MARKES international

TDTS

Thermal Desorption Technical Support

TDTS 71: Summary of FLEC Applications (Apr 2003)

Keywords

paints, coatings, materials, compounds, biography, emissions

Introduction

The Field and Laboratory Emission Cell (FLEC) is primarily designed for the measurement of volatile organic compound (VOC) emissions from planar construction products and from applied paints/coatings. However, since its commercial introduction in the early 1990s, it has proved a convenient tool for many other materials emissions applications. A summary of the range of materials that have been tested using the FLEC is listed below.

Materials tested using FLEC

Flooring (Saarela, 1992)

Thermal insulation materials (Uchiyama *et al*., FLEC 2001)

Fire damaged construction materials (Riala and Back, 2000)

Oil-treated wooden flooring (Mortensen, 1999)

Sealant (Wolkoff, 1993)

Composite - PVC flooring and damp concrete (Offerman *et al*., 2000)

Vinyl flooring - various (Jensen, Wolkoff 1995 *etc*)

Cleaning materials/products (Vejrup and Wolkoff 1995a, b)

Metabolic VOCs from microbial cultures

Gravure printed papers (Jensen *et al*., 1996)

The effect of ozone exposure (Kleno *et al*., 2001)

The effect of humidity on construction products (Sjoberg, 2001)

Paints (Roache *et al*., 1996) (De Bortoli *et al*., 1999) (Afshari, 1999)

Lacquers (Jann *et al*., 1997) (Hansen *et al*., 2000) (Jann *et al*., FLEC 2001)

Waxes (*e.g.* floor treatments) (Roache *et al*., 1995)

Textile floorings (*e.g.* carpet) (De Bortoli *et al*., 1999)

MDF and other bio-composite products (Akutsu *et al*., 2000; Jann *et al*., 2000)

Particulates (*e.g.* microbial spore emissions - Kildeso *et al*., FLEC 2000)

Sorption/emission of ETS (Work in progress - Hodgson, 2001)

Concrete (Alexanderson, FLEC 2001)

Wall coverings (Tanabe *et al*., FLEC 2001)

Ceiling tiles (Armstrong Industries, Private comm., for FLEC 2001)

Natural wood (Jann and Wilke, 2000)

Concrete levelling compounds (Alexanderson, FLEC 2001)

Adhesives (Armstrong industries, Private comm.,for FLEC 2001) (Funaki and Tanabe, FLEC 2001)

General VOC emissions from materials (Ekberg and Gunnarsen (1995), Pejtersen *et al*. (2001), Rossel *et al*. (1996), Tirkonnen *et al*. (1997), Zellweger *et al*. (1995))

Wooden furniture (Fuhrmann and Salthamer, 1996)

Target compounds tested using FLEC

Quantitative materials emissions data, obtained using FLEC, is reported for many volatile and semi-volatile organic compounds from all classes of chemical group. Many methods (*e.g.* draft ISO 16000-6/ ENV 13419-4) restrict quantitation to those compounds ranging in volatility from n-hexane to n-hexadecane by selecting Tenax sorbent for the sample tube. This range may be extended by using a wider range of sorbents in the sample tube (as described in ISO 16017-1) and/or by modifying sampling/test conditions. Examples of the types of compounds reported in the literature as compatible with FLEC are as listed below. Most, but not all, of these are compatible with subsequent TD-GC-MS analysis.

Ammonia

Formaldehyde and other aliphatic aldehydes (TD-GC-MS analysis is not usually used)

Fungicides,

Ketones *e.g.* MIBK, benzaldehyde, cyclohexanone

Esters *e.g.* Ethyl acetate, butyl acetate,

SVOCs (general) *e.g.* benzophenone,

A-pinene and other monoterpenes, isoprene

Aromatics such as Benzene, toluene, xylenes, ethyl benzene, trimethyl benzenes, propyl benzene, other substituted aromatics and styrene

Alcohols and glycol ethers including decanol, texanol, propylene glycol and ethylene glycol, 2-ethyl hexanol, 2-butoxy ethanol, 2-(2-ethoxyethoxy) ethanol,

Higher alkenes: Decane, dodecane,

Acids such as acetic acid

Halogenated compounds *e.g.* p-dichlorobenzene

Plasticizers *e.g.* di-isobutylphthalate, diethylhexylphthalate (DOP)

Phenolic compounds

Toxic/odorous compounds *e.g.* (TXiB) Trimethylpentandiol-di-isobutyrate

FLEC Biography (incomplete) - reproduced with kind permission of Dr P. Wolkoff (AMI Copenhagen) from his keynote presentation at the 2001 International FLEC Symposium. (Please contact Markes International Limited for information on how to obtain a copy of these proceedings.)

