THEME I - ENERGY OPTIMIZATION OF OUTER WINDOW-AND-DOOR FRAMES

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0. Foreword

The activity of the research group in 1978 has been mainly concerned with perviousness to air of openable joints and of building integration joints (according to the results of the work carried out in previous years).

We'll point out how such perviousness together with thermal transmittance of the frame/joint combination reveal if the component can comply with the energy-saving requirements.

The main objectives pursued in 1978 can be summarized as follows:

- collection, processing and evaluation of openable-joints perviousness data, collected during certifications or tests.
- Evaluation of the influence of building technologies and component materials on perviousness.
- experimental evaluation of the reasons for the choice of wall/frame combination and of the relative joint components
- Experimental evaluation of the correlation between perviousness to air and sound-insulation power in order to define new ways of perviousness checks after installation through acoustic property measurements.

Let's see how these objectives have been pursued within every operating unit.

1. Montedison C.S.I. Research Programme

"Research on perviousness to air of the wall/frame joints, according to different types of the two components and of the joint".

The work carried out by the CSI in the previous year within the PFE had pointed out the main factors linked to the loss of heat through outer window-and-door frames and the importance of perviousness to air of the joints between window-and-door frame and wall and of the joints of the box itself and with the wall.

Actually in Italy we have hundreds of measurements of perviousness of frame openable joints but there are no quantitative indications available as far as fixed joint and box perviousness is concerned. This clearly happens because the performance of these joints depends mainly on installation and installation cannot be controlled by the frame supplier or by the certification laboratory.

Therefore the second part of the CSI experimental programme has dealt with these aspects of the energy-behaviour of outer window-and-door frames.

In this programme the following window-and-door frames have been tested (using also the results of the previous study):

no. 2 of pvc
no. 2 of steel
no. 1 of wood
no. 1 of aluminium

The two frames, one of pvc the other of steel, used for the

study, were fixed on a brick-wall. The first had a false frame and no reveal, the latter had also no reveal with mortar filling in the fixed frame. Some of the remaining window-and-door frames were fixed on a brick-wall, others on a reinforced concrete wall.

All frames were fixed with reveals, except for the steel frame which was inserted on a steel frame without reveal. The wood frame was fixed on a steel false frame.

The fixing of each frame has been first carried out accurately, generally in compliance with the supplier instructions and then a different fixing, generally changed for the worse, has been tested (i.e. without the prescribed weather strips or seals).

All frames tested had 2 vertical wings with rolling shutters and the surface that could be opened was 2 m^2. These frames belonged to the best perviousness class (A3).

Table I makes a synthesis of the results, giving the average perviousness (between increasing and decreasing pressure test) at 100 Pascal (10 mm of water column) making a difference between the frame itself, the box, the joints between fixed frame and wall and the total perviousness.

Owing to test uncertainties, the sum of the 3 first elements is not always equal to total perviousness.

All values refer to 1 m^2 of openable surface.

Without giving full details of the reasons why the various results differ (these reasons are discussed in the final CSI report) we can make the following general remarks:

- Boxes are almost always sources of loss of value even 2-3 times more than the frame itself; these losses are

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TAB I

test no.	w-&-d frame	class	wall	rabbet	Perviousness at 100 Pa m^2/hm^2 false frame	install.	w-&-d frame	box	fixed joints	total	result. class	notes
1	PVC	A2	bricks	no	wood	reg.	16	--	--	57	not cl.	1976
2	PVC	A2	bricks	no	wood	negl.	16	--	--	101	not cl.	1976
3	steel	A2	bricks	no	no	reg.	15.5	--	--	30.5	A1	1976
4	steel	A2	bricks	no	no	negl.	15.5	--	--	59.-	not cl.	1976
5	wood	A3	bricks	yes	steel	reg.	3.5	1.-	27.-	31.5	A1	
6	wood	A3	bricks	yes	steel	impr.	3.5	1.-	14.-	18	A2	
7	PVC	A3	RC	yes	--	reg.	4.5	8.5	3.5	12	A2	side fix.
8	PVC	A3	RC	yes	--	negl.	5.-	7.-	not meas.	not meas.	not cl.	"
9	PVC	A3	RC	yes	--	reg.	4.-	7.-	7.-	14.-	A2	"
10	PVC	A3	RC	yes	--	negl.	3.5	8.5	110	118	not cl.	"
11	allum.	A3	RC	no	--	reg.	3.5	6.5	9.5	26.5	A1	
12	allum.	A3	RC	no	--	negl.	5.-	9.-	66	76	not cl.	
13	steel	A3	bricks	no	steel	reg.	4.-	15.-	11.5	17.-	A2	
14	steel	A3	bricks	no	steel	negl.	5.5	18.5	13.-	30.-	A1	

generally due to the joints between the box and the walls which are often overlooked. Losses of this relevance can degrade the window-and-door frame to a lower class.

- The joints between fixed frame and wall, if not correctly executed, can be responsible for such losses as to make even higher class frames inclassifiable. In this connection, together with inaccuracy of installation it is also important to take into consideration the conception of the joint: some joints can be made almost watertight more easily than others; on the contrary some joints (may be the same, see tests 7-10) are more affected than others by mistakes or inaccurate fixing.

