# MARIA: AN EXPERIMENTAL TOOL AT THE SERVICE OF INDOOR AIR QUALITY IN HOUSING SECTOR

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## ABSTRACT
CSTB has built an experimental house MARIA: **M**echanised house for **A**dvanced **R**esearch on **I**ndoor **A**ir. The house is dedicated to study pollutants transfers, test ventilation systems, settle field investigation methods, and validate computational models.

MARIA will be instrumented and automated according to pre-established scenario of operation reproducing parameters related to human presence and behaviour. The human presence is simulated with heat load and water vapour and pollutants emission. The operation of equipments such as doors and windows, domestic devices, will be automated. Indoor air quality parameters, meteorological parameters, outdoor pollutants and parameters related to house appliances will be measured.

The control system of the house can manage both the measurement and automation systems. In this way, the experiments can be performed not only for pre-established scenario, but priority commands derived from measurements can be taken into account. Demand-controlled strategies based on measured environmental parameters can be studied.

## INDEX TERMS
Laboratory, Measurement methods, Residences, Air transfers, Human activities

## INTRODUCTION
People typically spend 90% of their lives indoors. The effect of indoor exposure is therefore very important for people's health and well-being. Many people experience that their health and well-being deteriorate when they stay in their dwellings or workplace, in schools or other premises. There is a growing incidence of symptoms and many consider the exposure to indoor climate to be the main reason. It is essential that buildings be designed to meet basic human requirements for a healthy and comfortable indoor environment. To gather more knowledge about the buildings effects on human health, CSTB has at its disposal a number of unique facilities for multidisciplinary research. This set of facilities, so-called "ARIA Laboratories" gathers 2000 $m^2$ of laboratories and facilities for carrying out research and experimentation connected with evaluation and management of sanitary risk in the area of air and water.

One of these facilities is the experimental house, called MARIA (**M**echanised house for **A**dvanced **R**esearch on **I**ndoor **A**ir), the aim of which is to study pollutants transfers for given sequences of everyday life. The paper presents the tool and its capabilities, the method for piloting the house and the first results obtained.

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**DESCRIPTION OF THE HOUSE**

The house has been built as the usual construction process for the French single-family dwellings. The basic structure is load-bearing masonry. The walls are built with concrete block with polystyrene inner insulation. The house has three floors of 71 $m^2$. At the ground floor there are the garage and the control room for the management of experiments; at the first floor there are the living room, the kitchen and the toilet; at the second floor there are four bedrooms, the bathroom and the shower room. The total surface area is 214 $m^2$ and the total volume is 507 $m^3$. The habitable surface area - 1$^{st}$ and 2$^{nd}$ floors – covers 143 $m^2$. MARIA house is equipped with furniture and floor and wall coverings commonly used in the French market in order to be realistic in terms of pollutant emission from materials. Furniture and coverings can be easily changed as need of experiments.

The façade is equipped with purpose-made circular openings of a 5 cm diameter in order to simulate various air leakages which can affect the ventilation system operation. Five openings are located close to each window at different levels above the floor. The openings can be closed up, in order to make possible to simulate leakage located either at the bottom of the room, or at the top. When the five openings are opened, an equally distributed air leakage can be simulated.

The house is equipped with various ventilation systems: passive stack shafts, mechanical exhaust ventilation and balanced ventilation. In addition in the kitchen, there is a cooker hood which can operate either in extract air or in recirculated air (Figure1). In this way, the effect of ventilation type on indoor air quality (IAQ) can be studied. Two heating systems have been installed: electric convectors and hydronic floor heating. The boiler of the floor heating is located in the kitchen (Figure 1). We can expect that the pollutant emission from the floor covering will be noticeably different depending on the type of heating system. In addition, a fireplace could be put in the living room.

**Figure 1**. View of kitchen.
At the right of the gas/electric cooker is the actuator for its automated operation

MARIA house is equipped with a radon sump system and a tracer gas injection system for simulating the radon in the ground basement. In addition, pipes have been put in to measure pressure and concentration in the basement. These pipes also enable to vary the basement air leakage. This equipment makes possible to test the soil depressurisation system.

The house has also a rain water recovery system. The rain water is collected from the roof in a 3000 l tank, located in the ground floor, connected to the toilet. The studies will mainly aim to test water recovery and reuse efficiencies and the sanitary quality of the rain water. They will be performed under conditions simulating the actual behaviour of a four persons family using toilet flush.

## METHOD

The method is based on both the measuring IAQ-related parameters and the simulation of human occupation from all its sides. For this, we use pre-established scenario of operation reproducing parameters related to human presence and behaviour. For a given experiment, the scenario runs in time for automation tasks defined in each room of the house. The duration of an experiment is typically one week. Figure 2 describes the whole functional frame of control system; the software controlling the measurement and automation system will be developed under Labview® environment.

