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Radon management in buildings: Applied research on building characterization and protection

IAEA Webinar, 25 April 2018

Bernard Collignan, Senior Scientist,
(bernard.collignan@cstb.fr)

Building Research Institute (CSTB), France

Member of the Executive Commitee of the European Radon Association (ERA)

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ERA
European Radon Association

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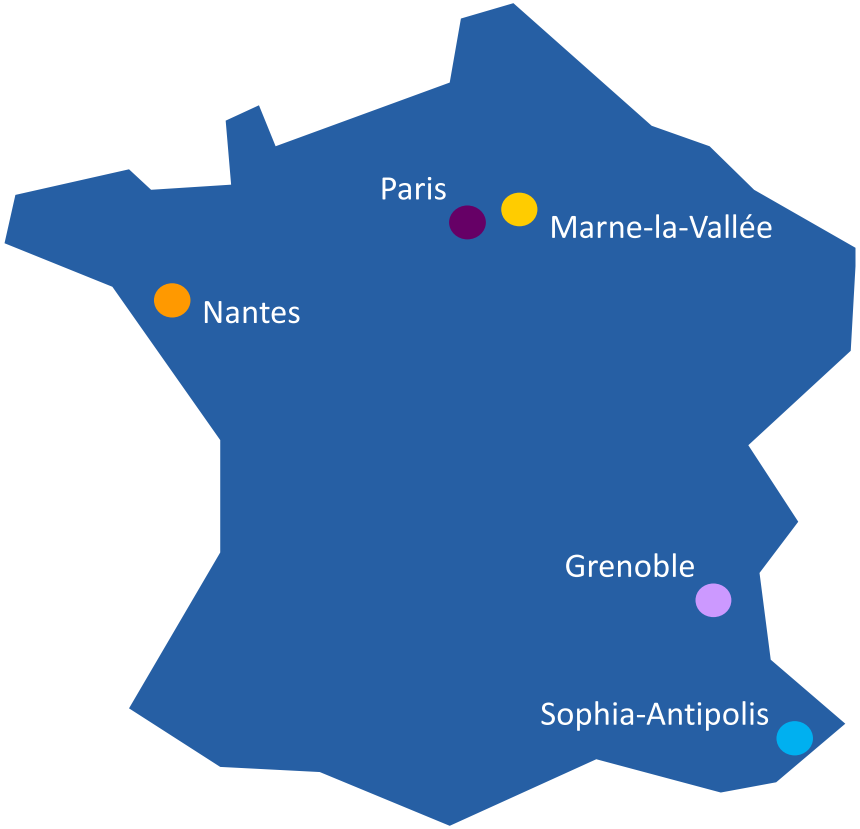

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Head office

- Energy-Environment
- Health-Comfort
- Envelope and Roofing
- Insulation and Cladding
- Safety, Structures, and Fire performance
- Hydraulics and Sanitary Equipment
- Information Technologies and Knowledge Dissemination
- OQAI (Indoor Air Quality Observatory)

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- Economics and Social Sciences

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- Energy-Environment
- Health-Comfort
- Insulation and Cladding
- Envelope and Roofing
- Information Technologies and Knowledge Dissemination
- Acoustb, subsidiary of the CSTB group

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- Information Technologies and Knowledge Dissemination
- Envelope and Roofing
- Energy-Environment

CSTB : Building Research Center

Answering ecological and energy transition stakes : 4 key activities

Recognized scientific excellence at the national and European level.

Presence in European and international scientific networks.

Scientific and technical expertise in the field of innovation and prospective.

Supporting the professionals through dissemination of knowledge and training.

CSTB: a stakeholder trusted by business and public authorities.

→ More than 900 employees

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Summary

1) **PHYSICS OF RADON ENTRY IN BUILDINGS**

2) **CHARACTERIZATION OF INDOOR RADON EXPOSURE IN BUILDINGS**

3) **PRINCIPLES OF BUILDING PROTECTION**

4) **SOIL DEPRESSURIZATION SYSTEMS (SDS)**

   4.1) SDS, PRINCIPLES

   4.2) SDS, EXISTING BUILDING (PILOT STUDIES)

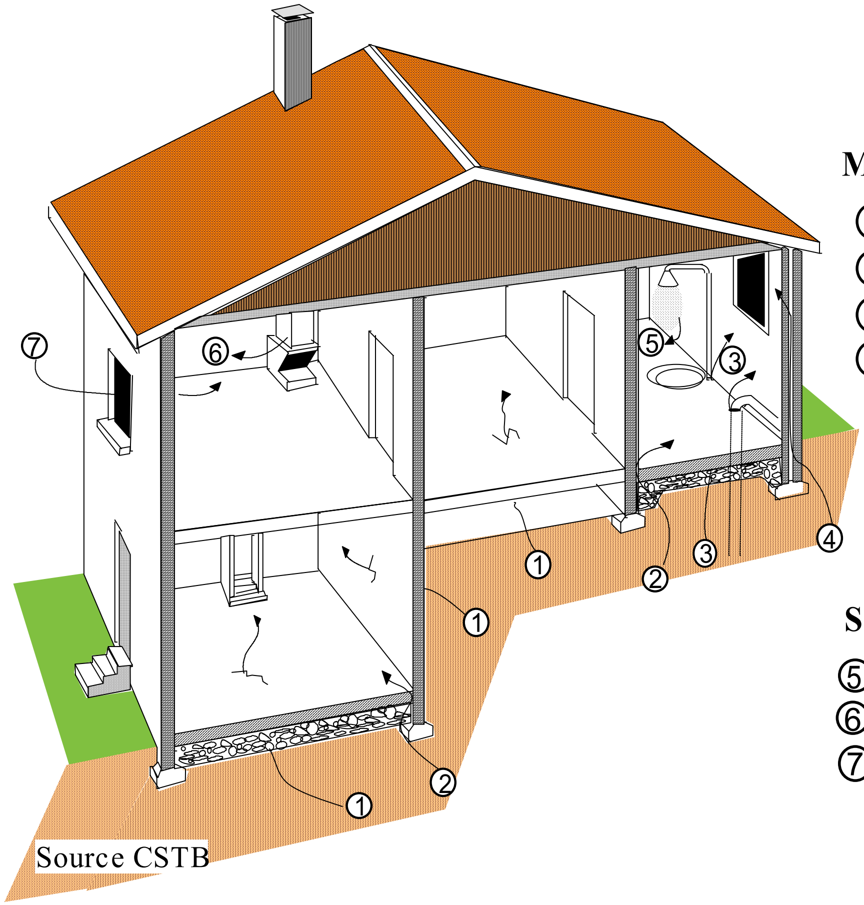
   4.3) SDS, NEW BUILDING (EXPERIMENTAL HOUSE)

CONCLUSIONS

1) Physics of radon entry in buildings

1) Physics of radon entry in buildings

In case of high radon level indoors (few hundreds Bq/m³), main cause: radon from the ground



Main causes

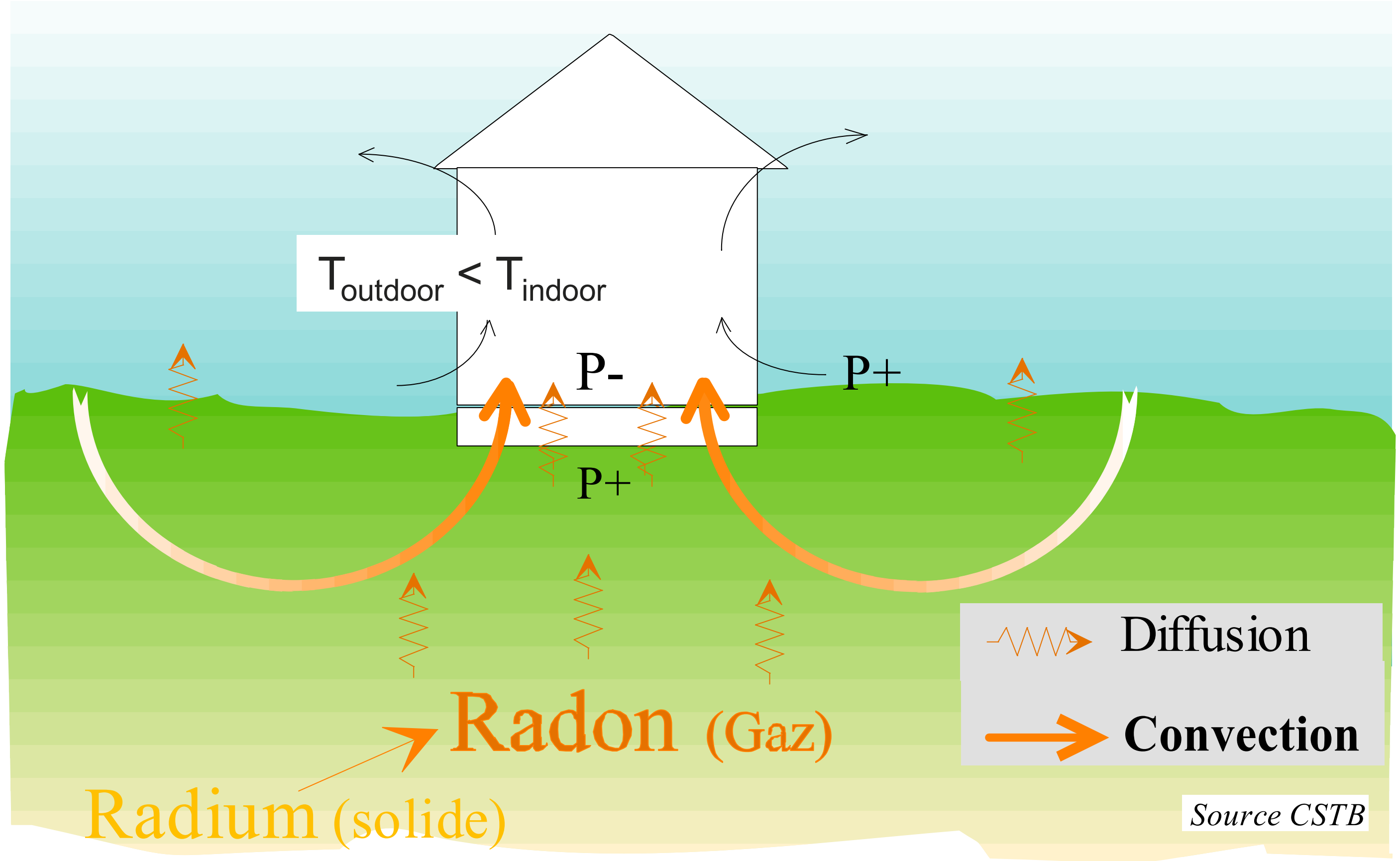
1. Cracks
2. Joints between components
3. Penetration networks
4. Cavities in walls

} coming from the ground

Secondary causes

5. Use of water
6. Building materials
7. Outdoor air

1) Physics of radon entry in buildings



Entry mechanisms into building:

- Diffusion, linked with concentration differences
- **<u>Convection</u>, linked to slight depressurisation of building**

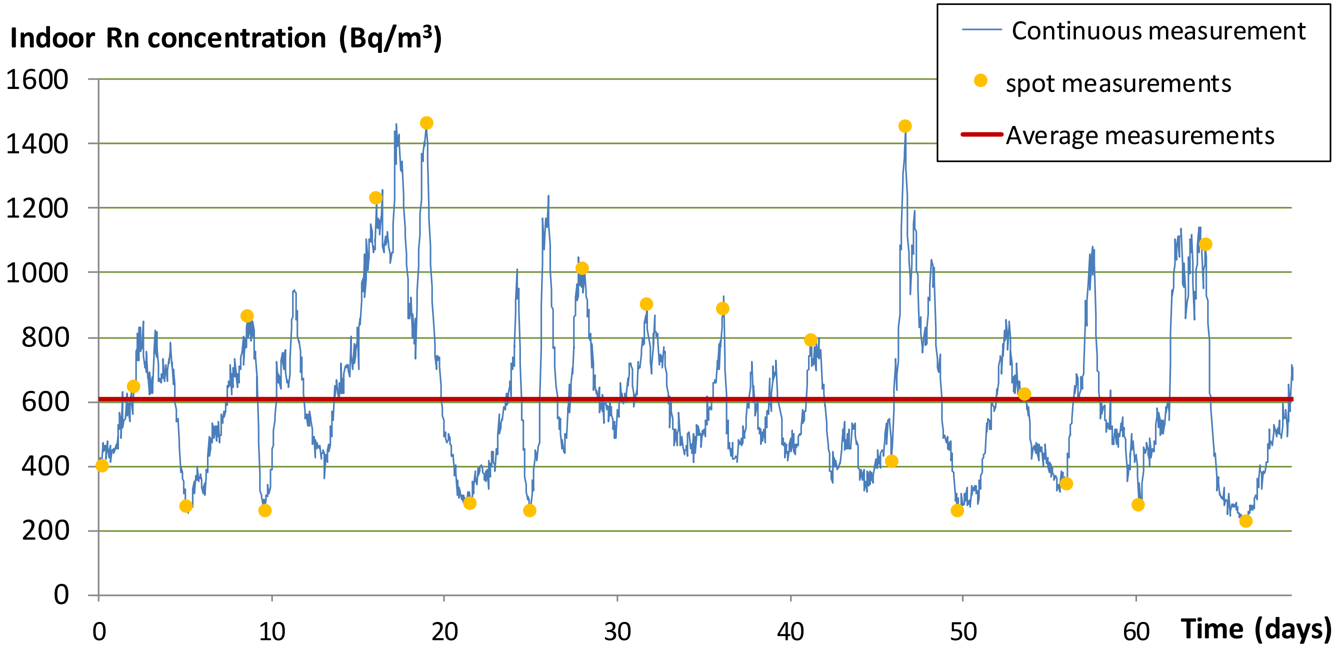
2) Characterization of indoor radon exposure in buildings

2) Characterization of indoor radon exposure in buildings

Indoor radon concentration results on many parameters:

- Ground potential (nature, permeability)
- Building characteristics (geometry, foundation, systems,…)
- Meteorological conditions (temperature, wind)
- Behaviour of occupants (opening window, doors, heating habit)

→variable over time



Radon risk assessment based on annual averaged indoor radon concentration

→ Difficulties to compare short time measurement to average value

2) Characterization of indoor radon exposure in buildings

NF* ISO 11665-8 January 2013

Measurement of radioactivity in the environment — Air: radon-222 — Part 8: Methodologies for initial and additional investigations in buildings

Scope

- Specifies requirements for the determination of the activity concentration of radon in all types of buildings.
- Describes the measurement methods used to assess, the average annual indoor radon activity concentration
  Initial investigation or screening

- Selection of measuring devices
  use of passive detectors following ISO 11665-4 standard
- Location of the measuring points in the building
- Definition of the number of devices required
- Installation of measuring devices

→ at least half of the measurement **period during the winter or the heating season**;

→ at least **two months of the measurement period** during normal occupancy

***French standard (NF)**

2) Characterization of indoor radon exposure in buildings

NF ISO 11665-8 January 2013

Protocol used in regulation in France for building with public access and working places, also in many other countries

Advantages:

- Good approximation of annual averaged indoor radon concentration
- Easy to install
- Low cost

Disadvantages:

✓ Duration: at least two months of measurement

✓ Restriction of the period of measurement: heating season

✓ Representativeness of occupant exposure

→ Difficult to use this protocol in existing dwelling (real estate transactions, occupant behaviour, ...)