A quantitative evaluation of the importance of these effects for energy supply of buildings must make a distinction between comfort and consumption. Comfort is linked to the limitation of the thermic power installed introduced by law 373.
From the viewpoint of comfort, and in accordance with UNI regulation "Building outer frames - classification and choice criteria pertaining to perviousness to air watertightness and wind resistance" (UNI/CE 0015 June 1978, being printed as regulation), frames with perviousness higher than class A1 can by no means be accepted. Most frequently class A2 is required. Classes A1 and A3 are required respectively for less and more demanding situations as regards windy areas, type of exposure, climatic zone and height of the building.
It is rather difficult to evaluate now the effects on seasonal heating consumption of building perviousness to air.
A proper processing of climatological data is clearly necessary

and we hope that it will be one of the results of the PFE.
As is well known, the pressure difference between the inside and the outside of buildings (and therefore the change of air in natural ventilation) is mainly due to the temperature difference between the inside and the outside and to the wind action.
Generally the wind action is the prevailing reason, the temperature difference being important only in the case of very high buildings with few horizontal divisions.
A rough processing of the meteorologic data applied to a few exemplifications, leads to the conclusion that from the point of view of the seasonal energy-consumption the higher perviousness values of table I are tolerated only in low winter windiness areas (Actually only the Po Valley).
In all other cases only frames with an adequate level of perviousness (from A1 to A3) are in compliance with the restraints of law 373; whereas, the perviousness pointed out in the table (which can be typical of ordinary frames without weather strips or can depend, as we saw, on careless fixing or auxiliary elements) can cause, in the space of the season, a fuel consumption which, in some borderline but not exceptional cases (for instance for 8-10 storey-buildings exposed to wind zone 3 and to climatic zone E) can be 60% higher than the total loss (conduction and change) admitted by law 373.
The importance of the control of air infiltrations for energy saving in heating is thus demonstrated and it has been pointed out how much accuracy is needed when installing joints -

between frames and wall.

Considering the general lack of information in this connection, in order to make the most of these remarks, it will be necessary to promote information and to create regulations pertaining to frame-wall joints which are still very inadequate. Such regulations should take into account dimensional and morphologic aspects as well as performance aspects and a practice code on the subject.

2. ICITE-CNR Research Programme

In 1978 the main activity of ICITE-CNR has dealt with the collection and processing of perviousness to air data collected thanks to the certification activity which is carried out by ICITE and by other Italian laboratories among which ITAC in Turin following Italian and European regulations and agreement procedures /1/;/2/.

ICITE and ITAC have collected data on perviousness of approximatively 300 window-and-door frames of different types and technologies. In order to arrange the collected data in an easily processible form, the data themselves have been implemented in a data bank set up in the data processing centre of ICITE within the framework of the studies on building technical information.

Using such system it is possible to sort out, from the tested window-and-door frames data bank, sets of components with one or more well-defined typological and/or morphological simultaneous characteristics (such as pvc frames, sliding wing steel frames, wood frames with 2 vertical wings.

