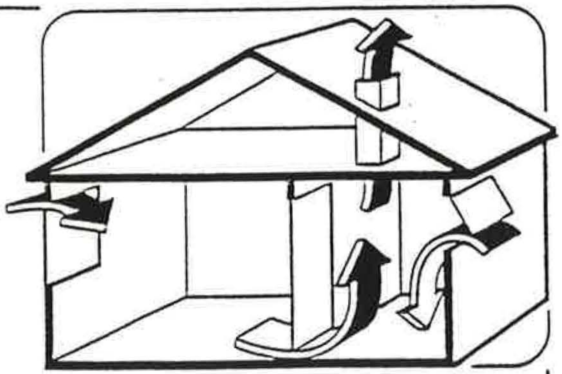
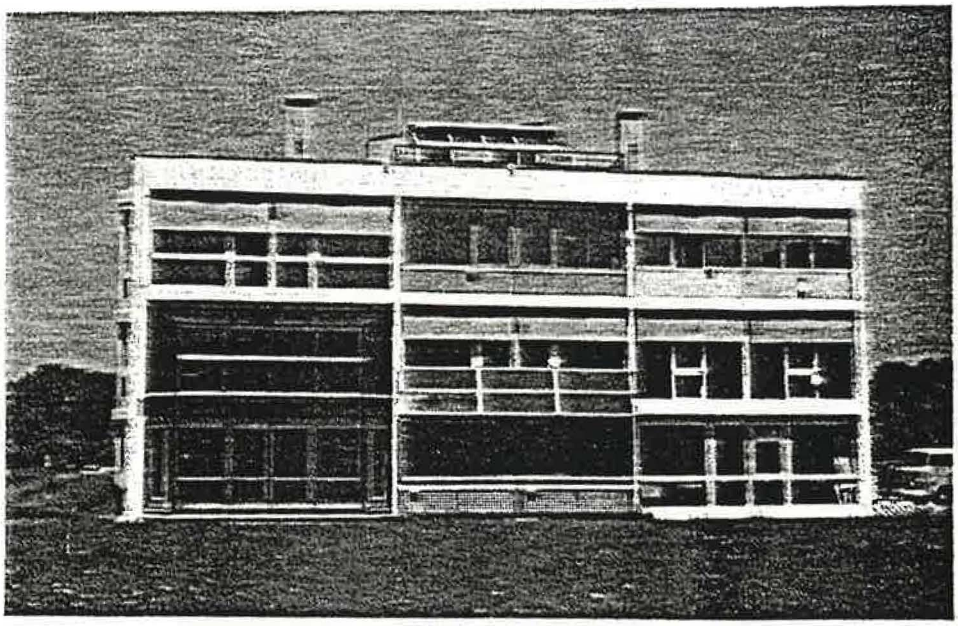


Weather and aeraulic data set for validation

The LESO Building

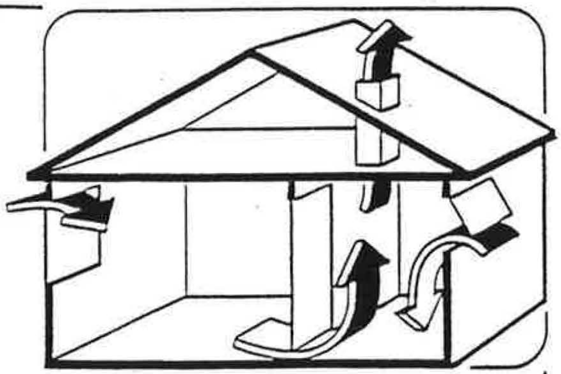
Part 1. Content of the data set

(February 1989)



J.-M. Fürbringer, R. Compagnon
Laboratoire d'Energie Solaire et de Physique du Bâtiment
Ecole Polytechnique Fédérale de Lausanne
CH - 1015 Lausanne, Switzerland

