes of discrepancies: i) analytical errors ii) sorption on walls iii) heterogeneity of the building products. Also, variable film paint thicknesses were used. *N.B.* 28 h may be insufficient to reach equilibrium
20 m^3, 1 m^3 and 20 L stainless steel[13] - 28 d	UV-cured lacquers	TVOC	Emission cell time/concentration profile was highest during first 10 d, thereafter superimposable with that for 0.02 - 20 m^3. 1 m^3 chambers showed lowest time/concentration profiles
German round robin (9 labs)[14]. Up to 1 m^3 stainless steel/glass-/28 d	UV -cured acryl. lacquer	Sum of VOCs + SVOCs and individual VOCs	Observed differences less than and equal to 15%
ADSEC (stainless steel)[15]	Wood based	Formaldehyde	Satisfactory correlation (>0.99)
1 m^3 stainless steel (51 1 L glass)[16] - /24 h	Paint on steel plate	Higher aldehydes, decanol	Satisfactory comparison; variation less than and equal to 15%
Round robin (8 labs)[7] - up to 200 d	Lacquer on MDF	VOCs	Recovery generally better than 90%. Satisfactory analyses of spiked tubes. Apparent material heterogeneity

Table 2: Parallel emissions testing with emission chambers and the type of emission cell illustrated in Figure 1

References

1. Wolkoff, P. *et al*., (1991) Field and Laboratory Emission Cell FLEC, Proceedings of Healthy Buildings, ASHRAE,160-165.

2. Wolkoff, P. (1996) An emission cell for measurement of volatile organic compounds emitted from building materials for indoor use - the field and laboratory emission cell FLEC. *Gefahrstoffe - Reinhaltung der Luft* **56**:151-157.

3. Uhde *et al*. (1998) Characterisation of the FLEC: Flow field and air velocities. *Atmos. Env*. **32(4)**: 773-781.

4. Murakami *et al*. (2002) 3D-CFD analysis of diffusion and emission of VOCs in a FLEC cavity Proceedings: 9th International Conference on Indoor Air Quality and Climate. H. Levin. Santa Cruz: *Indoor Air* **2**: 548-552.

5. Guo, Z., Tichenor, B.A., Krebs, K.A., Roache, N,F. (1996) Considerations on revisions of emissions testing protocols, in: Tichenor, B., ed. Characterising Sources of Indoor Air Pollution and Related Sink Effects. Philadelphia: ASTM STP 1287, 225-236.

6. De Bortoli, M., Kephalopoulos, S., Kirchner, S., Schauenburg, H. and Vissers, H. (1999) State-of-the-Art in the Measurement of VOCs Emitted from Building Products: Results of an European Interlaboratory Comparison. *Indoor Air* **9**: 103-116.

7. Hansen, V., Larsen, A. and Wolkoff, P. (2000) Nordic round-robin emission testing of a lacquer: consequences of product in-homogeneity. Healthy Buildings 2000, O. Seppänen and J. Säteri. Helsinki: SIY Indoor Air Formation 4, 99-104.

8. Roache *et al*. (1996) Comparing the FLEC with traditional emission chambers, In: Tichenor B, ed. Characterising Sources of Indoor Air Pollution and Related Sink Effects. Philadelphia: ASTM STP 1287; pp 98-111.

9. Salthammer, T. and Fuhrmann, F. (1996) Emission of monoterpenes from wooden furniture. *Proceedings of Indoor Air '96* **3**: 607-612.

10. Vejrup, (1996) Importance of chemicals in cleaning agents for the indoor environment, PhD Thesis, Danish Tech Univ.

11. Zellweger *et al*. (1997) Emissions of VOCs from building materials – methods and results, KWH-EMPA, Bundesamt fur Energiewirtschaft, Dubendorf, pp 1-104.

12. Risholm-Sundman (1999) Determination of HCO emissions with the FLEC & correlation to chambers. *Indoor Air* **9**: 268-272.

13. Jahn *et al*. (1997) Procedure for the determination and limitation of VOC emissions from furniture and coated wood-based products. *Healthy Buildings '97/IAQ* **3**: 593-598.

14. Jahn *et al*. (2000) ECO-label for low emission wood products and wood base products (RAL-UZ 38) – Part 2: Test procedure and results. *Healthy Buildings* **4**: 525-530.

15. Akutsu *et al*. (2000) Development of a measurement device (ADSEC) for aldehyde emission rates using a diffusive sampler, *Healthy Buildings* **4**: 477-482.

16. Afshari, A. *et al*. (2003) Comparison of three small chamber test methods for VOC emission rates from paint. *Indoor Air* **13**: 156-165.

Other relevant references:

17. Clausen, P.A., Hansen, V., Gunnarsen, L., Afshari, A. and Wolkoff, P. (2004) Emission of di-2-ethylphthalate from PVC flooring into air and uptake in dust: Emission and sorption experiments in the FLEC and CLIMPAQ. *Env. Sci & Technology* **38**: 2531-2537.

18. Wolkoff P. (1998) Impact of air velocity, temperature, humidity, and air on long-term VOC emissions from building products. *Atmospheric Environment* **32**: 2659-2668.