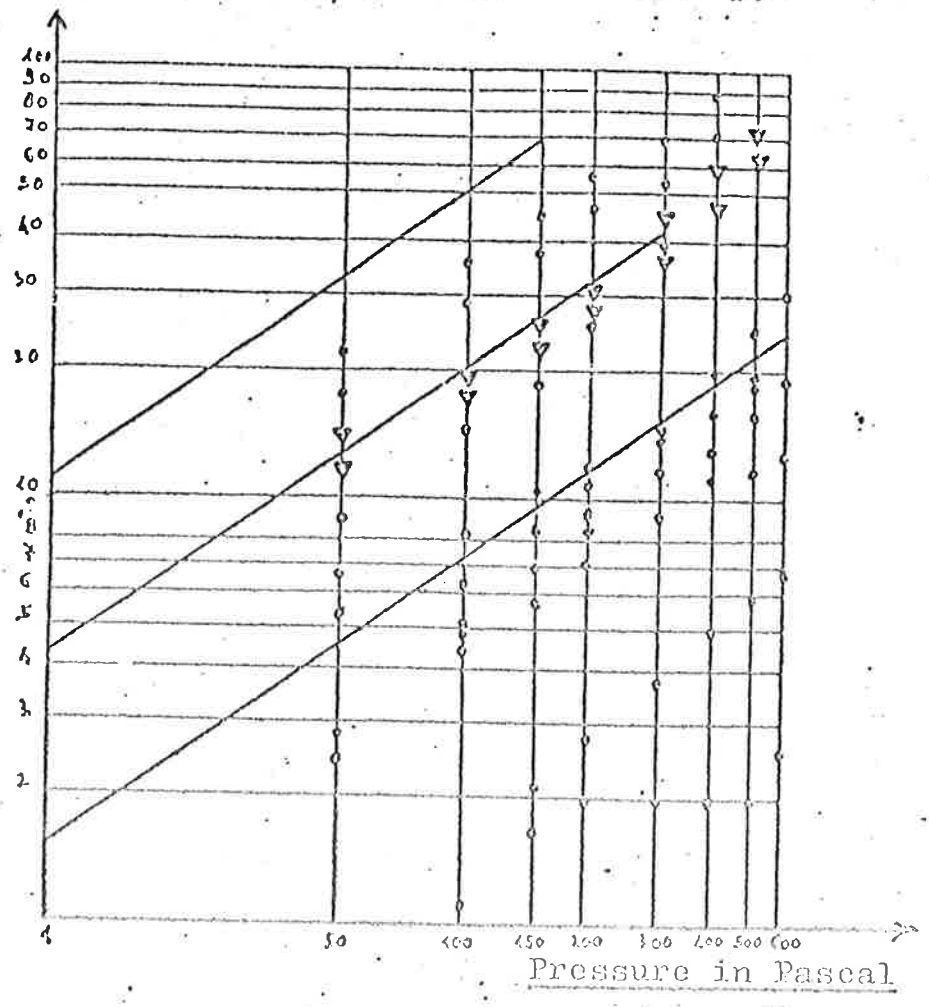
RAPH. 1

Rate of flow m^3/hm^2

Wooden painted window

with strips

without strips



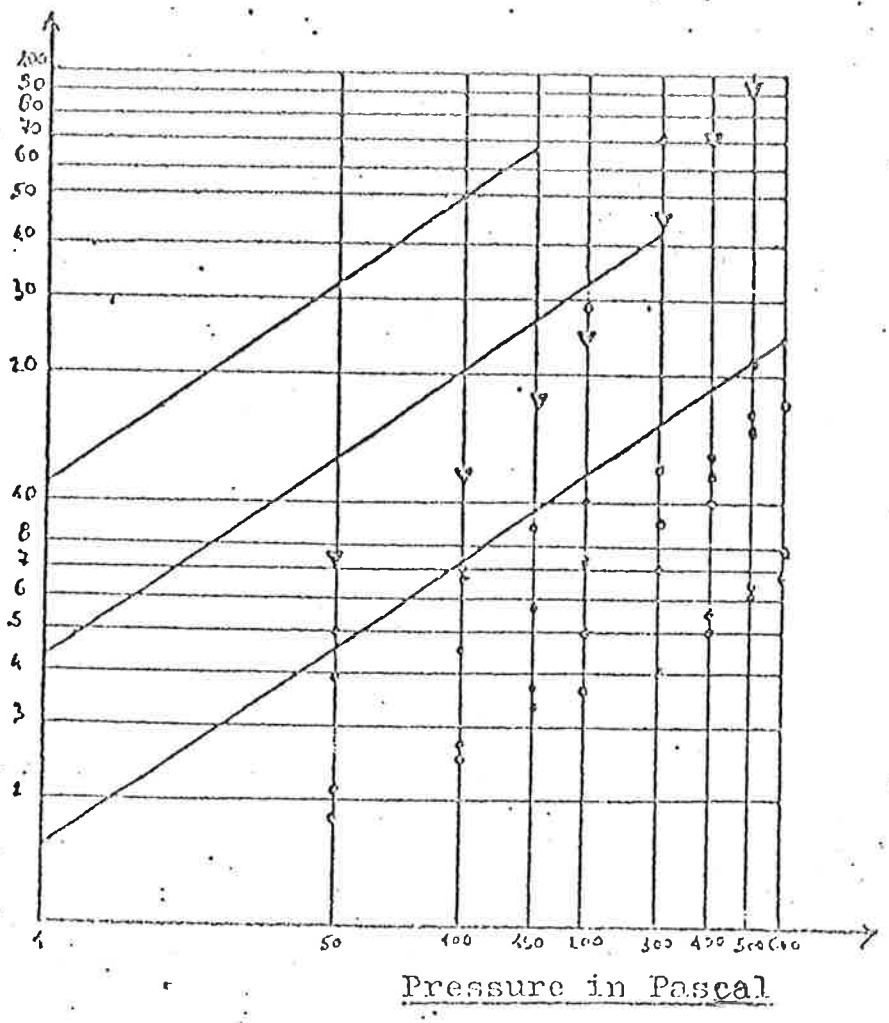
RAPH. 2

Rate of flow m^3/hm^2

Rigid PVC window