Mail Vax facility : Fürbringer @ ELDP . EPFL . CH

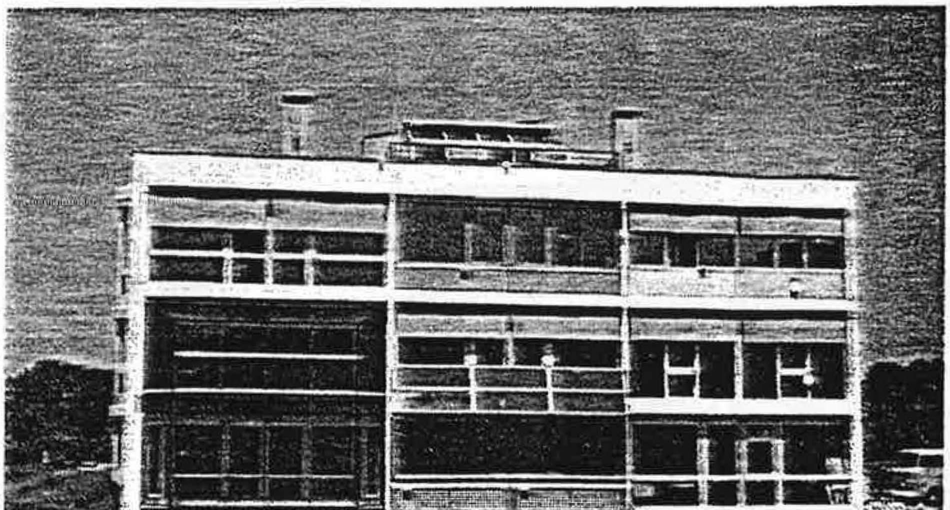


Weather and aeraulic data set for validation

The LESO Building

Part 1. Content of the data set

(February 1989)



J.-M. Fürbringer, R. Compagnon
Laboratoire d'Energie Solaire et de Physique du Bâtiment
Ecole Polytechnique Fédérale de Lausanne
CH - 1015 Lausanne, Switzerland

Mail Vax facility : Fürbringer @ ELDP . EPFL . CH

ECOLE POLYTECHNIQUE FEDERALE DE LAUSANNE

CONTENT

1. PRESENTATION

The LESO building settled on the EPFL campus is a mid-sized administrative building. It is composed of 9 south oriented cells with solar passive façades and some differently oriented rooms distributed over 3 floors with a staircase as backbone [1].

This building is occupied by the LESO-PB team (Laboratoire d'Energie Solaire et de Physique du Bâtiment) belonging to the Architecture Department of the EPFL.

The figure 1 presents a perspective view of the building while the figure 2 present its conductance net.

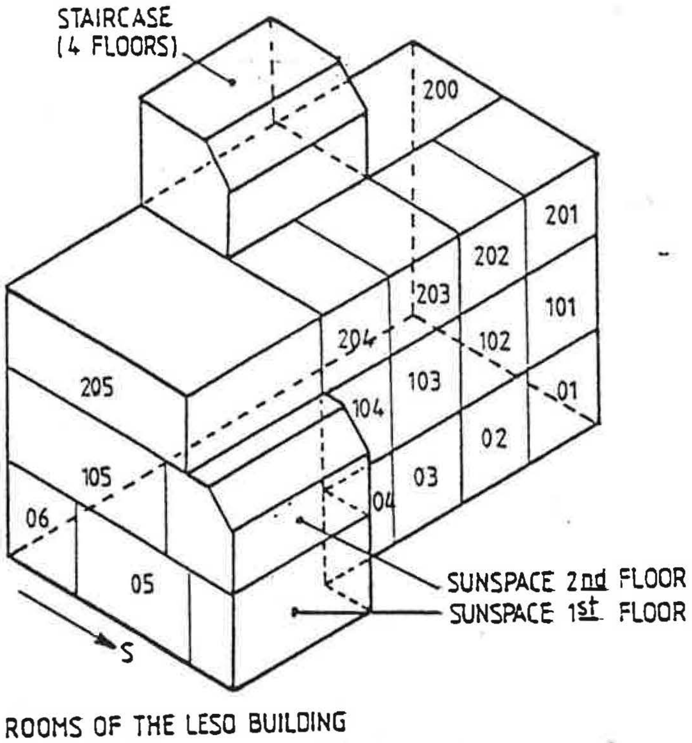


Figure 1 - Perspective view of the LESO-building.

Within the framework of the Swiss ERL-project (Energierelevante Luftströmungen in Gebäuden) which is the global air infiltration research project connected with the IEA-ECB Annex XX and COMIS, the LESO-PB has, between others, the task to validate air flow computer programs [2], [3].

For that purpose, some measurements on the LESO building have been undertaken since two years, constituting a data set for validation available for others researchers.