1. Determination of VOC Emissions fron Surface Coatings by Environmental Chamber Measurements, **Afshari**, PhD Thesis, Chalmers University of Technology, pp 1-152, 1999.

2. Development of measurment device (ADSEC) for aldehyde emission rates using a diffusive sampler, **Akutsu** *et al*., SIY Indoor Air Formation, Vol. 1, pp 477-482, 2000.

3. Emission measurement from coating and coating products, **Bayer** *et al*., Proc. of Indoor Air, 1996, Tokyo Institute of Public Health.

4. Building products - Determination of the emission of volatile organic compounds - Part 2: Emission test method, CEN, EP ENV 13419-2, 1999.

5. Emission of Volatile Organic Compounds from a Vinyl Floor Covering, **Clausen** *et al*., Am. Soc. for Testing and Materials, pp 3-13, 1993.

6. State of-the-art in the measurement of volatile organic compounds emitted from building products: Results of an European interlaboratory comparison, **De Bortoli** *et al*., Indoor Air 9: 103-116, 1999.

7. Determination of VOCs emitted from indoor materials and products - Interlaboratory comparison of small chamber measurements, European Collaborative Action, Commission of the European Communities, Brussells-Luxembourg, 1993

8. Identification of air pollution sources in office buildings using the Field and Laboratory Emission Cell, **Ekberg** *et al*., Milan Healthy Buildings, Vol. 3, pp 1353-1368, 1995.

9. Emission of monoterpenes from wooden furniture, **Fuhrmann and Salthammer**, Indoor Air, Vol. 3, pp 607-612, 1996.

10. Design and characterization of the

CLIMPAQ, chamber for laboratory investigations of materials, pollution and air quality, **Gunnarsen** *et al*., Indoor Air, vol. 4, pp 56-62, 1994.

11. Chemical emission from paints and other surface materials - measurements with Field and Laboratory Emission Cell (FLEC) and Other Climate Chambers, **Gustafsson** *et al*., expert Verlag, pp 95-105, 1995.

12. The Field and Laboratory Emission Cell - FLEC, **Gustafsson**, Organic Indoor Air Pollutants, Wiley-VCH, pp143-152, 1999.

13. Trade standards for testing chemical emission from building materials; Part 1. measurement of flooring materials, **Gustaffson and Jonsson**, Proc of Indoor Air, Vol.2, pp 437-442, 1993.

14. The Influence of damp concrete on emissions from flooring materials, **Gustafsson and Jonsson**, Presented at Healthy Buildings, 1994.

15. Nordic round-robin emission testing of a lacquer: Consequences of product in-homogeneity, **Hansen** *et al*., SIY Indoor Air Formation, Vol. 4, pp 99-104, 2000.

16. Round-robin: Chemical emission testing by use of FLEC, **Hansen** *et al*., Espoo, Nordtest Report 1390-98, pp 1-18, 1999.

17. **Hansen** *et al*., Proceedings of the Second International FLEC Conference, pp116-120, 2001.

18. ECO-label for low emission wood products and wood base products (RAL-UZ 38) - Part 2: Test procedure and results, **Jann** *et al*., SIY Indoor Air Formation, Vol. 4, pp 525-530, 2000.

19. Procedure for the determination and limitation of VOC-emissions from furniture and coated wood based products, **Jann** *et al*., Healthy Buildings/IAQ, Vol. 3, pp 593-598, 1997.

20. Characterization of linoleum. Part 3: Identification of oxidative emission processes, **Jensen** *et al*., Healthy Buildings, Vol. 1, pp 243-246, 1994.

21. Characterisation of linoleum. Part 2: Preliminary odour evaluation, **Jensen** *et al*., Indoor Air, Vol. 5, pp 44-49, 1995.

22. Characterisation of LInoleum. Part 1: Measurements of volatile organic compounds by use of the Field and Laborartory Emission Cell, FLEC, **Jensen** *et al*., Indoor Air, Vol. 5, pp 38-43, 1995.

23. Characterization of Linoleum: Identification of oxidative emission processes, **Jensen** *et al*. in Characterizing sources of indoor air pollution and related sink effects, ed. Tichenor, Philadelphia: ASTM 1287, pp145-152, 1996.

24. Toluene in rotogravure printed brochures - High speed emission testing and comparison with exposure data, **Jensen** *et al*., Applied Occ. & Environ. Hygiene, Vol.11, pp 1055-1063, 1996.

25. Emission from wall paints - The influence of the wall material, **Jørgensen** *et al*., Milan Healthy Buildings, Vol.2, pp 977-982, 1995.

26. Determination of ozone removal rates by selected building products using the FLEC emission cell, **Klenø** *et al*., Envi. Sci. & Techn., Vol. 35, pp 2548-2553, 2001.

27. Materials emissions of chemicals - PVC flooring materials, **Lundgren** *et al*., Indoor Air, Vol. 9, pp 202-208, 1999.