2) Characterization of indoor radon exposure in buildings

METHODOLOGY FOR THE CHARACTERIZATION OF THE RADON ENTRY IN DWELLINGS

Objective:

To develop complementary or alternative tool with a short time characterization

Protocol developed:

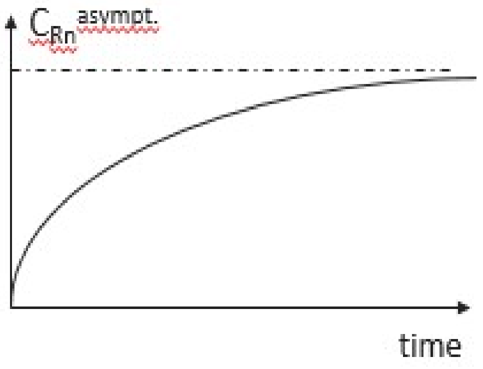
Based on previous works undertaken by M. Sherman, W. Ringer, A. Fronka

- To define experimentally a **radon potential entry** for a given building (entry law)
- To **assess averaged annual indoor radon concentration** using the entry law with numerical ventilation model

2) Characterization of indoor radon exposure in buildings

Summary of protocol

- Depressurization of dwelling using a "blower door"
- Realization of 2 or 3 depressurization levels (ΔP: pressure difference between outdoors and indoors), measuring air exhaust level
- Continuous measurement of Rn Concentration at the exhaust
- Additional characterization:
  - Air permeability of the dwelling (blower door)
  - Assessement of ventilation system performances



Analysis of results

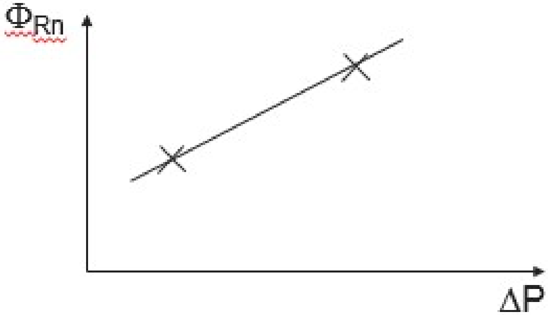
- For given depressurisation (ΔP) and air exhaust level (AEL):

$$\Phi_{RN} = C_{Rn\ asympt} \times AEL$$

- Test undertaken at different depressurisation levels

→ Definition of a radon entry law:

$$\Phi_{RN} = k\ \Delta P^{n}$$



2) Characterization of indoor radon exposure in buildings

Example of indoor radon evolution for three different depressurization levels

C_{Rn} (Bq/m^3)

Time

2) Characterization of indoor radon exposure in buildings

Definition of radon entry potential

Bq/s	Example of Rn entry law determined experimentally $\Phi_{Rn} = 13{,}6 \times (\Delta P)^{0{,}6}$
Bq/s	Radon entry for a 4 Pascal depressurization (*Pa*) $\Phi_{Rn}\ (4\ Pa) = 13{,}6 \times (4)^{0{,}6}$
Bq/s/m²	**Radon entry potential** $P_{Rn4} = Q_{Rn}\ (4\ Pa)\ /\ Soil\ surface$

Potential reflecting the amount of radon entering the building by m² of heated ground floor at 4 Pascal depressurization level

→ Depends only on building characteristics

→ The greater the potential, the more there is indoor radon exposure

2) Characterization of indoor radon exposure in buildings

Protocol tested on 28 dwellings

> Distributed in 5 regions : Auvergne, Limousin, Bretagne, Languedoc-Roussillon and Rhône-Alpes

> Old buildings (18th century) to very recent (2010)

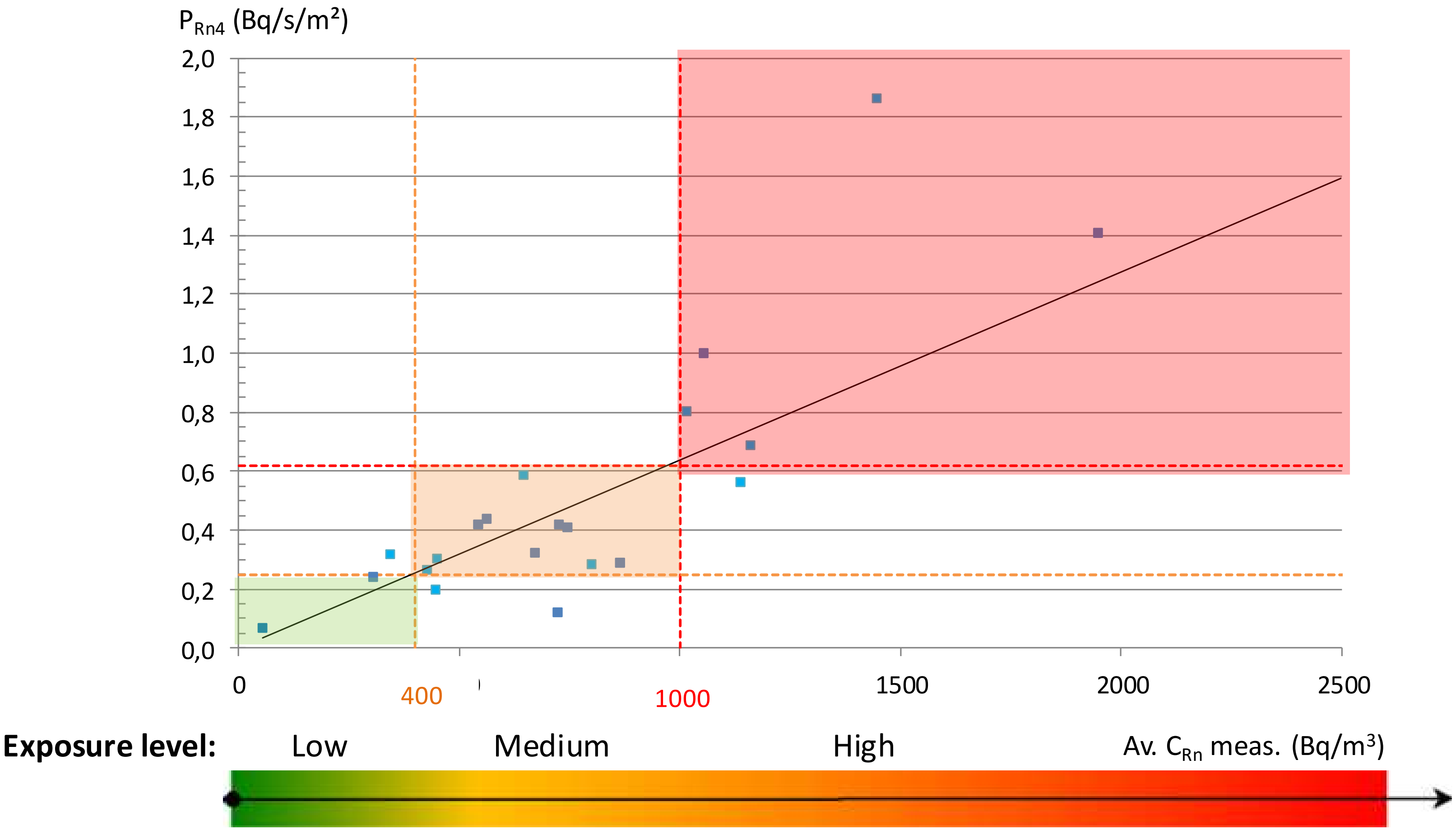
> Very permeable to very airtight dwellings

> Different ventilation systems

> Exposure to radon low to high: from 50 to 7 000 Bq/m^3, measured using two months with passive detector measurements

2) Characterization of indoor radon exposure in buildings

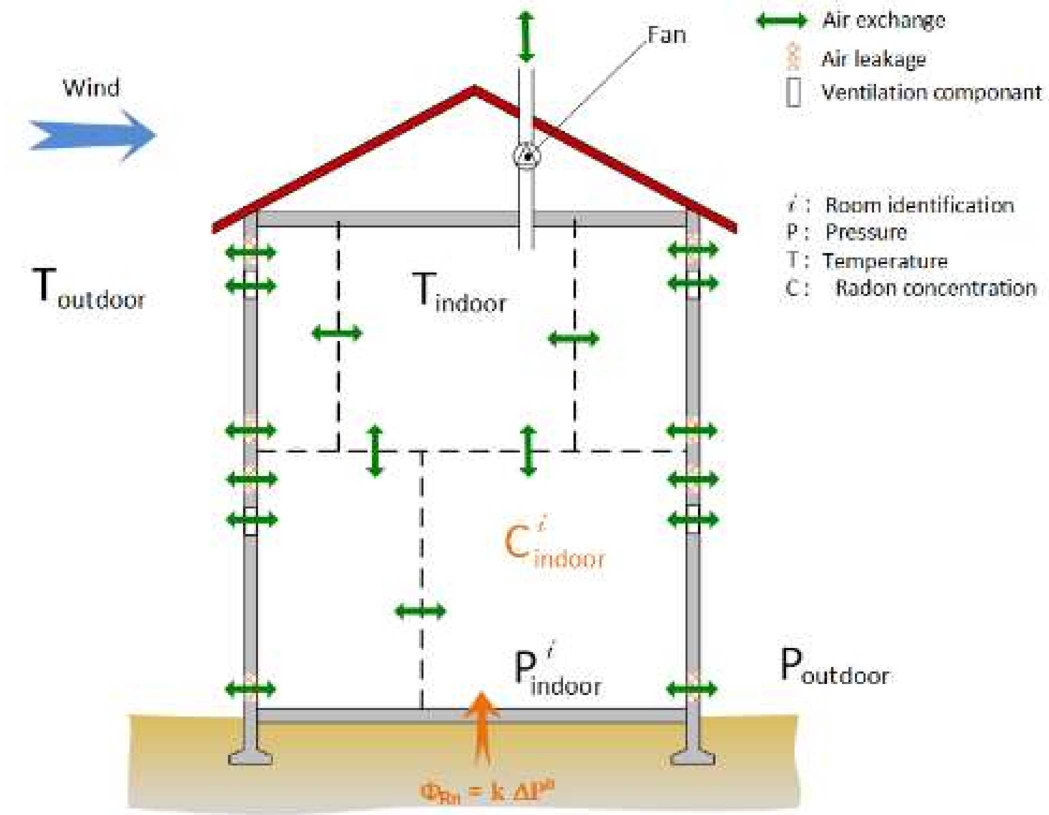
Comparison of radon entry potential (P_{Rn4}) with averaged indoor concentration measurement (Av. C_{Rn} meas.)