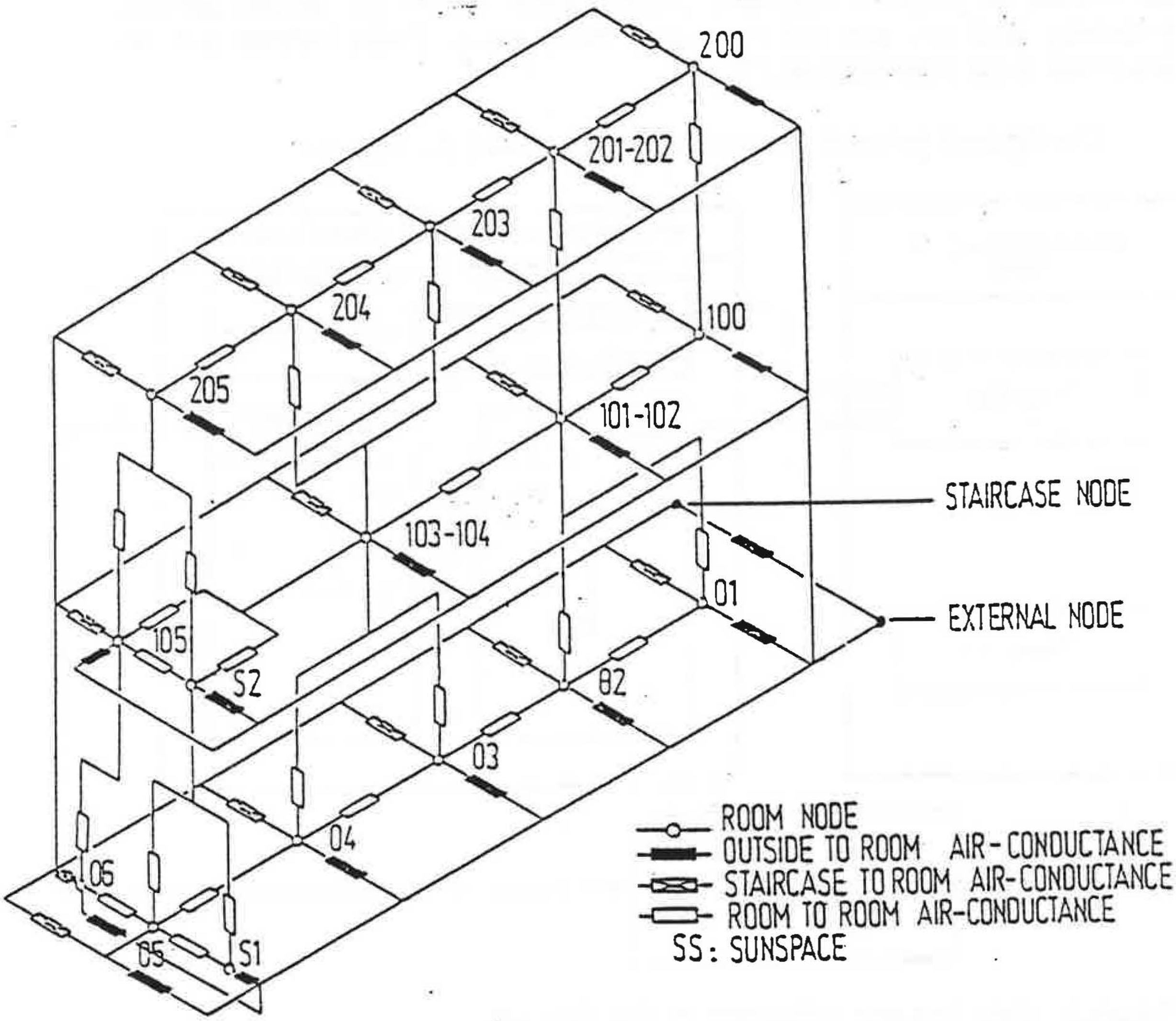


Figure 2 Conductance net of the LESO-building.

This note is a description of the data set content. It also gives some possibilities for future enlargements. The variables and parameters are described in the column "feasibility" as either D (done), P (possible without special work) or I (imaginable with more equipment). The idea is to develop the data set in function of the user's necessity by a feed-back process. This dynamic procedure is necessary since the air simulation codes become every day more sophisticated and the validation process is mandatory for a useful code.

The development of different measurement systems at the LESO-PB, the most importants being the MAGE and the CESAR apparatus, has made these high quality measurements possible.

The MAGE (Mesure avec Anneau de Garde de l'Etanchéité) system was developed to perform multizone pressurization tests. It is a two fan automatically controlled system allowing the use of a guarded zone pressurization technique.

The CESAR (Compact Equipment for Survey of Air Renewal) was developed to perform constant concentration tracer gas measurements, primarily with one gas and now with three gases. These instruments are described in the references [4], [5], [6].