with strips

without strips



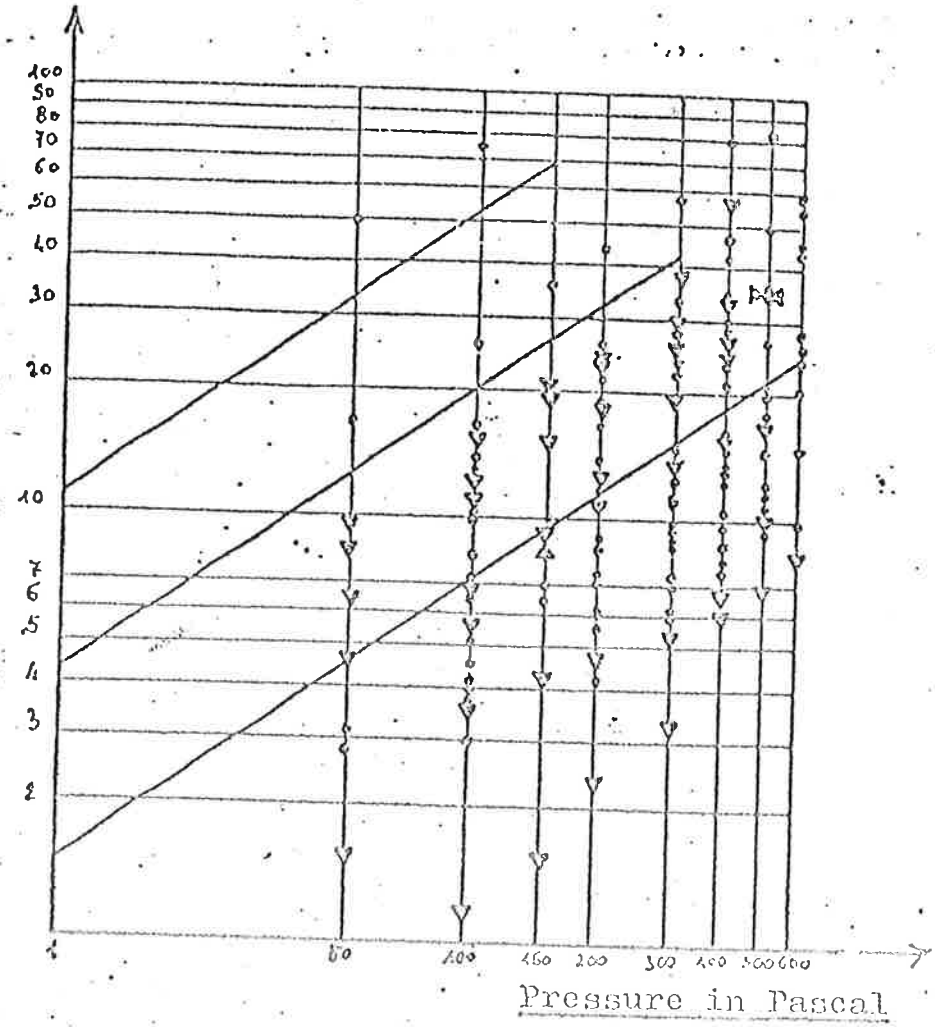
GRAPH. 3

Rate of flow m^3/hm^2

Anodized aluminium window

o with strips

▽ without strips



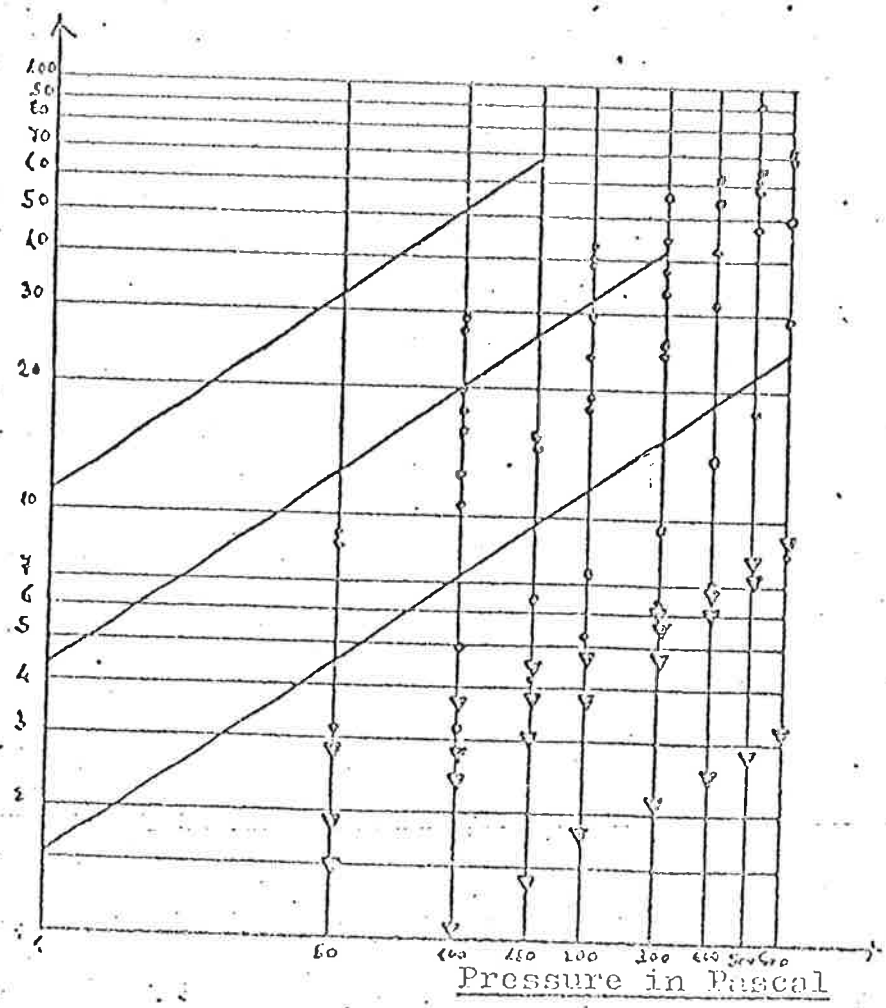