28. **Mortensen**, Miljø-Kemi (Danish Environ. Centre), Private communication

29. Contaminant emission rates from PVC backed carpet tiles on damp concrete, **Offerman** *et al*., SIY Indoor Air Formation, Vol. 4, pp 379-384, 2000.

30. Effect of renovating an office building on occupants' comfort and health, **Pejtersen** *et al*., Indoor Air, Vol. 11, pp 10-25, 2001.

31. Estimation of damage to flooring materials caused by a fire during construction, **Riala and Bäck**, SIY Indoor Air Formation, Vol. 4, pp 423-427, 2000.

32. Determination of formaldehyde emission with Field and Laboratory Emission Cell (FLEC) - Recovery and correlation to the chamber method, **Risholm-Sunderman**, Indoor Air, Vol. 9, pp 268-272, 1999.

33. Comparing the Field and Laboratory Emissions Cell (FLEC) with traditional emissions testing chambers, **Roache** *et al*., EPA/600/A-95/094, pp1-28, 1995.

34. Comparing the Field and Laboratory

Emission Cell (FLEC) with traditional emissions testing chambers, **Roache** *et al*., in Characterizing Sources of Indoor Air Pollution and Related Sink Effects Sinks, ed. Tichenor, Philadelphia: ASTM STP 1287, pp98-111, 1996.

35. Observations on application of the field and laboratory emisison cell (FLEC) for latex paint emissions - Effect of relative humidity, **Roache** *et al*., Indoor Air, Vol., 2, pp 657-662, 1996.

36. Biozidemissionen aus Dispersionsfarben, Rofzkamp et al, Gefahrstoffe - Reinhaltung der Luft, Vol. 61, pp 41-47, 2001.

37. Indoor air quality and material emissions in a house designed for allergic persons, **Rossell** *et al*., Indoor Air, Vol. 3, pp 301-305, 1996.

38. Demonstration of good IAQ in Finnish allergy house, **Saarela** et al, SIY Indoor Air Formation, Vol. 4, pp 493-498, 2000.

39. Preliminary investigation of ammonia levels in indoor air and evaluation of ammonia sources, **Saarela**, IAQ, pp 232-237, 1992.

40. Secondary emissions from concrete floors with bonded flooring materials - effects of alkaline hydrolysis and stored decomposition products, **Sjöberg**, PhD Thesis, Chalmers University of Technology, pp 1-188, 2001.

41. Adsorption of VOCs on interior surafces in a full scale building, **Tirkkonen and Saarela**, Healthy Buildings/IAQ, Vol. 3, pp 551-556, 1997.

42. Characterization of the field and laboratory emission cell- FLEC flow and air velocities, **Uhde** *et al*., Atm. Environ., Vol. 32, pp 773-781, 1998.

43. High speed emission testing of volatile organic compounds from cleaning agents with the FLEC. Part 1: Method development, **Vejrup and Wolkoff**, Proc. Healthy Buildings, Vol. 1, pp 983-988, 1995.

44. High speed emission testing of cleaning agents with the FLEC. Part 2: Conversion from FLEC to a standard room, **Vejrup**, Healthy buildings, Vol. 2, pp 989-994, 1995b.

45. The importance of chemical components in cleaning agents for the indoor environment, **Vejrup**, PhD Thesis, Danosh Tecknical University, pp 1-103, 1996.

46. A new approach for indoor climate labelling of building materials - Emission testing, modeling, and comfort evaluation, **Wolkoff and Nielsen**, Atm. Envir., Vol. 30, pp 2679-2689, 1996.

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

48. Application of Field and Laboratory Emission Cell "FLEC" - Performance study, intercomparison study and case study of damaged linoleum, **Wolkoff** *et al*., Indoor Air, Vol. 5, pp 196-203, 1995.

49. Characterisation of emissions from building products. Long term chemical evaluation. The impact of air velocity, temperature, humidity, oxygen, batch/repeatibility in the FLEC, **Wolkoff**, Proc. of the 7th Int. Conf. on Indoor Air Quality and Climate, Tokyo, Inst. of Public Health, Vol. 1, pp 579-584, 1996.

50. Documentation of Field and Laboratory Emission Cell "FLEC" - Identification of emission process from carpet, linoleum, paint and sealant by modeling, **Wolkoff** *et al*., Indoor Air, Vol. 3, pp 291-297, 1993.

51. Field and Laboratory Emission Cell: FLEC, **Wolkoff** *et al*., Proc. Healthy Buildings, ASHRAE, pp 160-165, 1991.

52. Impact of air velocity, temperature, humidity and air on long-term VOC emissions from building products, **Wolkoff**, Atm. Environ., Vol. 32, pp 2659-2668, 1998.