2) Characterization of indoor radon exposure in buildings

Assessment of averaged annual indoor radon concentration

Use of numerical model of ventilation in association with radon entry law



Unsteady Ventilation Model

Input data

- Dimensions and orientation of the dwelling
- Air-tightness of dwelling
- Ventilation system
- Annual local weather (Wind, Text)
- Rn entry law ($\Phi_{Rn} = K\,\Delta P^n$)

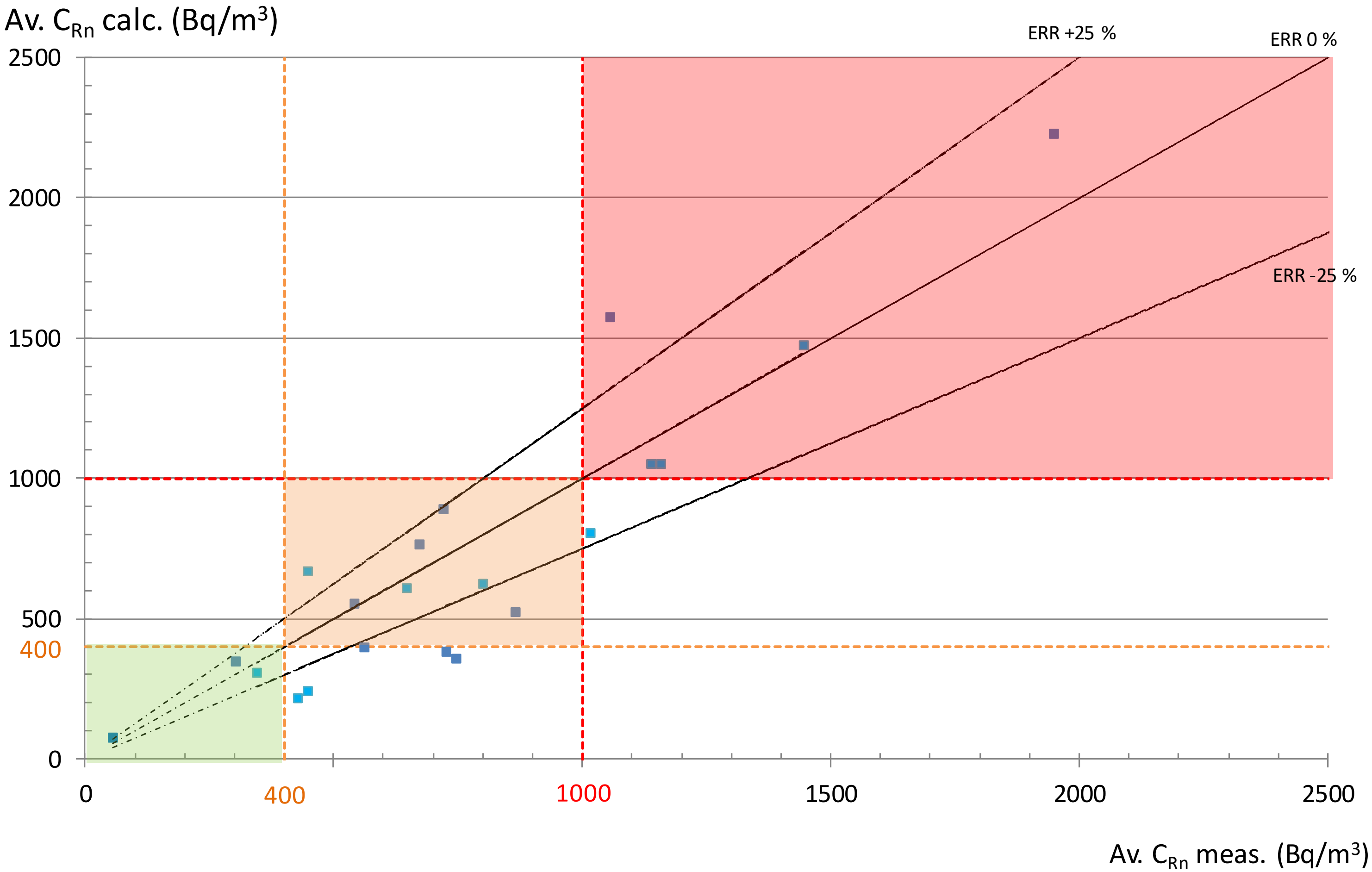
Resolution: mass balance equation

Results

- Building depressurization throughout the year
- Air exchange rate
- Indoor radon concentration (C_{Rn})

2) Characterization of indoor radon exposure in buildings

Comparison of calculated averaged indoor concentration (Av. C_{Rn} calc.) with averaged indoor concentration measurement (Av. C_{Rn} meas.)



2) Characterization of indoor radon exposure in buildings

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Constraints and limitations

Experiments with calm weather.

Numerical assessment of annual average concentration doesn't take into account occupant behavior (frequency and length of time of windows opening)

Promising results

Housing classification proposal

In most cases, consistent results

Strength of the method

Characterization performed in one day measurement, in every season

Publications

- Procedure for the characterization of radon potential in existing dwellings and to assess the annual average indoor radon concentration. Collignan B, Powaga E. Journal of Environmental Radioactivity, 2014 Jul 7;137C:64-70. doi: 10.1016/j.jenvrad.2014.06.024
- Development of a methodology to characterize radon entry into dwellings. Collignan B., Lorkowski C., Améon R. Building and Environment 57, 176 – 183, November 2012

3) Principles of building protection

3) Principles of building protection

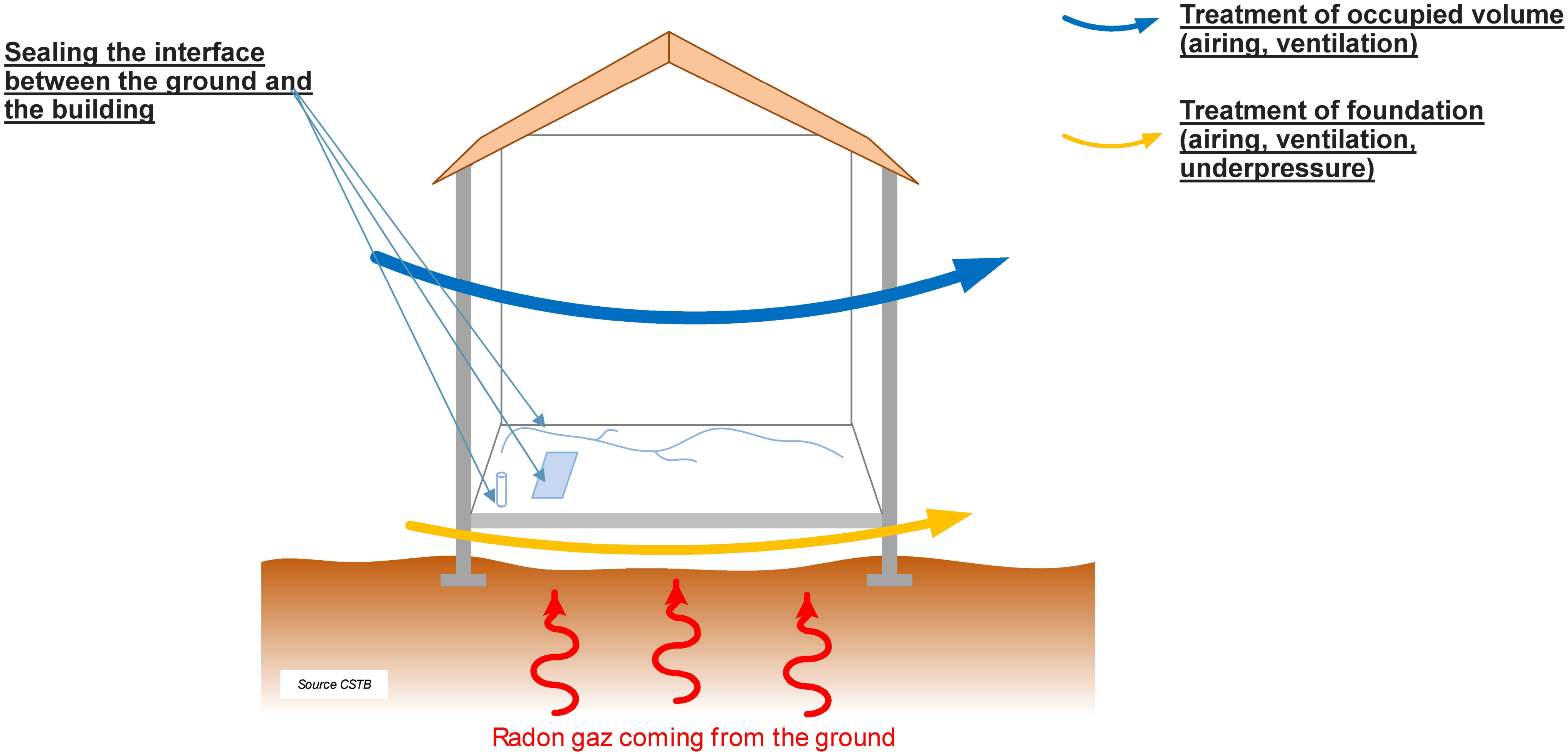
Two principles:

- ✓ To avoid radon entry into buildings
- ✓ To dilute indoor radon concentration

Three types or « groups » for solutions:

- ➢ Sealing the interface between the ground and the building
- ➢ Treatment of occupied volume (ventilation, pressure)
- ➢ Treatment of foundation (ventilation, pressure)

3) Principles of building protection



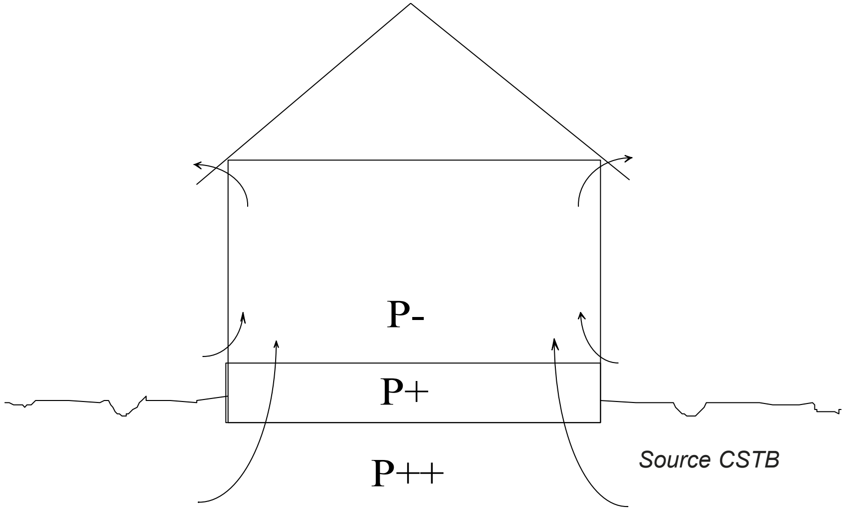
4) Soil Depressurization Systems (SDS)

4.1) SDS, principles

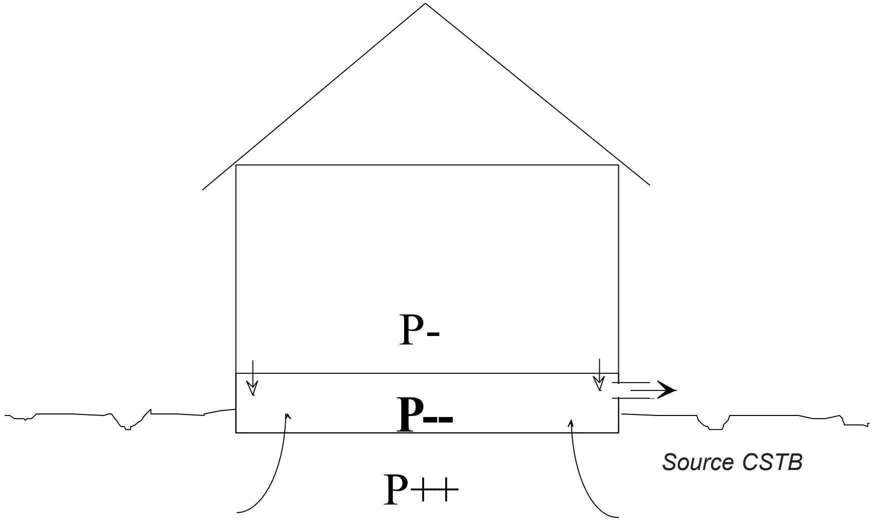
4.1) SDS, Principles

Treatment of foundation

Principle of Soil Depressurization System (SDS)



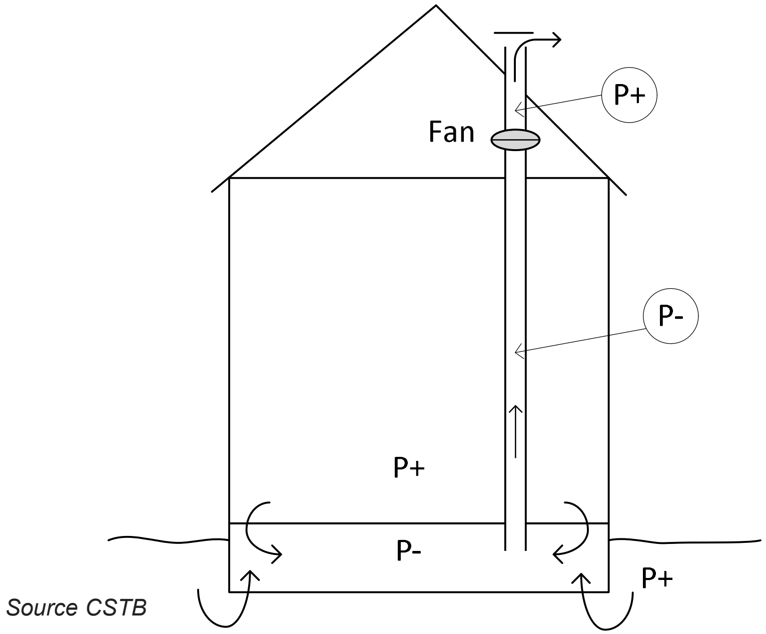
Initial pressure field



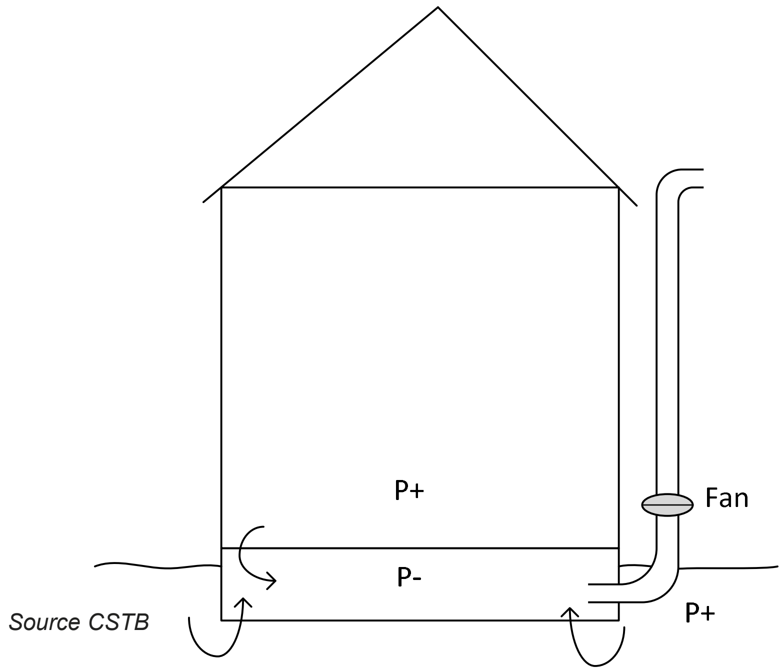
Pressure field generated with SDS

Treatment of foundation

Principle of Soil Depressurization System (SDS)