GRAPH. 4

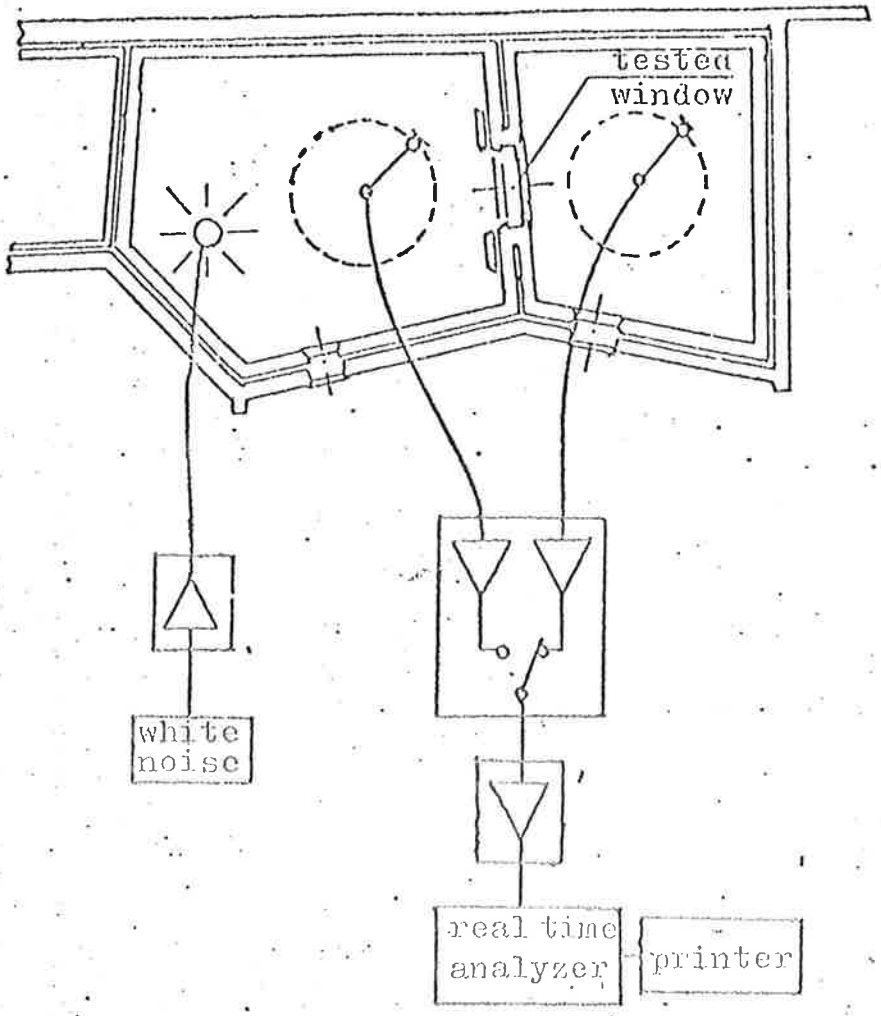
Rate of flow m^3/hm^2

Painted and zinc plated steel window

o with strips

▽ without strips

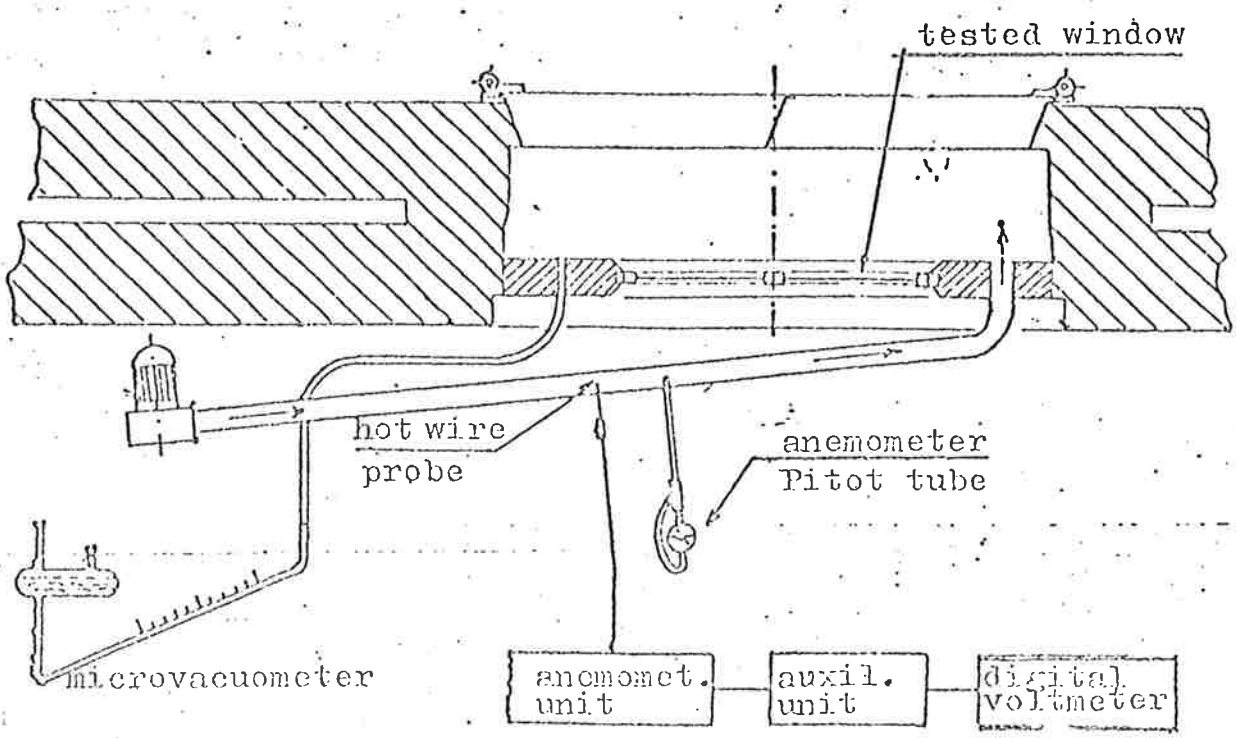




PICTURE 6:

Measurement of the sound insulation power

PICTURE 5: Measurement of perviousness to air



GRAPH. 7: Sound insulation power versus perviousness to air

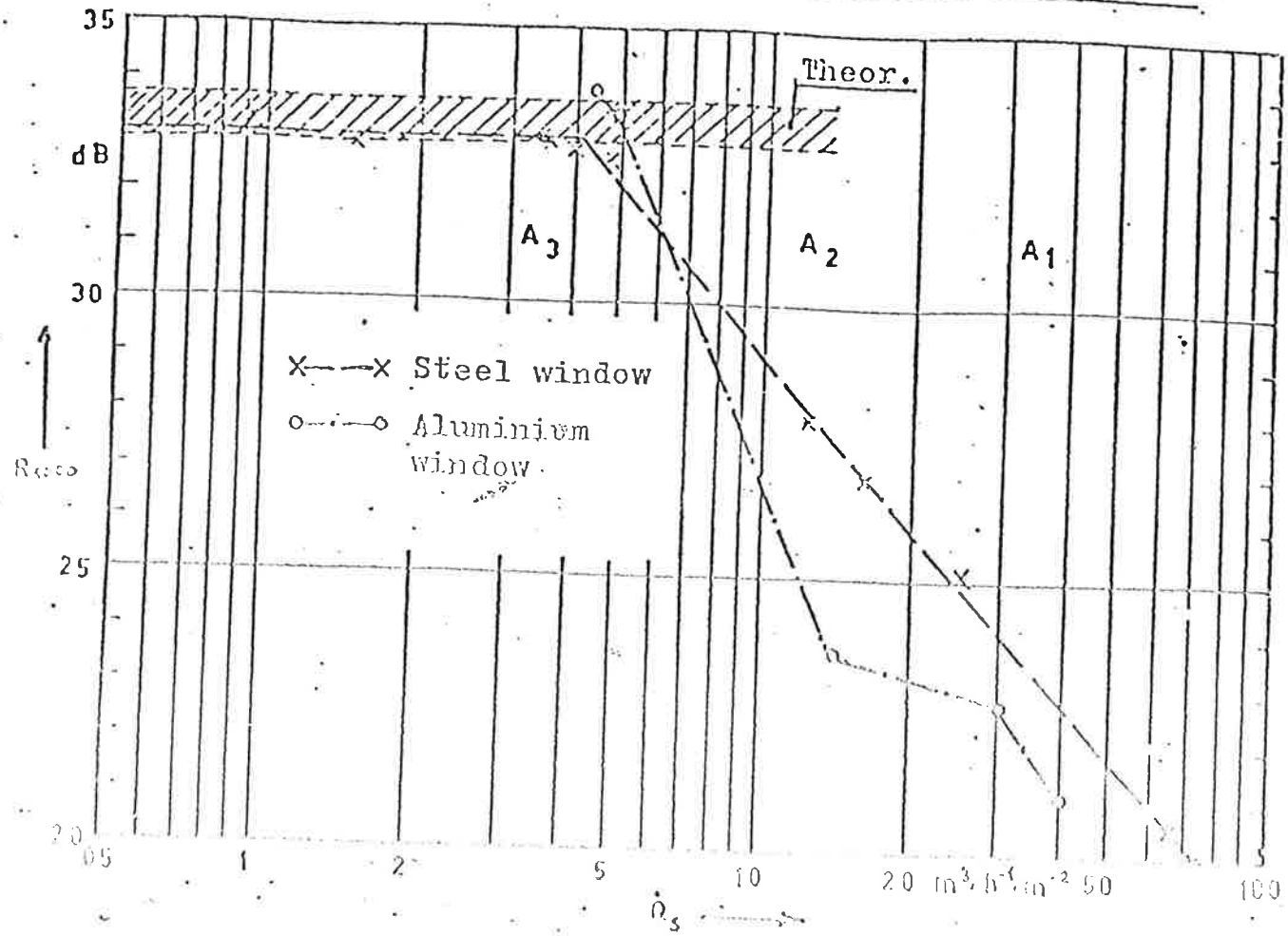
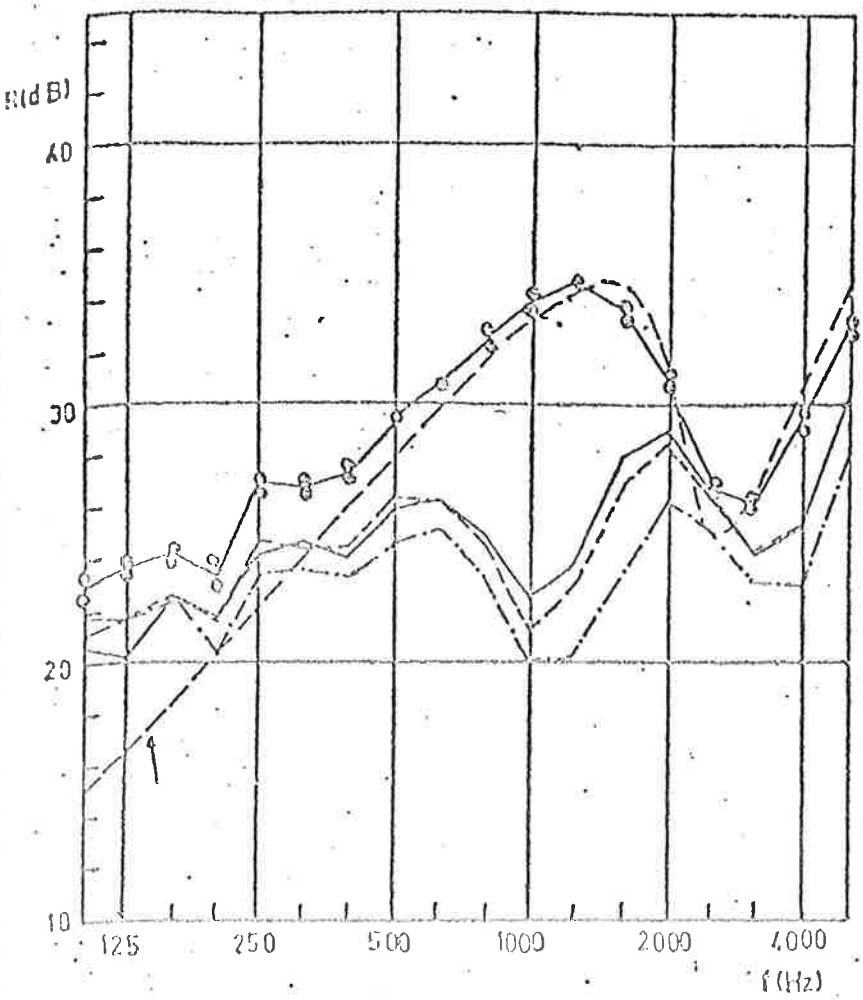


TABLE II: Comparison between perviousness to air at the pressure of 100 Pa (Q_s) and sound insulation power at 1000 Hz (R_{1000})

	Test condition	Q_s ($m^3 \cdot h^{-1} \cdot m^{-2}$)	R_{1000} (dB)
Aluminium w-&-d frame	1	4,4	33,8
	2	4,8	33,5
	3	14,2	23,6
	4	29,8	22,8
	5	40,5	21,1
Steel window and door frame	1	0,9	33,4
	2	1,5	32,9
	3	2,3	33,1
	4	3,5	33
	5	4,0	32,8
	6	4,8	32,6
	7	12,2	27,9
	8	16,2	26,9
	9	25,4	25,2
	10	67,5	20,6