53. Indoor climate labeling of building materials - Chemical emission testing, Long-term modeling, and indoor relevant odour thresholds, **Wolkoff and Nielsen**, National Institute of Occ. Health, Denmark, pp 1-81, 1993.

54. Indoor climate labeling of building materials. The experimental approach to a prototype, **Wolkoff and Nielsen**, in Characterizing Sources of Indoor Air Pollution and Related Sink Effects, ed. Tichenor, Philadelphia: ASTM STP 1287, pp 331-349, 1996.

55. Emissions of volatile organic compounds (VOC) from building materials - Methods and results, **Zellweger** *et al*., KWH-EMPA,

Bundesamt für Energiewietschaft, Dübendorf, pp 1-104, 1997.

56. VOC emission from building materials: comparison of chamber emission data with concentrations in real rooms, **Zellweger** *et al*., Milano, Healthy Buildings, Vol. 2, pp 845-850, 1995.

Additional References

1. Practice for selection of sorbents and pumped sampling/thermal desorption analysis procedures for volatile organic compounds in air, ASTM, Am. Soc. for Testing and Materials, D 6196-97,West Conshohocken, PA, 1998.

2. Effects of selected process parameters on emission rates of volatile orgainc chemicals from carpet, **Hawkins** *et al*., Am. Ind. Hyg. Assoc. J., Vol. 53, pp 275-282, 1992.

3. Indoor, ambient and workplace air - Sampling and analysis of volatile organic compounds by sorbent tube/thermal desorption/capillarty gas chromatography, ISO, ISO/FDIS 16017-1, 2000.

4. The release of fungal spores from water damaged building materials, **Kildesø** *et al*., SIY Indoor Air Formation, Vol. 1, pp 313-318, 2000.

6. Sensory and chemical charactrization of VOC emissions from building products: Impact of concentration and air velocity, **Knudsen** *et al*., Atm. Environ., Vol. 33, pp 1217-1230, 1999.

7. Air sampling and analysis of volatile organic compounds with solid phase microextraction, **Koziel and Pawliszyn**, J. of Air & Waste Management, Vol. 51, pp 173-184, 2001.

8. Usefulness of the Finnish classification of indoor climate, construction and finishing materials: comparison of indoor climate between two new blocks of flats in Finland, **Tuomainen** *et al*., Atm. Environ., Vol. 35, pp 305-313, 2001.

9. How to evaluate VOC emissions from building products. A perspective, **Wolkoff**, Sci. of the Total Environ., Vol. 227, pp 199-213, 1999.

References from Proceedings of the 2nd International FLEC Symposium 6-7th September 2001, National Institute of Occupational Health, Copenhagen, Denmark.

1. Where are we with the FLEC? - An overview, **Wolkoff**.

2. Indoor air chemical pollution investigated in real sized model room, **Tanabe** *et al*.

3. Comparison of FLEC with other climate chambers, german experience, **Jann** *et al*.

4. An appraisal of the FLEC by a US researcher, **Tichenor**.

5. The applicability of the FLEC for industrial products, **Salthammer** *et al*.

6. The use of FLEC with special focus on formaldehyde, **Risholm-Sundman**.

7. The FLEC from the perspective of European standardisation, **Crump**.

8. The Swedish experience with FLEC in practise at SP, **Lundgren** *et al*.

9. Comparison of three small chamber test methods for the measurement of VOC emission rates from paint, **Afshari**.

10. Measurements of emission rates from wall covering adhesives - comparing with FLEC and a small scale chamber ADPAC, **Funaki and Tanabe**.

11. Phthalate emission from PVC flooring - FLEC *vs*. CLIMPAQ, **Clausen** *et al*.

12. Emissions resulting from alkali attack on adhesives and floor coverings, **Alexanderson**.

13. P-FLEC - The particle FLEC - Measurement of resuspended particles, **Kildesø**.

14. The use of FLEC for field measurements, **Mortensen**.

15. Identification of formaldehyde sources in a school by FLEC testing, **Ganz** *et al*.

16. Evaluation of improvement technique for chemical pollution in multi-family residential building by using FLEC, **Bano and Tanabe**.

17. FLEC emission tests in Norway, **Bjørseth and Bramming Jørgensen**.

18. Comparison of diffusive type device

(ADSEC) with FLEC and small chamber (ADPAC) for measurement of aldehyde emission from building materials, **Aoki** *et al*.

19. Comparison of results from two different sampling and analytical techniques for aldehydes, **Stridh** *et al*.

20. Emission rate measurement of chemical compounds emitted from thermal insulating materials, **Uchiyama** *et al*.

21. Quality control measures for FLEC emission testing - validation of analytical method, **Hansen** *et al*.

22. In search of indoor airway irritants - and what to measure from building products emission, **Wolkoff**.