The figure 3 presents the utilization process of the data set.

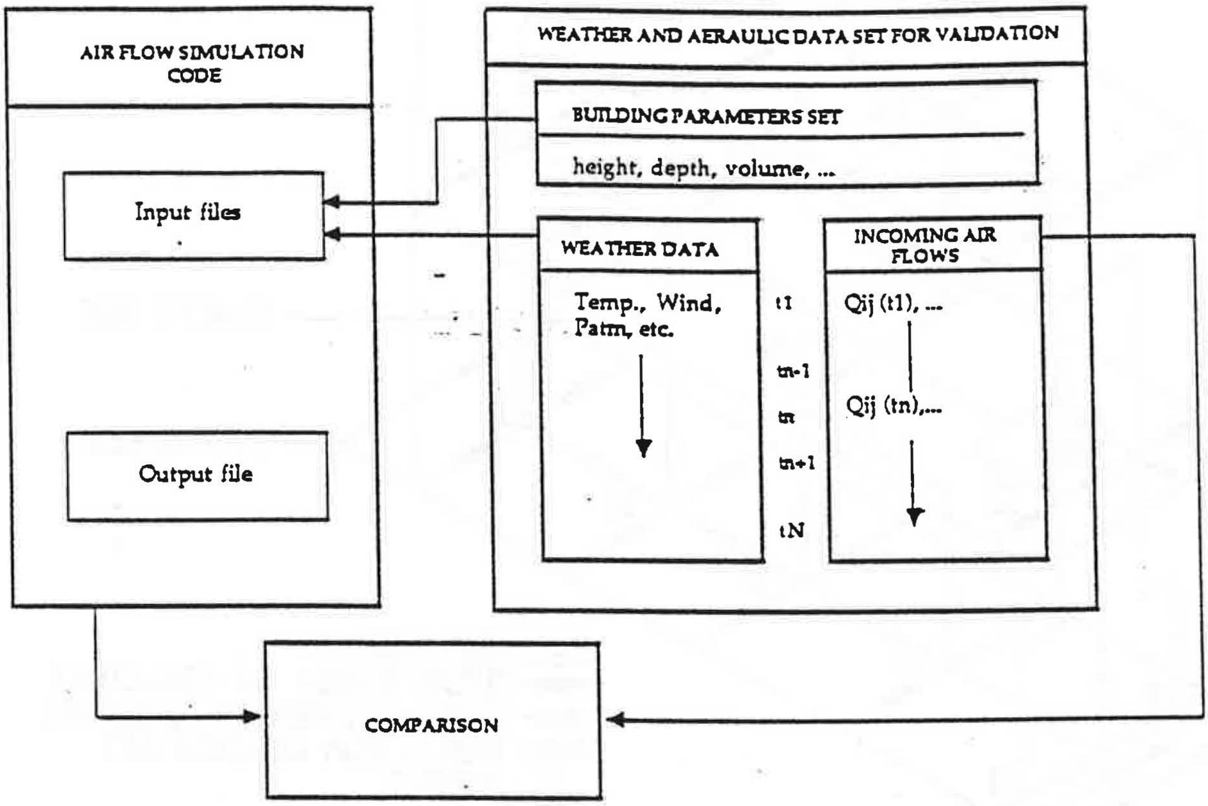


Figure 3 Structure and utilization of the data set.

2. TABLE AND CODIFICATION EXPLANATION

The content of the data set is presented in tables (fig. 3). Here are some explanations about the way these tables should be read.

2.1 *Observable*

This column presents the ***observables*** contained in the data set. When necessary a short explanation is made above the corresponding table.

2.2 *Nature*

The "nature" column informs on the ***nature of values*** with the following possibilities.

Var	→	Time depending ***variable***, corresponding to a measurement campaign
P	→	Constant ***parameter***, describing the building
F	→	***Function*** of variables other than time

2.3 *Type*

The "type" of the observable indicates the ***origin of the values*** and if they have been submitted to mathematical transformations :

M	→	Measured, measurable
C	→	Computed, computable
E	→	Estimated, estimable

2.4 *Orientation*

The pressure probes are specified with the orientation of the corresponding façade.

S	→	South
E	→	East
N	→	North
W	→	West

2.5 *Channel*

The LESO-PB performing meteorological measurements since a few years, has developed his own standard codification to spot the different kinds of measurements in the records.