Internal position for extraction

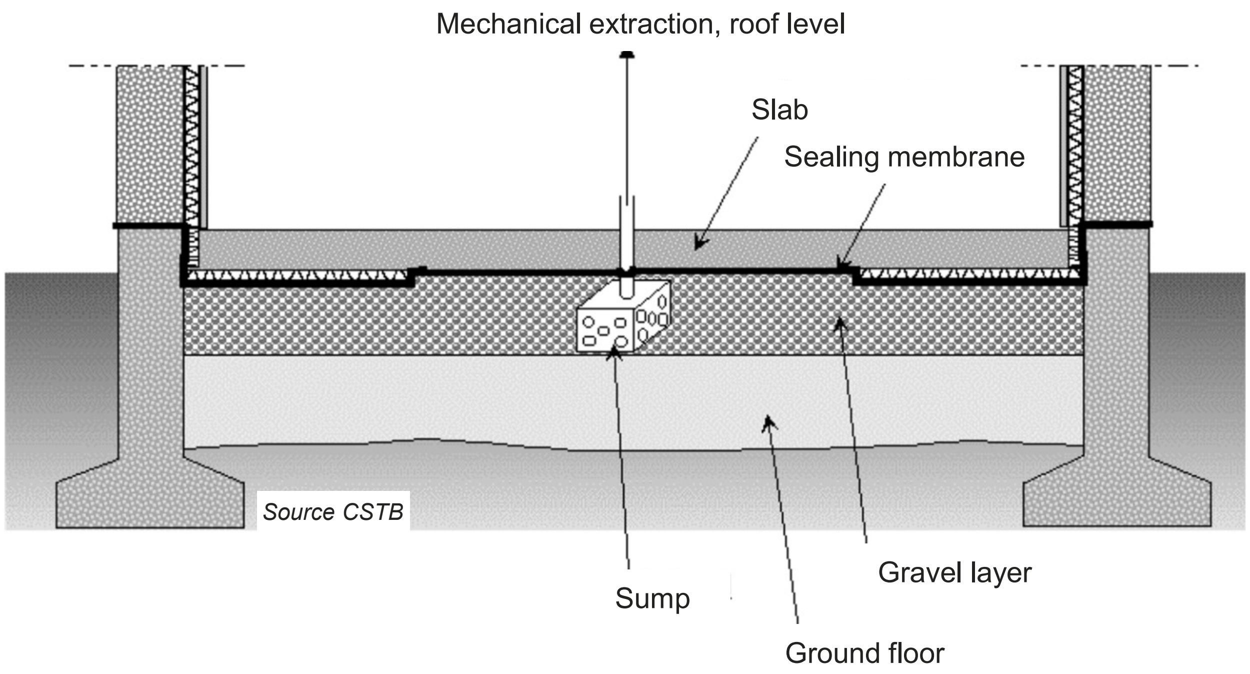


External position for extraction

4.1) SDS, Principles

Principle of SDS

- Example of installation in new building (or strong renovation)

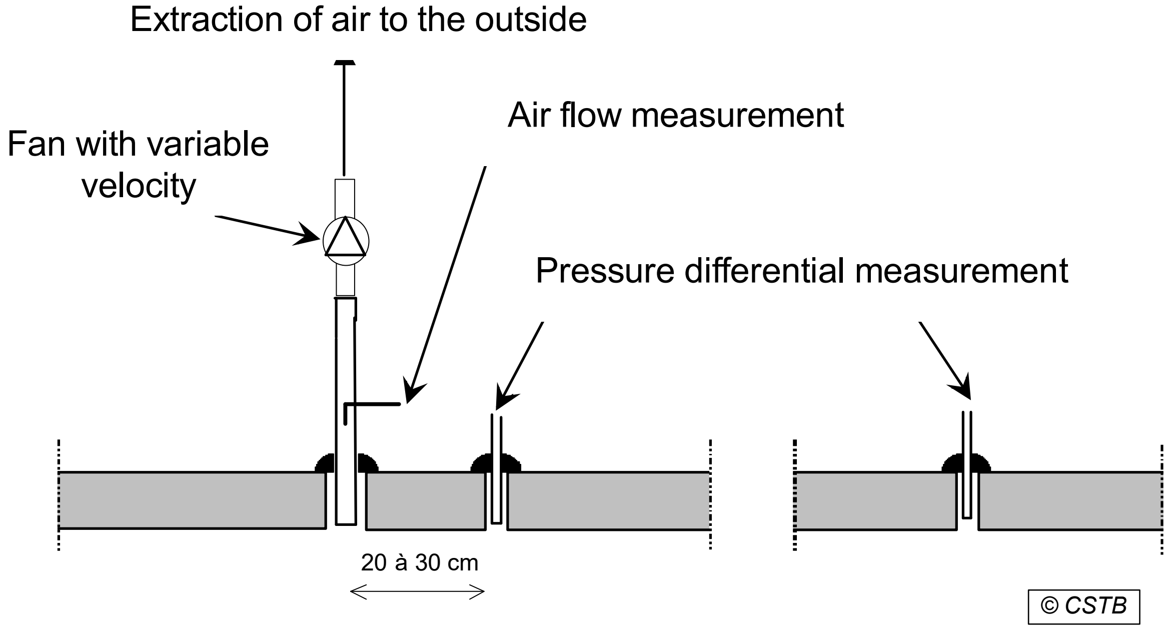


- Could be tested in existing building, depending on nature of foundation (generally slab on grade with gravel layer below)

4.2) SDS, existing buildings

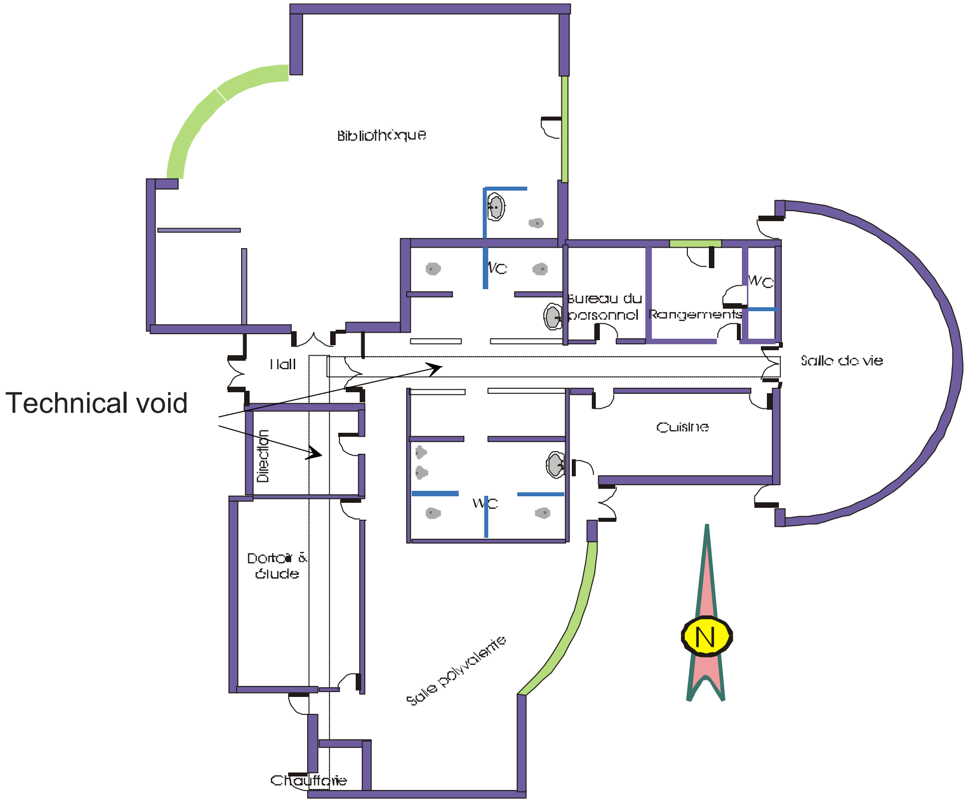
4.2) SDS, existing buildings

Feasibility and sizing test of SDS, principle (from US-EPA)



→ Presentation of two pilot studies for this test

4.2) SDS, existing buildings (1st pilot study)



Screening level: 1990 Bq/m^3

Built in 1995 using concrete bloks,

One floor of 630 m^2

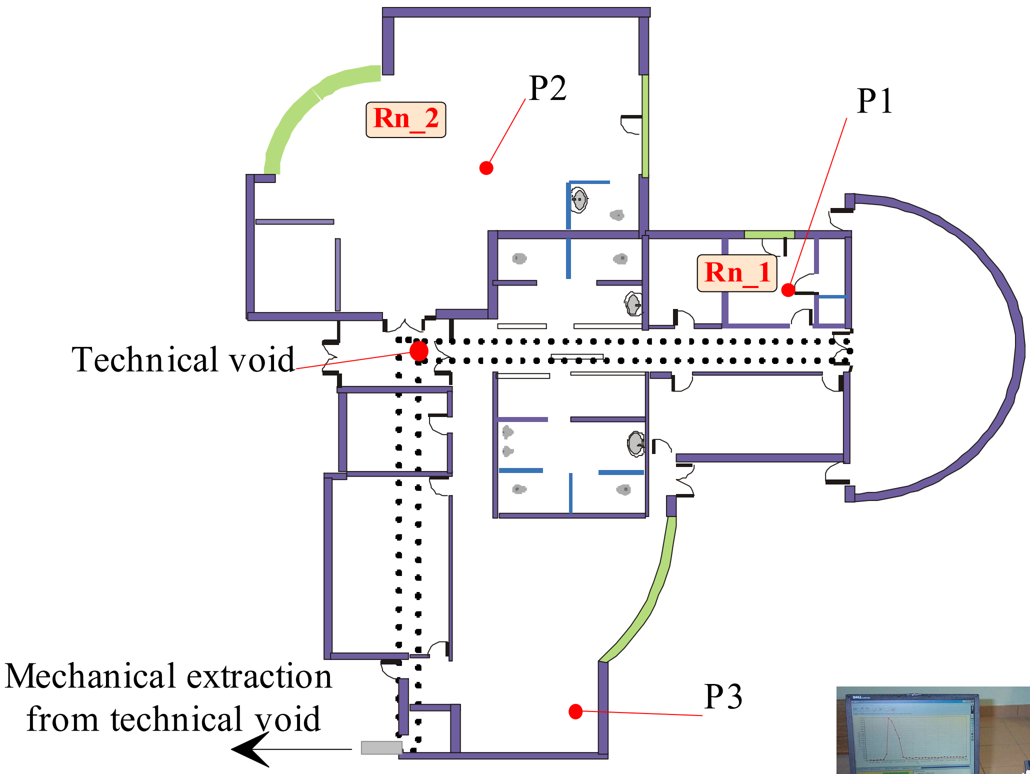
Concrete slab on grade with a technical void in central part (section 2 m x 2 m)

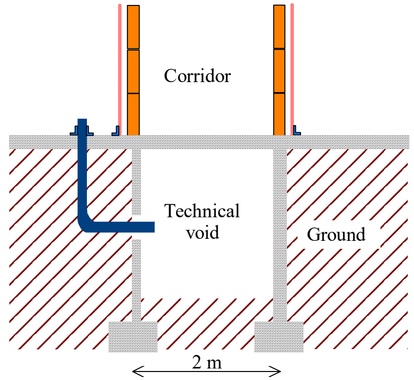
Exhaust mechanical ventilation system

Technical void

4.2) SDS, existing buildings (1st pilot study)