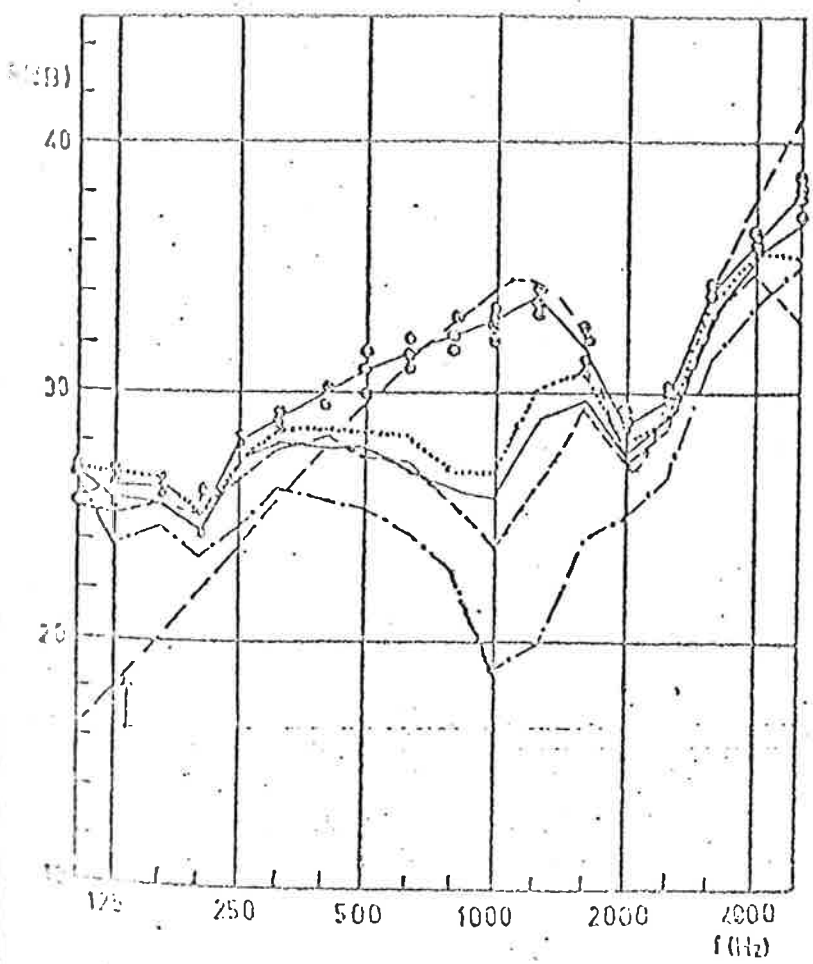


Graph. 8: MEASUREMENT OF THE SOUND INSULATION POWER

Aluminium window-and-door frame

Test conditions:

1-2 $Q_s < 4,8$
3 $Q_s = 14,2$
4 $Q_s = 29,8$
5 $Q_s = 40,5$



Graph. 9: MEASUREMENT OF THE SOUND INSULATION POWER

Steel window-and-door frame

Test conditions:

1,2,3,4,5,6 $Q_s < 4,8$
7 $Q_s = 12,2$
8 $Q_s = 16,2$
9 $Q_s = 25,4$
10 $Q_s = 67,4$

The first research developed according to what carried out in the other operating units involved has dealt with the evaluation of the meaning of the 4 building technologies chosen for the research.

The experimental results obtained for each examined technology are represented in the diagrams of graph. 1, 2, 3 and 4. Perviousness to air is expressed in m^3/hm^2. The difference between window-and-door frames without weather strips or with some kind of strips is also represented.

When examining the data, the following considerations came out:

- Most of the tested frames belong to perviousness to air classes A2 and A3.
- Frames perviousness has been improving in the last few years in fact higher perviousness degrees are more frequent in tests carried out in previous years.
- Generally weather strips don't seem to significantly influence perviousness. In a limited number of tests it has been noticed that good frames (A2) have further improved their waterproofing performance thanks to weather strips.
- Generally experimental data coming from ICITE, ITAC and Montedison were in concert. A difference between ICITE and ITAC has been found only for steel window-and-door frames.

It must be underlined that these data refer to perviousness of window-and-door frames openable joints. In this connection we should remember the considerations resulting from Montedison-CSI research on integration joints.

Available data are been processed now in order to evaluate the possibility of obtaining perviousness characteristical values for openable joints of window-and-door frames where the building technology and the opening system must be defined.
As far as other developments are concerned, this year we have been working for the creation of AGA THERMOVISION image treatment procedure. ICITE has been equipped with the digital analogical convertor able to transfer the signal from the telecamera to a compatible magnetic tape. Some programmes for visualization and interpretation of the image have been created and we expect to finish them before the 1979 programme starts. Such programme will deal with thermal transmission coefficients.

3 I.E.N. Galileo Ferraris Research Programme

The previous year's programme dealt with how to forecast theoretically the sound-insulation power of a window - and door frame knowing the thickness of the sheet of glass and the conditions on the edges.
The study aimed mainly at checking the reliability of such forecast methods in view of their subsequent use as terms of comparison of the experimental data relative to already installed frames. Thus indirectly obtaining informations about their perviousness to air performance.
Within the data collected, theoretical results and experimental data seem to be in agreement.

This year the research has been mainly concerned with the parallel measuring of the sound-insulation power and of the perviousness to air of window-and-door frames whose installation condition has been simulated in the laboratory together with various tightness conditions which have been artificially created in order to benefit from a large range of performances.

The test installation created this year and the instruments used are schematized in pict. 5.

Such test installation allows to measure perviousness to air according to Italian and European regulations /1/;/2/.

As we represented in pict. 6, this installation was placed inside the rooms to measure the sound-insulation power.

These rooms have been accomplished according to procedures required by regulation ISO 140. Pict. 6 shows also a scheme of the instruments used. Further considerations are expressed in the 1978 Report /4/.

Two metal window-and-door frames have been chosen: one of aluminium and one of steel both having two wings with the size of 2m.2m imposed by the maximum available light.

Different tightness conditions have been created on each frame: through plastic strippings placed along the perimeter, the tightness has been postulated until the extreme measuring possibility while on the contrary, perviousness has been increased enlarging the cracks on purpose. The stripping of the sheet and of the movable frame has been carried out, for the steel window, through rubber strips and for the aluminium window through silicone putty.

On both kinds of movable frames the loss factor has been

measured beforehand according to the procedures described in the previous report.

As synthetic datum for perviousness we assumed the value of the capacity corresponding to the pressure difference of 100 Pascal, in that, the lines delimiting the classification areas refer to this pressure.

In the case of the sound-insulation power, as the loss depends on the frequence, we decided to characterize the performance by considering the points where the phenomenum is more evident.

The sound insulation power was then adopted as synthetic data. Such power corresponds to the octave band of nominal frequence 1000 Hz (average of the values at the three bands 1/3 of octave 800, 1000 and 1250 Hz).

Thus we got a series of quantity pairs which have been represented in table II and in the diagram of graph. 7, where as a function of the rate of flow at 100 Pa (Q_s) in relation to the surface of the frame, the trend of the sound-insulation power is traced at 1000 Hz (R_{1000}). In the same graphic the limiting values at 100 Pa for the 3 classification areas have been indicated on the abscissa.

Furthermore the values of R_{1000} estimated by the calculation, obtained from 2 theoretical curves represented in graph. 8 and 9 are indicated on the ordinate.