This codification is constituted by two letters (X, Y). The first (X) gives information on the ***physical quantity***. The second (Y) precises the ***type of record*** : the data logger scans the channels at short time intervals (***measuring intervals***) and records the data at longer intervals (***recording interval***). It has then the possibility to record on the tape for every recording interval either the ***instantaneous value*** or the ***integrated value*** which is the sum of the measurements performed during the recording intervals or the ***average value*** which is the integrated value divided by the measurements number. Here are the code for X and Y :

X:	P	→	Temperature (Pt100)
	E	→	Power (or Energy if integrated)
	K	→	Pressure
	S	→	Solar radiation
	G	→	Opening angle (window, doors)
	D	→	Wind direction
	W	→	Wind speed
	H	→	Humidity
	F	→	Flow

Y:	N	→	Instantaneous value
	M	→	Averaged value during the recording interval
	I	→	Integrated (sum) value during the recording interval
	S	→	Root mean square during the recording interval

2.6 *Instruments and probes*

This column presents the instrument, probe or sensor used to make the measurements.

As there are different probes for the same measurement having their own characteristic behaviour, it is some time useful to compare their results.

Some of these instruments or probes have been developed in the LESO-PB.

2.7 *Measurement campaign*

For purpose of comparison with ***time dependent simulation*** it was necessary to measure the air renewal of the uninhabited building during a large period. Till today the LESO-PB has performed two periods of ***tracer gas measurements***. Other campaigns will be organized and will expand the data set.

The tracer gas measurements are performed in connection with ***meteorological measurements*** (weather data). For these set the hourly number of measurements HNM in [h^{-1}] and the campaign duration Δt in [h] are given. Sometimes the measurement points number is given under the symbol #.

2.8 *Feasibility*

As quoted in 1. measurements not yet made but which could be useful to perform are included in this description. On the feasibility criteria the variables are sorted as :

D	→	done
P	→	possible
I	→	imaginable

The possible measurements do not need special work while imaginable ones need some developments or the acquisition of more equipment.

3. BUILDING PARAMETERS SET

3.1 *Geographical and geometrical parameters*

This part of the data set contains the location and the dimensions of the building, plans and a description of the surroundings.

	Information	Unit, kind of information
Geography		
	Latitude Longitude Altitude (above see level) Terrain	[°] [°] [m] Drawings

Geometry		
	Building height Building width Building depth Building volume Room configurations	[m] [m] [m] [m³] drawings

3.2 *Building Airtightness - Pressurization test Results*

The presented measurements were performed by the MAGE system for multizone pressurization [6]. They were fitted on the power law

$$Q = C\,\Delta P^n$$

C-value is the permeability coefficient in [m^3/h Pa] and n is the corresponding exponent.

Q_{50} (in [m^3/h]) which is the air flow through a given element for a pressure difference of 50 [Pa], is also given [7].

The indices, used to determine which element is considered have the following meaning

"tot" refers to the whole building shell
"out" refers to outside
"in" refers to the staircase
"i" or "j" refers to the room

And the permeabilities are specified by the two spaces they connect.

The "#" column gives the number of each variable included in the data set.

Observable	Nature	Type	#	Instrument	Accuracy %	Feasibility
C_{tot}, n, Q_{50}	P	M, C	13	Mage	<10	D
C_{i-out}, n, Q_{50}	P	M, C	10	Mage	<10	D
C_{i-in}, n, Q_{50}	P	M, C	10	Mage	<10	D
C_{i-j}, n, Q_{50}	P	M, C	7	Mage	<10	D

Table 3.2 The data set content about airtightness.

3.3 *Pressure coefficients*

The results from the three classical approaches of the dimensionless pressure coefficients C_p are included in the data set.

The wind tunnel measurements performed at the Lawrence Berkeley Laboratory and the full scale measurements performed at the LESO consist on discreet values while the harmonic analysis according C. Allen's Works [8] is represented by functions of the location ("Source" column).

"# Point" column refers to the number of measurement points on the building or the scale model.

"$\Delta\theta$" column refers to the variation of wind angle between the discreet values.

"P_{ref}" column refers to the location of the reference pressure probe used to calculate the C_p. (for other column cf. 2).

Observable	Nature	Type	Source	# Points X_i	$\Delta\theta$	P_{ref}	Feasi-bility
C_p (X_i, θ_j)	P	M	Wind tunnel (LBL)	41	15°	chimney	D
C_p (X_i, θ_j)	P	M	Full scale measur.	9	10°	roof	P
C_p (X, θ)	F	C	Harmonic analysis	-	-	roof, local	D

Table 3.3 The data set content about C_p.