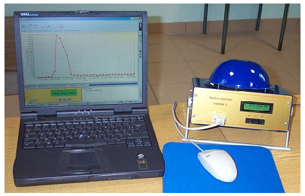
Test of SDS



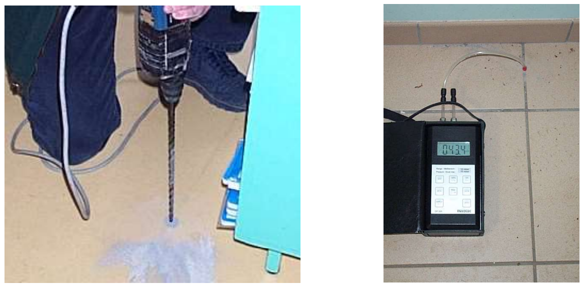


Technical void

Mechanical extraction from the void



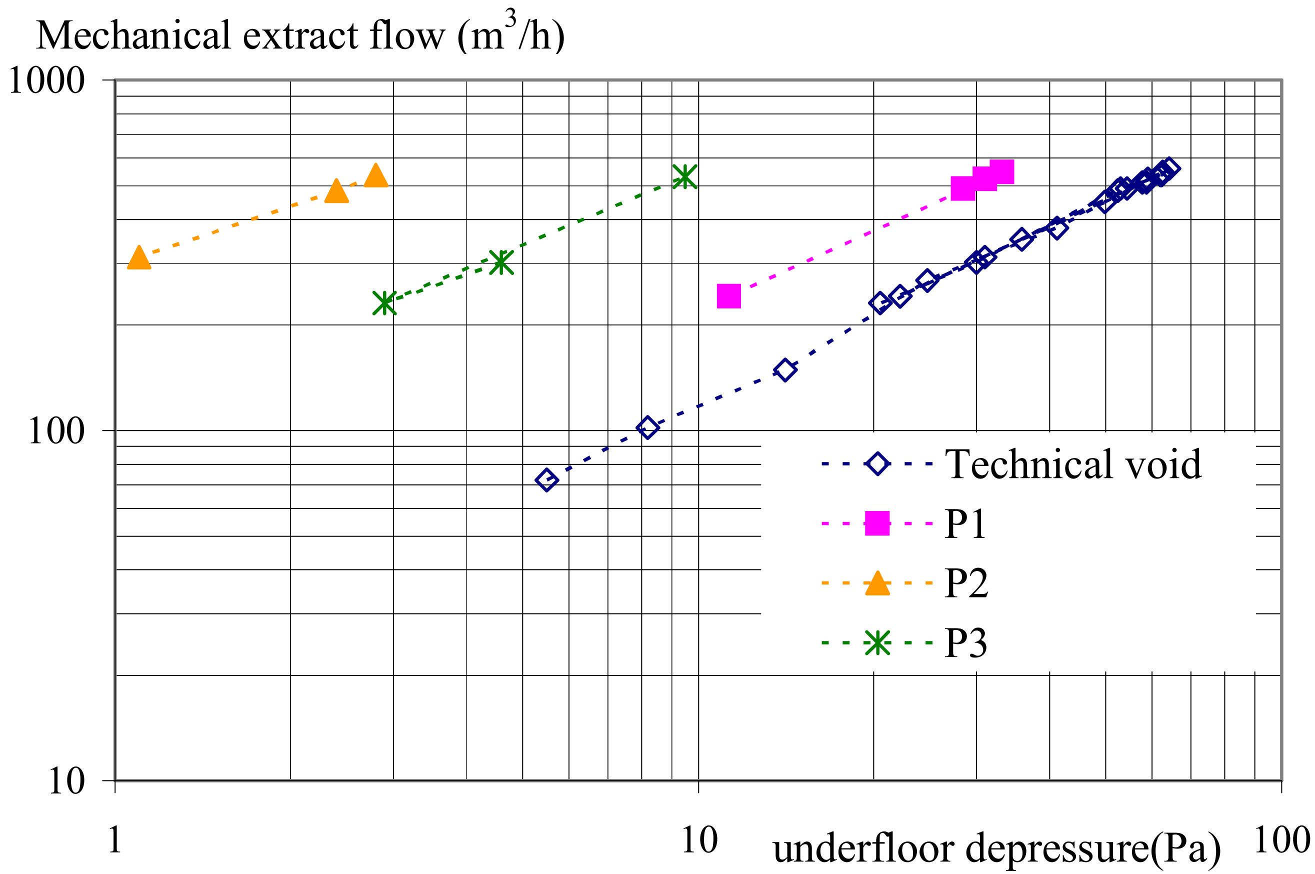
Radon measurement



Pressure measurement below slab P1, P2, P3

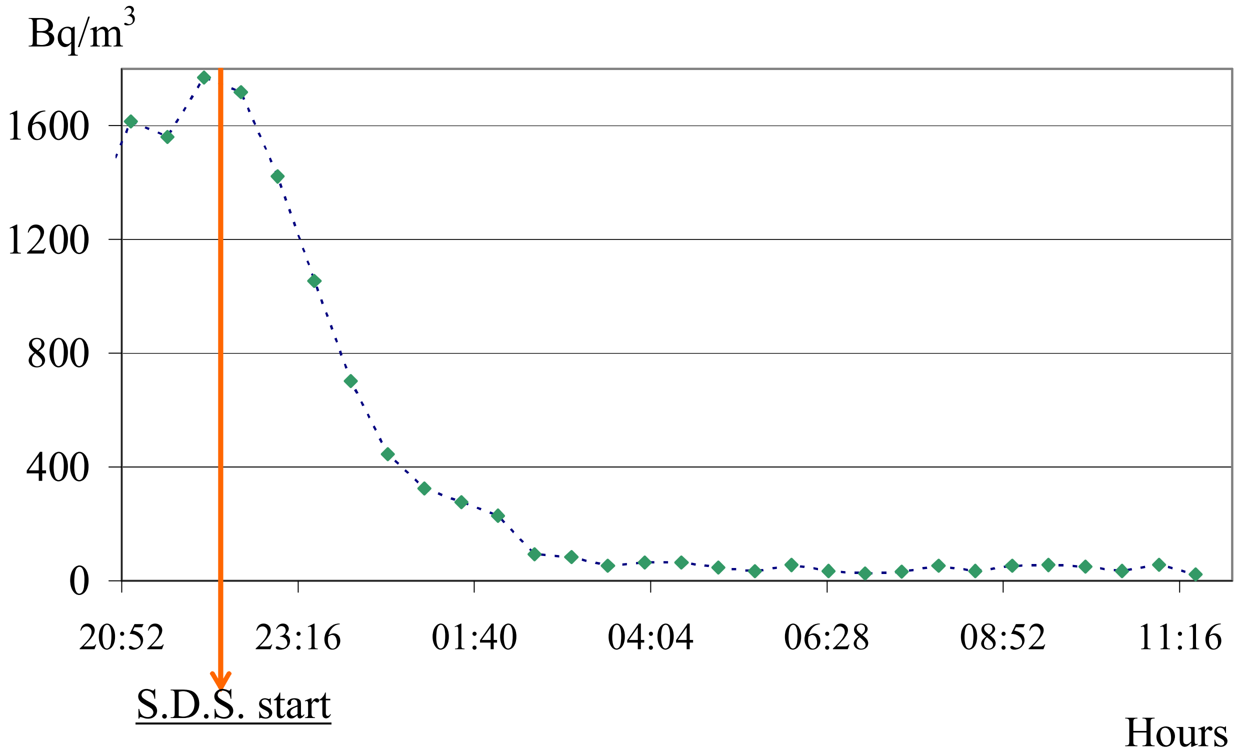
4.2) SDS, existing buildings (1st pilot study)

Sealing interface and SDS test results



4.2) SDS, existing buildings (1st pilot study)

Evolution of indoor radon concentration



Exhaust from void of 0.5 m³/h/m²

4.2) SDS, existing buildings (1st pilot study)

Corrective actions works

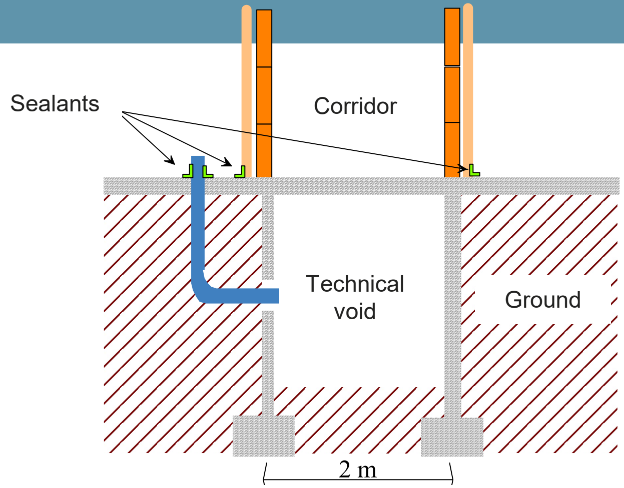
- Sealing of the slab
- Exhaust level on void:

  450 m^3/h

  corresponding to 0.7 $m^3/h/m^2$ of ground
- Upgrade of building ventilation

Measurement control: 37 Bq/m^3 (eff. : 95%)

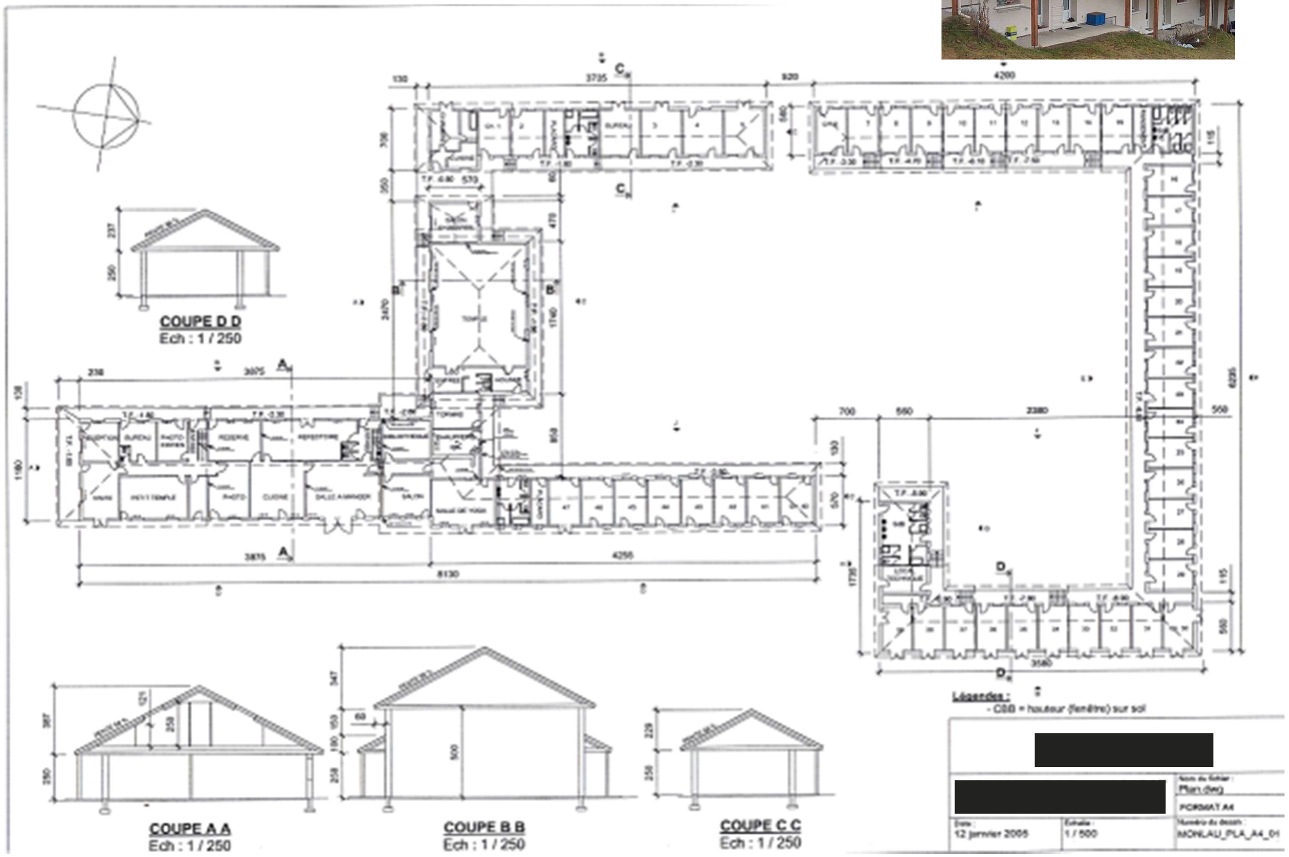
Cost : 15 000 €.



Sealing slab

Exhaust fan in technical void

4.2) SDS, existing buildings (2nd pilot study)



Screening level:

Different rooms above1000 Bq/m^3

Built in1994 in concrete, one level

Concrete slab on grade

Natural airing with air entrance for each room

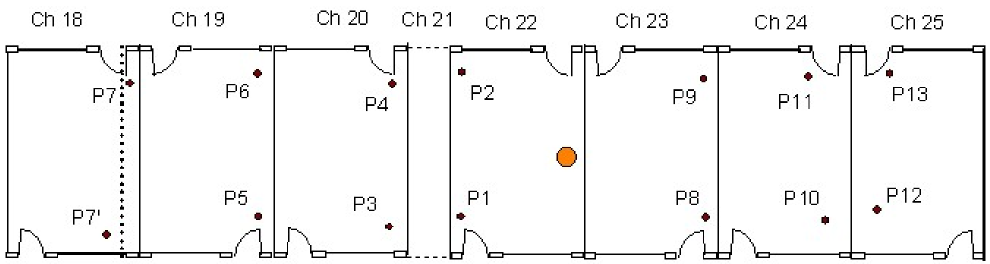
4.2) SDS, existing buildings (2nd pilot study)

Test of SDS

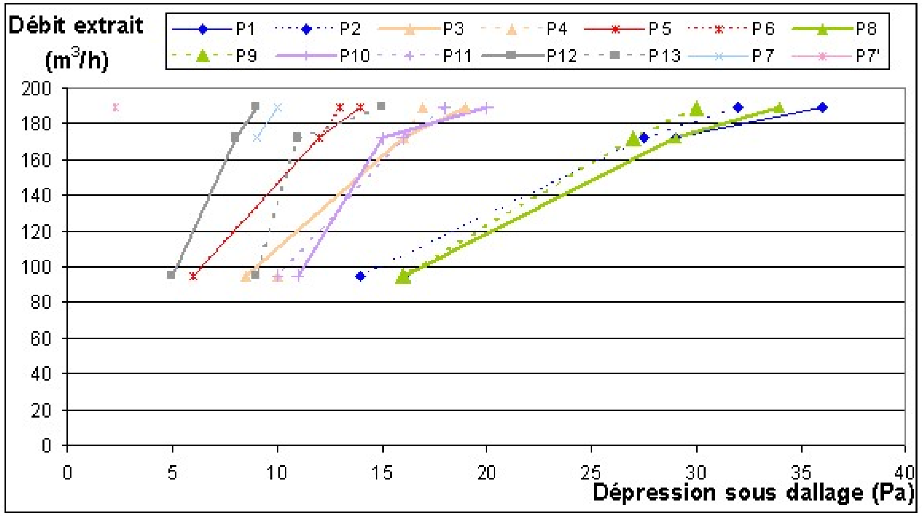
Installing 6 points for extraction in different rooms

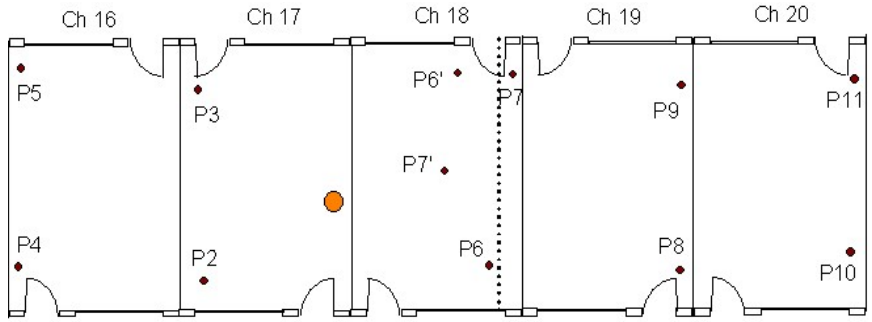
4.2) SDS, existing buildings (2nd pilot study)

Test results (six different locations)

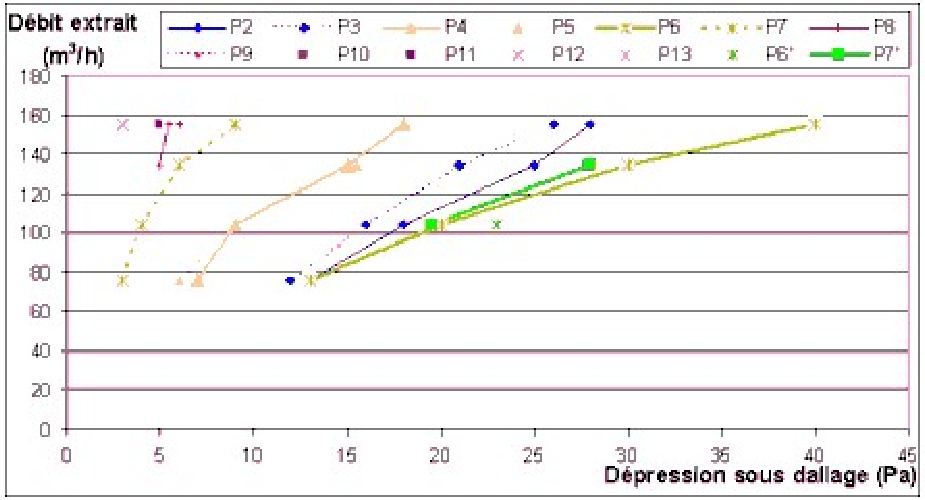


Extraction point
Pressure meas.