In these graphics the curves are compared to the experimental cases obtained at various conditions of perviousness.

Notice how up to certain tightness level the value of the calculated sound-insulation power is in agreement with the experimental values except in the case of low frequencies where oscillation can occur owing to test installation characteristics.

According to these results we can make the following remarks:

- the value of air capacity beyond which the drop of sound-insulation power occurs, is on the limits of zone A3. This zone includes window-and-door frames with the best performances as far as perviousness to air is concerned. Therefore from the acoustic point of view this class differs clearly from the other two.

- With class A2 performances, 7 ÷ 8 dB losses of sound-insulation power can occur whereas within class A1 these losses reach 12 ÷ 13 dB. This means that window-and-door frames considered acceptable as for perviousness, even if classified in the lowest category, can be definitely inadequate as for the acoustic level.

- Furthermore if we take into consideration the choice criteria which according to UNI/CE 0015 regulation suggest that, the exposure areas being equal, should the performances of perviousness to air increase according to the building height, we observe that, should any sound-protection be taken into consideration, these criteria should be changed.

In fact if we consider that, at least in towns, the main outer noise source is the noise of traffic, the acoustic performances of window-and-door frames should be increased at the ground level where the noise is louder.

4. ITAC Research Programme

The 1978 programme of this operating unit had to deal with the energy-contents of the current technologies in the field of "outer window-and-door frames".
The analysis was carried out in terms of quality and when possible in terms of quantity. In particular the following technologies were taken into consideration:

- fixed and movable frames:
  energy content of materials and technological "conceptions" both pertaining to production and to maintenance of the installed elements. The analysis in terms of quantity is largely incomplete due to the difficulty of separating at the source the energy data pertaining to the production processes. Qualitative remarks have been made on:

  wooden frames
  cold-profiled tubular steel frames
  plastic material frames
  aluminium frames
  rubber frames
  systems without frames (equipped glass)

- size:
  size (width and lenght), their relation and their absolute

value have for outer window-and-door frames different possible energy implications which have been listed and ordered logically.

For certain situations, programmes on table computer systems have been worked out in order to permit approximate evaluations of a number of planning decisions.

- Opening systems:

both for technological implications in manufacturing processes and for the implications in "the use pattern", the opening systems have various consequences on the "life cycle" energy contents. The main problems pertaining to the following elements have been examined:

revolving vertical wings
sliding wings (vertical and horizontal)
wasistas (revolving on a horizontal axis)
horizontal and vertical bascules
combined (wasanta)

The fundamental energy content pertaining to the "opening systems" is the content relative to the perviousness to air they allow. Experimental information in this connection can be obtained from the data computerized by ICITE where the functional characteristics have been correlated also to the opening systems of the tested samples.

- Transparent surfaces:

As for energy dynamics pertaining to the size of the

transparent surfaces (free increments, losses etc.) and to their thermal conductivity, a number of technological aspects considered in this paragraph permit to check in a selective way the irradiation obtained through the transparent surfaces by treating the materials or by superimposing various films.

- sealing, complementary fixed and movable strips:
  the ability to permit a proper checking of air infiltrations and the conceptual and technological reliability have implications in different sectors of the energy demand: some of the main aspects have been analyzed in terms of quality and a few problems have been opened to which other research sectors should give a contribution.

- inner and outer screens:
  the availability of efficient systems for the checking of the irradiation from the outside to the inside and viceversa, placed outside or inside the frame, is fundamental for the energy optimization of these elements of the structural envelope: illustratively through these screens a frame can become a passive system and contribute to the thermal balance of spaces in a conspicuous way. Technologies and fundamental concepts have been analyzed, and in this sector we referred to the researches being carried out both in Italy and in the USA relative to "passive systems".

5. Conclusions

We think it better to add some synthetic notes about present activities and about the activities which will be carried out in 1979.

ICITE will finish the 1978 programme continuing the implementation of data coming from other sources and the processing aiming at evaluating the importance of the different building choices (ex. type of closing, number of hinges, type of strips) on air perviousness of the certified components. The Galileo Ferraris Institute will complete the first experimental study testing pvc and wooden window-and-door frames.

As for 1979 activity, it is foreseen that Montedison C.S.I. and ICITE will develop their research activity on the problem of thermal transmittance of frames using, in this way, the results obtained during the explorative phase of the first year.

At the same time the thermal chamber for the transmittance measurement on real-scale walls (Method ASTM C 236) /5/ has been made, set up and made functionning at Montedison C.S.I. laboratories in Bollate. A system of the same kind will come into operation at ICITE at the end of March.

Meanwhile we started tests on curtain walls during which we also expect to find a method to treat the image using it to evaluate the thermal behaviour of front components after installation.

Further to the components already tested from the viewpoint

of "perviousness" we plan to evaluate also the thermal behaviour of components in which specific building changes have been performed to measure transmittance (ex: double glasses, thermal cavities,...)
At the Galileo Ferraris Institute, tests in laboratory on different kinds of components, with different glass thickness, will continue aiming at consolidating, in terms of quantity, the correlation researched between perviousness and acoustic behaviour of window-and-door frames, above all in rather high perviousness areas. We also intend to start a series of tests after installation checking window-and-door frames whose perviousness characteristics have been previously determined.
ITAC eventually, will go into thoroughly the evaluation of the incidence on energy behaviour of the building characteristics of window-and-door frames, comparing progressively with the energy results of research carried out by other operating units. Furthermore the main purpose of the research will be the evaluation, in terms of quantity, of the energy content due to the production and to the installation of components of various technologies and types.

6. Bibliography

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/3/ I.C.I.T.E. Report no 781106/548 "Towards the technical record of building components - Window-and-door frames testing data storing" (G. Caroli, F. Naldi, R Vinci) 1978

/4/ "1978 Technical Report for Theme I"; I.E.N. Galileo Ferraris Report - December 1978

/5/ ASTM C 236/66 "Thermal conductance and transmittance of built-in sections by means of the guarded hot-box"