4. WEATHER DATA SET

4.1 *Wind*

4.1.1 Instrumentation

The wind measurement were performed with two kinds of instruments.

First, a classical anemometer (Schiltknecht) was used, but it was not useable to the vectorial averaging. For this purpose, the LESO-PB has developed a vectorial vane : a vane connected on an electronic system giving the sinus and cosinus of the wind angle.

4.1.2 Measurements and variables

Here is an explanation of the symbols used for the wind-attached Observables. As the wind measurements constitue a part of the weather data, they are logically in time relation with other variables.

V (t) :

The instantaneous wind velocity, (unit = [m/s])
recording frequency = sampling frequency,

<V (t)> :

The scalar average of wind velocity corresponds to the sum of measurement results during the recording period Δt(rec) divided by the number of measurements N with, of course (cf. 2.5)

$$N = \frac{\Delta t\,(rec.)}{\Delta t\,(meas.)}$$

then $$\langle V(t)\rangle = \frac{1}{N}\sum_{i=1}^{N} \| \vec{V}(t_i) \| \qquad \text{(unit = [m/s])}$$

$\| \langle \vec{V}(t) \rangle \|$:

The vectorial average of wind velocity : since vectorial vane allows the projection of the wind velocity vector on two axes, we obtain :

$$\| \langle \vec{V}(t) \rangle \| = \left\| \frac{1}{N}\sum_{i=1}^{N} \vec{V}(t_i) \right\| \qquad \text{(unit = [m/s])}$$

θ (t) :

The instantaneous wind angle in degree with the values :

0	for North	coming wind
90	for Est	coming wind
± 180	for South	coming wind
- 90	for West	coming wind

the scalar angle average <arc tan $\left(\frac{V_y(t)}{V_x(t)}\right)$ is not measured because it has no physical meaning .

$<\theta(t)>$:

The coming angle of the vectorial average of wind velocity $\| < V(t) > \|$ defined as

$$<\theta(t)> = \text{arc tan}\left(\frac{\sum_{i=1}^{N} V_y(t_i)}{\sum_{i=1}^{N} V_x(t_i)}\right)$$

RMS (X) :

The root mean square of the X-observable

Wind speed distribution :

The wind velocity distribution will be an information about general wind condition in the LESO site. Wind measurements every 5 sec during more or less large periods for different characteristic seasons of the year will be analyzed and sorted versus velocity and angle to give the distribution.

Spectrum :

Wind speed and direction will be submitted to Fourier's transformation to analyze the short term (1 to 60 min) and the long term (1 hour to 1 year) periodicity of the wind intensity [9].

Gradient :

The wind velocity versus the altitude on the LESO-site.

Wind way :

The visualization of the flows around the building by smoke.

Observable	Nature	Type	Channel	Instrument Probe Range	1987 HNM [h^{-1}]	1987 Δt [h]	1988 HNM [h^{-1}]	1988 Δt [h]	feasibility
V (t)	Var	M	W N	Anemometer	4	270	6	120	D
<V>	Var	M-C	W M	Anemometer	4	270	6	120	D
‖<V>‖	Var	M-C	W M	Vectorial Vane	-	-	6	120	D
θ (t)	Var	M	D N	Anemometer	4	270	6	120	D
<θ (t)>	Var	C	D M	Vectorial Vane	-	-	6	120	D
RMS (V (t))	Var	C	W S	Anemometer	-	-	-	-	P
RMS (V (t))	Var	C	W S	Vectorial Vane	-	-	-	-	P
RMS (θ (t))	Var	C	D S	Anemometer	-	-	-	-	I
Spectrum & Distribution (V, θ)	F	M,C	-	Higher Frequency Measur. & Analysis	-	-	-	-	P
Gradient V (h)	F	M	-	Parafin & Camera	-	-	-	-	I
Wind Way	P	E	-	Smoke & Video	-	-	-	-	I

Table 4.1 The data set content about wind.