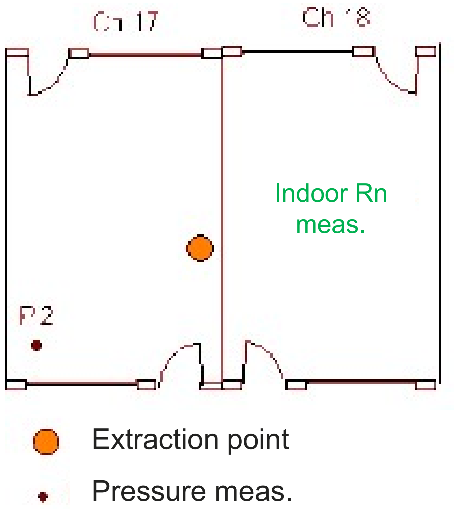


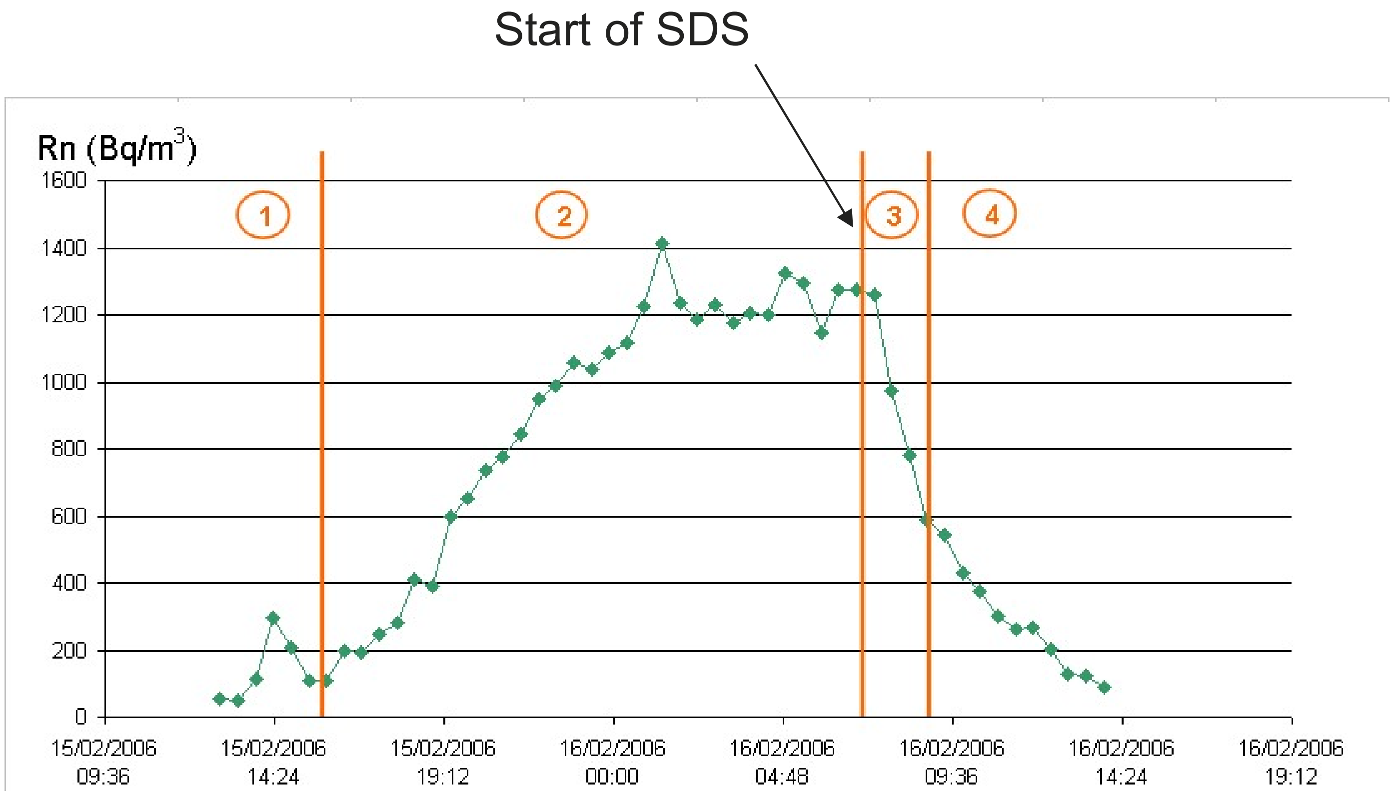
Extraction point
Pressure meas.



4.2) SDS, existing buildings (2nd pilot study)

Indoor radon concentration evolution





4.2) SDS, existing buildings (2nd pilot study)

Corrective actions works

- Installing exhaust fan on each point for SDS

Exhaust duct

Exhaust fan below roof

Measurement Control

	Screening (Bq/m^3)	Control (Bq/m^3)	Efficiency (%)
Room 11	1 106	133	**88**
Room 12 (exhaust)	1 741	34	**98**
Room13	570	49	**91**
Room14	**601**	**68**	**89**

Cost : Around 2 000 € + labour

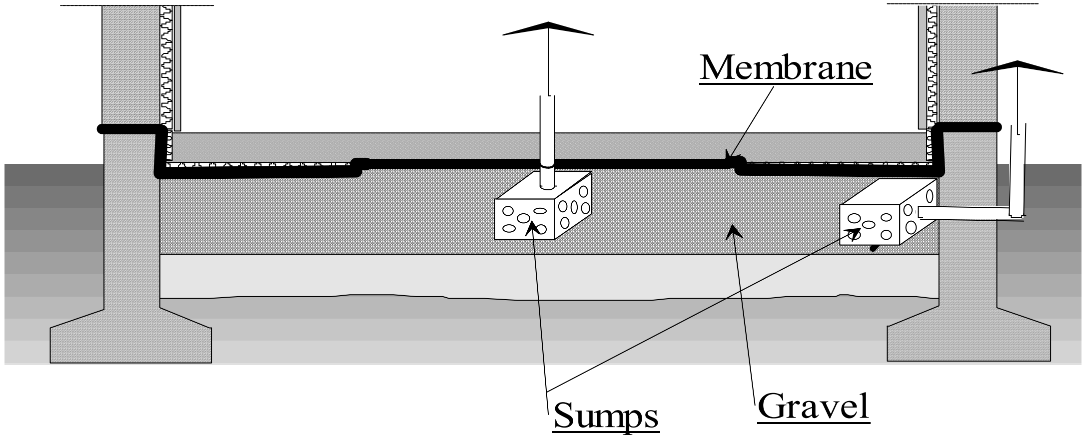
4.3) SDS, new buildings

4.3) SDS, new buildings (experimental house)

Experimental house to study links between ventilation and indoor air quality in housing sector

4.3) SDS, new buildings (experimental house)

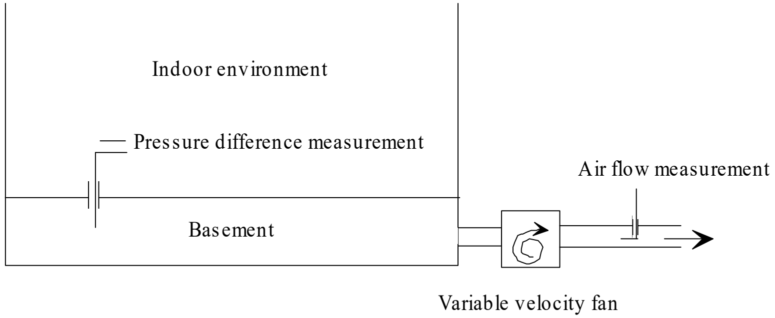
Installing a SDS during construction

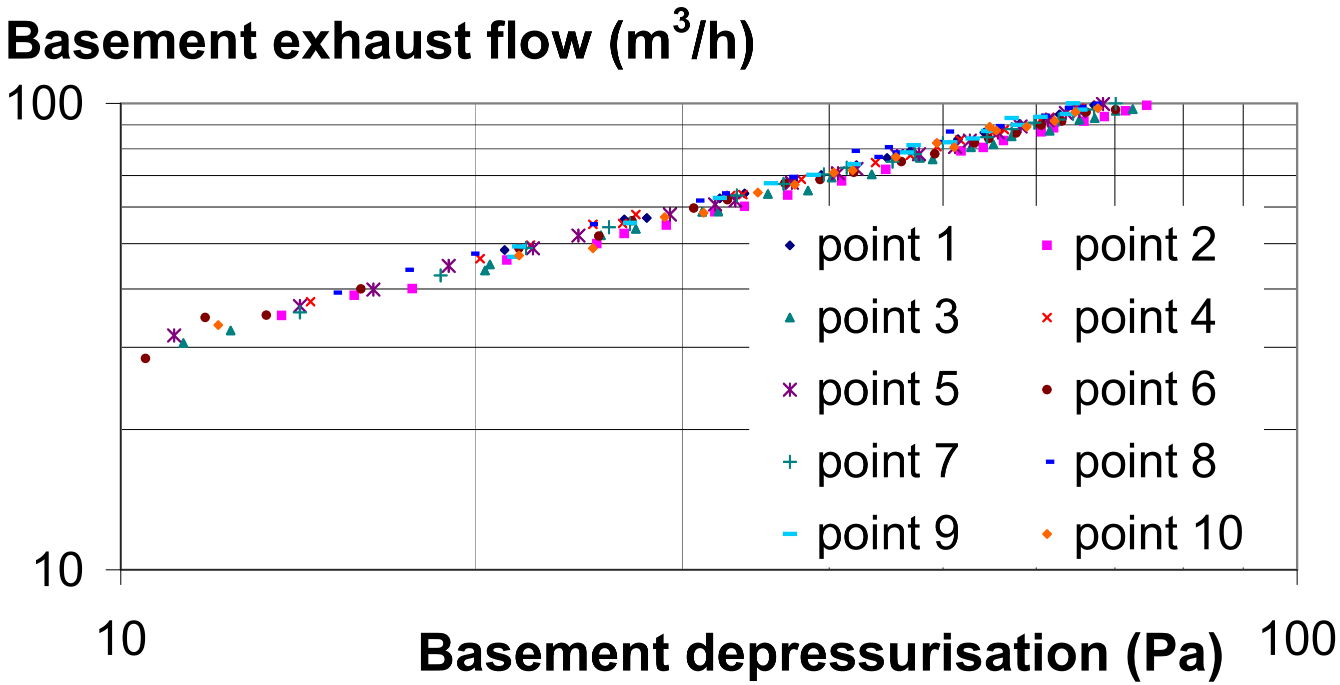


Holes managed through concrete floor for pressure measurements

4.3) SDS, new buildings (experimental house)

Characterisation of basement permeability





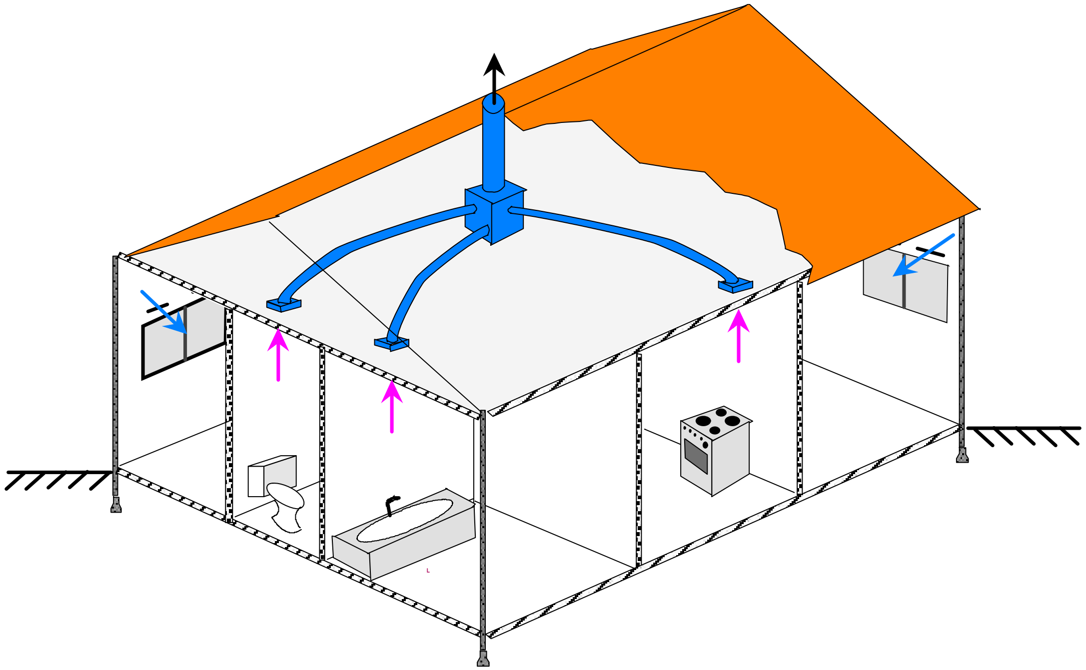
→ Running point :