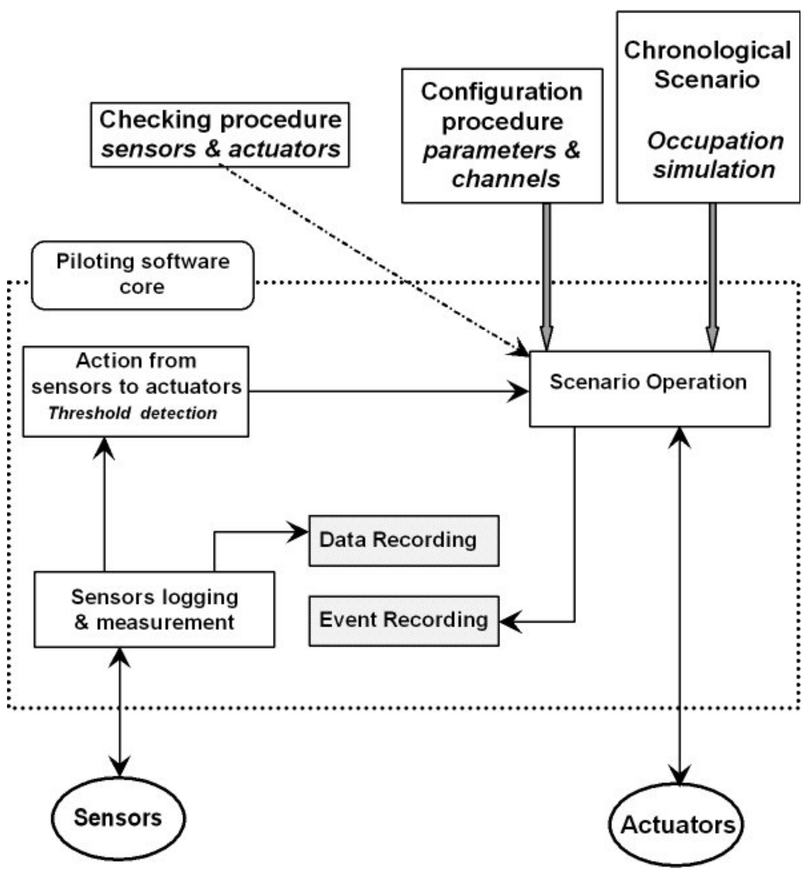


**Figure 2**. Overview of the control system

The human presence is simulated in each MARIA room with head load, water vapour and pollutants emission. Pollution inside certain service rooms, such as the toilet, can be simulated by tracer gas injection reproducing human bioeffluents. The simulator will be able to reproduce up to five persons family.

The human behaviour is simulated by automation of the operation of windows, of internal doors, of rolling shutters. Switching electrical lighting, operation of taps, domestic devices, sanitary appliances will be automated too. In particular, the starting up of the cooker will be automated in order to simulate the production of $H_20$ in the kitchen. The automation of shower and bath makes possible the vapour production in services rooms.

Maria will be equipped for measuring the main meteorological and environmental parameters outdoors (temperature, humidity, wind speed, rain, solar radiation, CO, $CO_2$, $SO_2$, NO, $NO_2$, $O_3$, VOC,… ), the main IAQ parameters (temperature, humidity, horizontal illuminance, $CO_2$, combustion products, particulate matter, VOC, bacteria and fungi,…) and the parameters related to house appliances (e.g. flow rates in ducts). Tracer gas techniques will be used to assess the air change rates and the air flow rates exchanged between rooms.

The control system of the house can manage both the measurement and automation system. In this way, the experiments can be performed not only for pre-established scenarii, but priority commands derived from measurements can be taken into account thanks to connection between both systems which is planned in the control software (Chambille and Gilliot, 2001). For example, if it is expected opening windows, but if, at this time, it is raining heavy and the wind is blowing in gusts, windows operation must be aborted.

The ability to connect measurement system with automation system enables to study demand controlled strategies. For example we can control the operation of window by response to one sensor, such as temperature. But it possible also to get operation control based on two or more parameters; for example window operation controlled by temperature and mixed gas sensors. When the means of controls require more parameters, decision tables have to be used.

MARIA, its equipments and its control system are designed to operate automatically without occupants indoors. For the experiments, human occupation will not be real but simulated in order to have a better control of the behaviour. But nevertheless, for certain experiments where real occupants presence is needed, we will be able to operate with one or several persons indoors MARIA.

## FIRST RESULTS

This experimental tool is being developed; in particular the software core for controlling both measurement and automation systems which should be delivered in six months. However, the first works have been performed in the house.

The air tightness of the envelope has been tested by depressurisation method using a blower door. The air leakage rate was equal to 1.1 ach@4 Pa (Vedel, 2000); this air tightness was not satisfactory. Measures have been taken in order to reduce as far as possible the fortuitous air leakage. After the first sealing works, the air tightness level was 0.95 ach@4 Pa. After the second sealing works, covering half the envelope surface area, the air tightness of MARIA is 0.7 ach@4 Pa. We expect to more improve air tightness when the whole envelope will be treated.

Experiments aiming to test the radon sump have been performed. The first results showed that it is easy to create a homogeneous negative pressure in the basement with a low extract air flow rate.

Olfactory tests were conducted in MARIA using trained panels in order to compare field sensory evaluation with laboratory assessment. The results are published elsewhere (Ramalho, 2002).

## CONCLUSION AND PERSPECTIVE

MARIA is an experimental tool especially adapted for studying indoor air quality within dwellings. Thanks to both automation and measurement systems, chronological scenario of human occupation and behaviour will be simulated and air quality parameters will be measured indoors and outdoors. The main research works will deal with emission and transfer of pollutant, assessment of indoor air quality and indoor climate. But other studies could be carried out such as test of ventilation system, test of air process devices, test of ventilation strategies, test of methods for field investigations and validation of numerical models.

The characterisation of the house and its equipments is needed to make possible a relevant analysis of phenomena affecting the indoor environment conditions. Especially, we need to better know the envelope air tightness, the actual characteristics of the ventilation systems and pollutant emission levels from furniture and coverings.

## ACKNOWLEDGEMENTS

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