4.2 *Pressures*

P_{atm} the atmospheric pressure (unit = [Pa])

ΔP_{ref}-LBL the reference pressure difference measured with the LBL-reference probe at the roof level (unit = [Pa])

ΔP_{ref}-CSTB the reference pressure difference measured with the CSTB-reference pressure probe at the roof level (unit = [Pa])

ΔP (int-ext) n [Pa] pressure difference between indoor, and outdoor at the façade of the room n

RMS (ΔP) [Pa] root mean square of the pressure difference ΔP

Spectrum (ΔP) spectrum of the pressure difference ΔP (cf. 4.1.2)

Distribution (ΔP) distribution of the pressure difference ΔP (cf. 4.1.2)

Observable	Nature	Type	Orient.	Channel	Instrument Probe Range	1987 HNM $[h^{-1}]$	1987 Δt [h]	1988 HNM $[h^{-1}]$	1988 Δt [h]	feasibility
P_{atm}	Var	M	-	K N	Schiltknecht	4	270	6	120	D
ΔP ref LBL	Var	M	-	K M*	Furness LBL ±20 [Pa]	4	270	6	120	D
ΔP ref CSTB	Var	M	-	K M*	Furness CSTB ±20 [Pa]	4	270	6	120	D
ΔP (int-ext)										
- 004	Var	M	S	K M*	Furness	4	270	6	120	D
- 005	Var	M	S	K M*	Manometer	4	270	6	120	D
- 100	Var	M	E	K M*	±20 [Pa]	4	270	6	120	D
- 101	Var	M	S	K M*	↓	4	270	6	120	D
- 106	Var	M	S	K M*		4	270	6	120	D
- 107	Var	M	S	K M*		4	270	6	120	D
- Stair	Var	M	W	K M*		4	270	6	120	D
- 201	Var	M	N	K M*		4	270	6	120	D
- 204	Var	M	S	K M*		4	270	6	120	D
RMS (ΔP)	Var	C	-	K S	Furness Manometer ±20 [Pa]	-	-	-	-	P
Spectrum & Distribution (ΔP)	F	M, C	-	-	Higher Frequency Measur. & Analysis	-	-	-	-	P

Table 4.2 The data set content about pressure.

* ΔP : measurement KN also possible.

4.3 *Temperatures*

The Pt 100 temperature probe can be ventilated (vent) or unventilated (unvent). The symbols used have the following signification :

$T_{out,roof}$ outside air temperature at the roof level

$T_{in,rooms}$ room air temperature. There are ventilated and unventilated probes

$T_{in,stairs}$ air temperature at different heights in the staircase

$T_{adjacent,\ LEA}$ air temperature in the adjacent laboratory LEA

					1987			1988			
Observable feasibility	**Nature**	**Type**	**Channel**	**Probe**	**#**	**[h^{-1}]**	**h**	**#**	**[h^{-1}]**	**h**	
$T_{out,\ roof}$	Var	M	PN	Pt100 vent	1	4	270	1	6	120	D
$T_{in,\ rooms}$	Var	M	PN	Pt100 unvent	19	4	270	18	6	120	D
$T_{in,\ rooms}$	Var	M	PN	Pt100 vent	19	4	270	19	6	120	D
$T_{int,\ stairs}$	Var	M	PN	Pt100 vent	4	4	270	4	6	120	D
$T_{adjacent}$ LEA	V	M	PN	Pt100 vent	1	4	270	1	6	120	D

Table 4.3 The data set content about temperature.

4.4 *Air humidity*

The air humidity is measured on the roof by an hair-hygrometer. In future tracer gas measurement campaigns the air humidity will be available in Vol % for every room and outside by mean of the infrared gas analyzer of the Cesar.

					1987		1988		
Observable	Nature	Type	Channel	Instrument	HNM [h^-1]	Δt [h]	HNM [h^-1]	Δt [h]	feasibility
External Relative Humidity	Var	M	HN	Hygrometer Vetter	4	270	6	120	D
Vol % (H_2O) for rooms and outdoor	Var	M	HN	Binos	-	-	-	-	P

Table 4.4 The data set content about humidity.

5. INCOMING AIR FLOWS

5.1 *Incoming air flows*

By using the constant concentration tracer gas technique and by interpreting the measurements using mass conservation equations, it appears that for each measured room i a set of global incoming air flows $Q^k_{A_i}$ (one for each tracer gas k) can be determined. These global incoming air flows are in fact equal to weighted sums of individual air flows coming from outside (Q_{oi}) or from adjacent rooms (Q_{ji}).

$$Q^k_{A_i} = Q_{oi} + \sum_j \eta^k_{ji} Q_{ji}$$

The weighting coefficients η^k_{ji} are function of the tracer gas concentration levels in each room, and can also be computed from the measurements. By properly choosing the different tracer gas concentration levels for each room, it is possible to cancel many of these coefficients. The global incoming air flows can then be combined to obtain some of the individual interzonal airflows Q_{ji}, or if, for example, only one gas at the same concentration level is kept in each room, all the outdoor coming air flows Q_{oi} can be individually determined.