5-10 Pa ; 20-30 m^3/h

4.3) SDS, new buildings (experimental house)

Basement depressurization using mechanical exhaust ventilation system

Description of mechanical exhaust ventilation principle in a dwelling

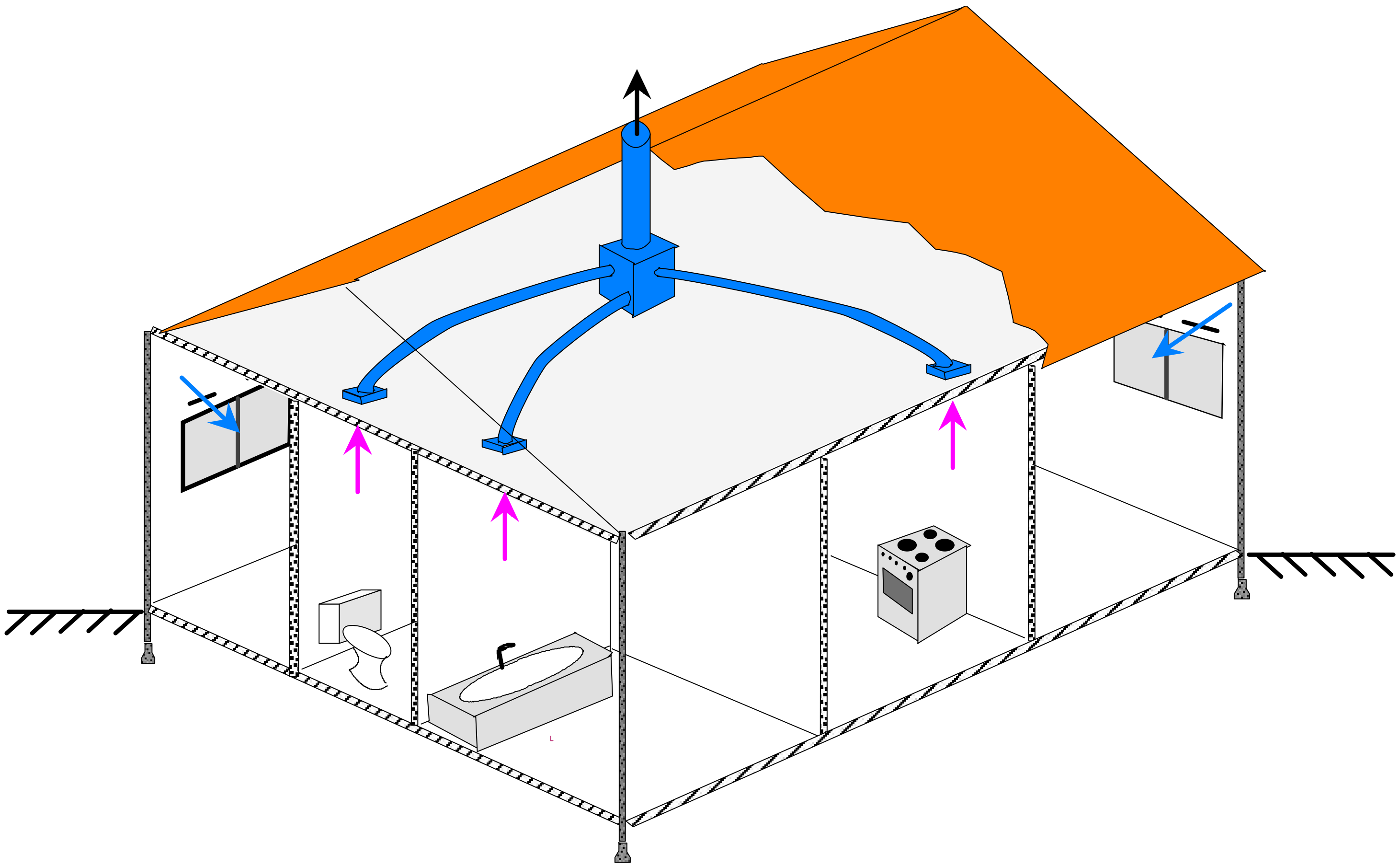


Kitchen	45 m^3/h
Kitchen, high flow, cooking activity	135 m^3/h
Bathroom	30 m^3/h
Toilet	30 m^3/h
Optional other bathroom	30 m^3/h
Optional other toilet	15 m^3/h

-- 5 living room

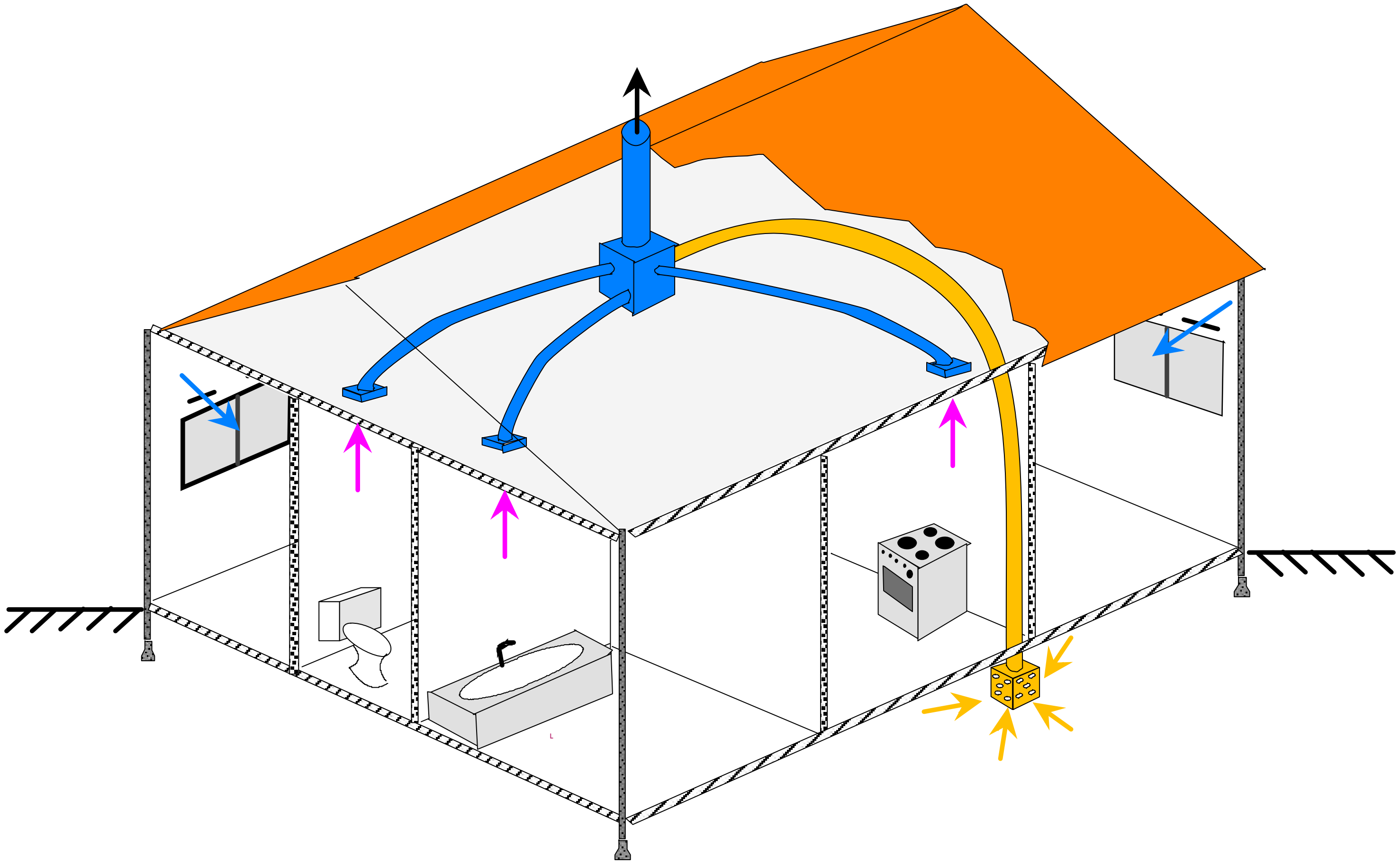
-- self regulated registers to obtain required exhaust flow

4.3) SDS, new buildings (experimental house)



classical installation of exhaust ventilation system

4.3) SDS, new buildings (experimental house)



SDS connection to the exhaust unit

4.3) SDS, new buildings (experimental house)

Different configurations tested:

- Two ventilation configurations
- Three cases of exhaust flow level for SDS
- Low and high exhaust flows tested for each case

4.3) SDS, new buildings (experimental house)

Results

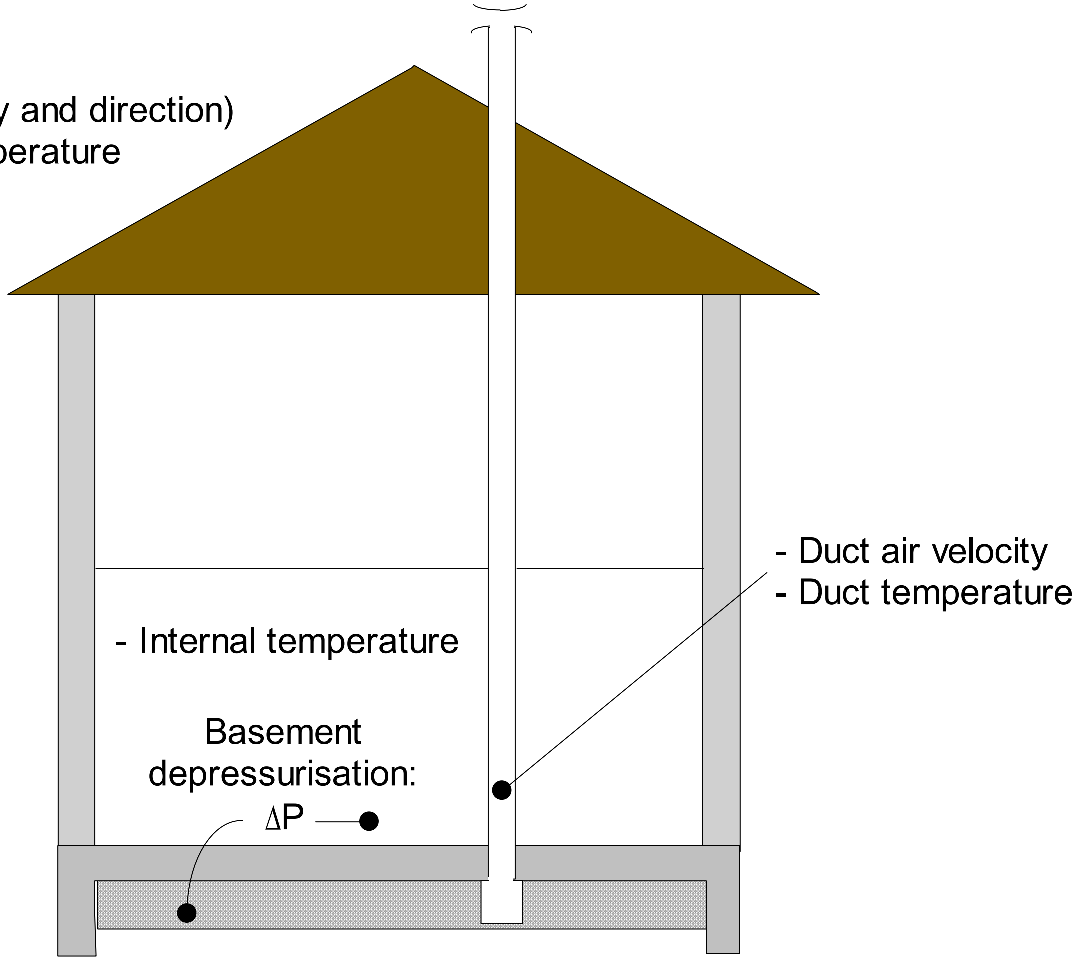
		Dwelling ventilation			S.D.S.	
		Kitchen exhaust flow (m^3/h)	Bathroom exhaust flow (m^3/h)	Toilet exhaust flow (m^3/h)	basement exhaust flow (m^3/h)	***Basement depressurization (Pa)***
Only mechanical ventilation	Low velocity	55	35	34		
	High velocity	149	30	30		
Sump with 15 m^3/h theoretical register	Low velocity	52	34	33	20	***5.8***
	High velocity	131	29	28	17	***4.8***
Sump with 30 m^3/h theoretical register	Low velocity	52	35	33	32	***12***
	High velocity	140	31	30	28	***9.9***
Sump connexion with no register	Low velocity	49	32	31	45	***18.9***
	High velocity	123	29	29	40	***14.9***

Kitchen, bathroom and toilet connection configuration

Experimental study on passive sub-slab depressurisation system

Protocol

- Wind (velocity and direction)
- External temperature



Basic extractor

Optimised shape to enhance the impact of wind on extraction flow

→ One year follow up

4.3) SDS, new buildings (experimental house)