The set of results include the global incoming air flows $Q^k_{A_i}$ for each room i, the 95 % confidence interval $\Delta Q^k_{A_i}$ for these values and the weighting coefficients η^k_{ji} for all adjacent room j.

Observable	Nature	Type	Channel	Instr.	1987 #	1987 HNM [h⁻¹]	1987 Δt [h]	1988 #	1988 HNM [h⁻¹]	1988 Δt [h]	feasibility
$Q^k_{A_i}$	Var	M→C	Q M	Cesar	8	4	270	8	6	120	D
$\Delta Q^k_{A_i}$	Var	M→C	Q M	Cesar	8	4	270	8	6	120	D
η^k_{ji}	Var	M→C	R M	Cesar	28	4	270	17	6	120	D
Q_{lm}	Var	M→C	Q M	Cesar 3	-	-	-	-	-	-	-

Table 5.1 : The data set content about incoming air flows.

The first two measurements sets were performed with one tracer gas kept at the same concentration in several rooms. The 1987 set is obtained with the tracer gas only in the offices. The Q_{Ai} are then weighted sums of the air flows coming from outdoor and the staircase.

With our new multigas CESAR3 system we expect to provide new sets of measurements with more outdoor and interzonal air flows Q_{Im} individually determined.

6. HARDWARE, SOFTWARE AND FORMAT

The principal operations to constitute the data set have been performed on a Vax 8530 / VMS.

The data set will be available on tape diskette and streamer and will contain in ASCII format approximately 4 M-bytes organized in self defined data blocks. (It would be possible to obtain recordings of 80 characters with a blocking factor equal to 48).

6.1 The tape version

The tape will be recorded with 1600 bpi on 9 tracks and will be available in ASCII or EBCDIC (IBM) format. This version will be the first one available. The other versions will be developed depending on the necessity and possibility.

6.2 The diskette version

The diskettes will be recorded under MS-DOS and if necessary compacted with a program given with the data set.

6.3 The streamer version

The streamer version of the data set will be recorded with a Sun workstation (Unix) on a 60 M streamer.

6.4 *Format*

Time dependent variables are recorded following the Gres-format. This format organises the data in self defined blocks. It has been developed in the LESO-PB in accordance with a data interpreting fortan code called Display.

Time independent parameters are included in specific files as Cp-file, Permeability-file, etc.

The exact description of the files will be given in the part 2. "Building Description and Measurement Report".

7. CONCLUSION

The data set content and its possibilities of expansion have been presented.

Today the tape is not yet recorded because the format must be chosen in accordance with other ERL- groups needs and because some basic measurements are still to be performed. A tape will be anyway available at the end of the year.

It is then important to understand this note as a work paper. For this purpose it is strongly recommended to make contact with the authors either to communicate your remarks or to specify your data needs for purpose of air infiltration computer code validation.

8. BIBLIOGRAPHY

[1] J.-L. Scartezzini, C.-A. Roulet, O. Jolliet
"Continuous air renewal measurements in different inhabited buildings" 6th AIC Conference, proc., 1985.

[2] 2. Status Seminar "Forschungsprogramm : Energierelevante Luftströmungen in Gebäuden" Lausanne, Switzerland, 1988 (in French and German).

[3] J.-L. Scartezzini, J.-M. Fürbringer, C.-A. Roulet
"Data needs for purpose of air infiltration computer code validation" 8th AIVC Conference Proc., Ueberlingen, RFA, 1987.

[4] "CESAR : Compact Equipment for survey of Air Renewal", communication at the reunion of the group on site measurement" of ISO, Washington DC, USA, 4-6 April 1987.

[5] J.-L. Scartezzini, C.-A. Roulet, O. Jolliet
"Continous air renewal measurements in different inhabited buildings" 6th AIC Conference proc. 1985.

[6] R. Compagnon, J.-M. Fürbringer, C. Roecker, C.-A. Roulet
"Nouveaux développements de deux méthodes de mesures aérauliques dans les bâtiments" Energieforschung im Hochbau, ETH-Zurich, Switzerland, 1988.

[7] J.-M. Fürbringer, C. Roecker, C.-A. Roulet
"The use of a guarded zone pressurization technique to measure air flow permeabilities of a multizone building" 9th AIVC Conference proc., Gent, 1988.

[8] C. Allen
"Wind pressure data requirement for air infiltration calculation" TN-AIC-13, January 1984.

[9] Aynsley R.M., Melbourne W., Vickery B.J.
"Architectural Aerodynamics"
Applied Science Pub. LTD, London, 1977.