Preparation of basement: need to install new sump with 200 mm diameter

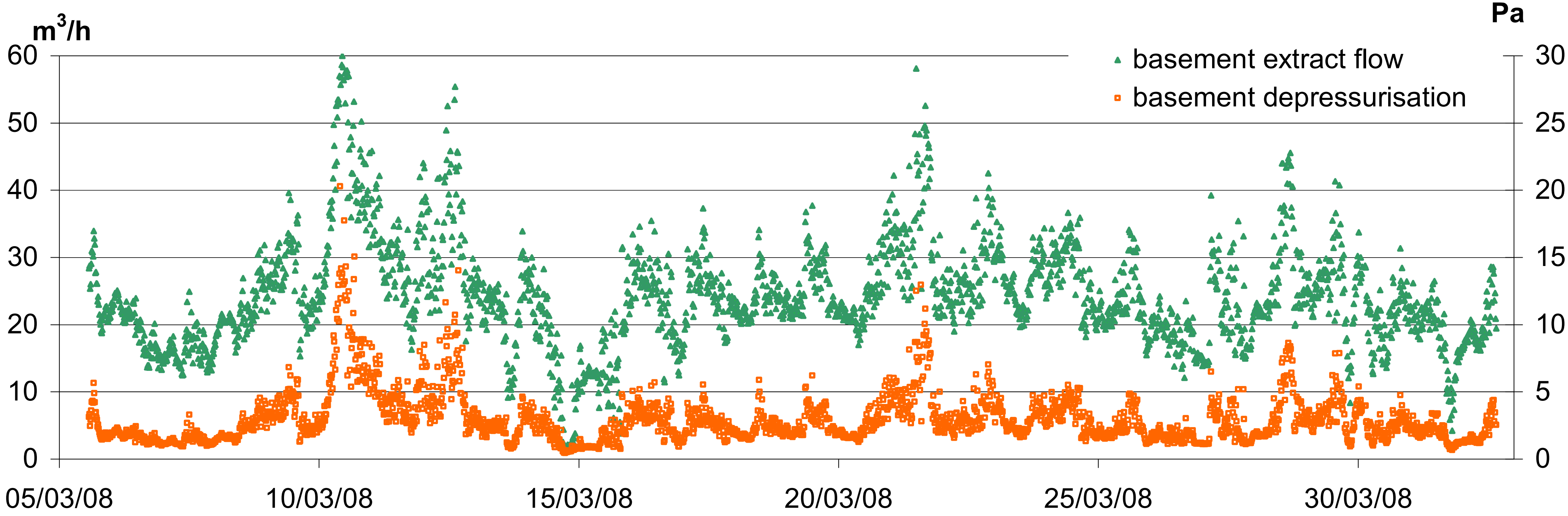






4.3) SDS, new buildings (experimental house)

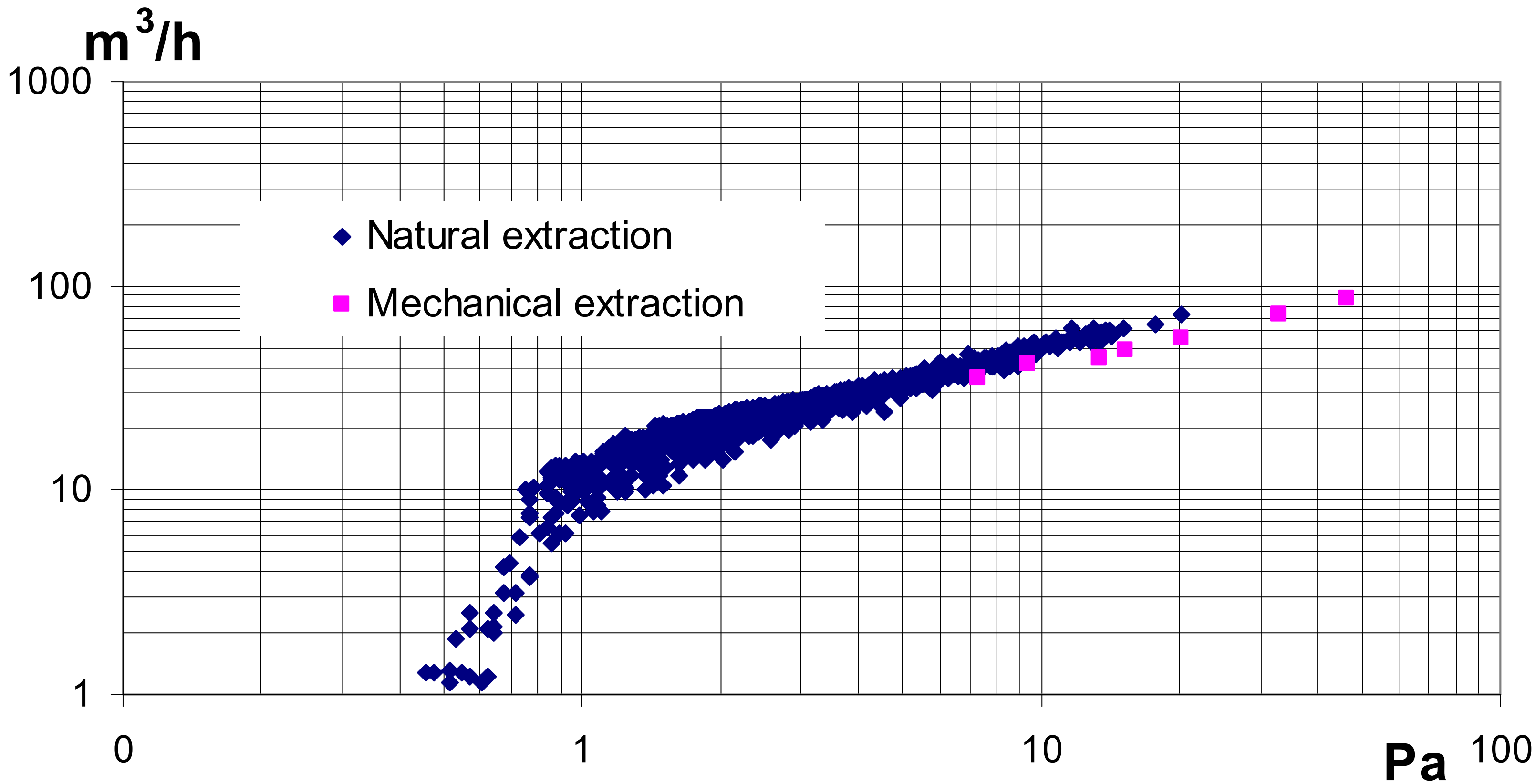
Monthly results



Evolution of basement extract flow and basement depressurisation during time

4.3) SDS, new buildings (experimental house)

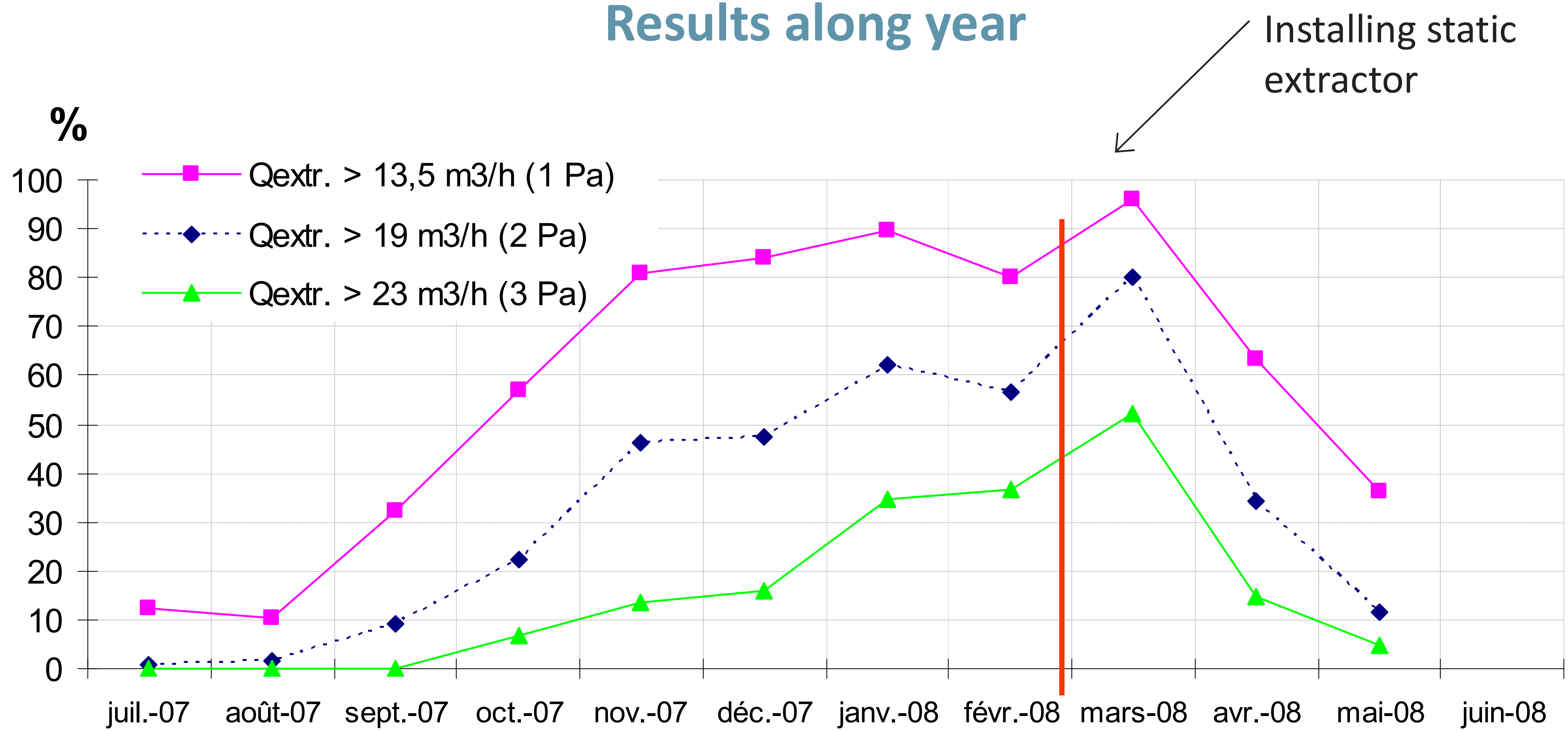
Natural characterisation of basement depressurisation



Comparison of basement depressurisation function of basement extract flow for natural and mechanical extraction

4.3) SDS, new buildings (experimental house)

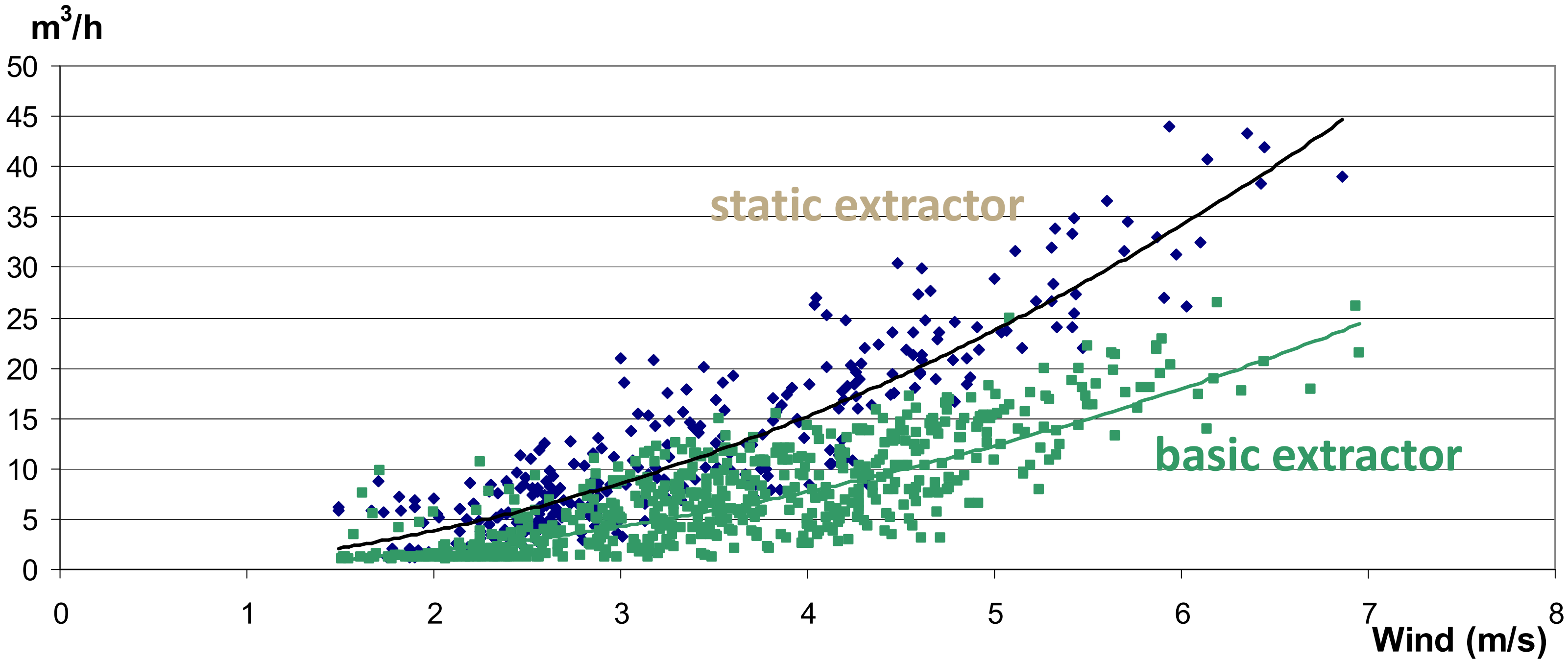
Results along year



Percentage of running time of the system along year above three thresholds

4.3) SDS, new buildings (experimental house)

Impact of static extractor



Extract flow from basement function of wind velocity (temperature difference < 4° C)

- Higher flow with static extractor, around twice
- Fluctuations of extraction for a given wind

4.3) SDS, new buildings (experimental house)

ANALYSIS FOR NATURAL SDS

- high variability of running along the year and even during a day
- significant percentage of running along year and mainly in winter season
- positive impact of static extractor on extract flow from basement

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Conclusions

→ Public health challenge to develop good practices for building management

→ To diminish efficiently indoor radon population exposure

- Relevant characterization of initial situations
- Recommendation and implementation of building protections adapted to a given context
- Development of professional skills

Thank you for your attention!