6895

TESTING OF FRESH AIR MIXING DEVICES

Prepared for:

Research Division
Canada Mortgage and Housing Corporation
700 Montreal Road
Ottawa, Ontario
K1A 0P7

CMHC Project Officer: Jim H. White

Prepared by:

IRTA Research
P. O. Box 250
Clarence Creek, Ontario
K0A 1N0

Project Manager: Charles LeMay

March 1993

DISCLAIMER

Testing of Fresh Air Mixing Devices

Executive summary

The new 1995 National Building Code will call for larger and more effective fresh air intakes in residential buildings. Three types of problems could arise if unmixed cold air reached a furnace heat exchanger: 1) condensation; 2) metal stress; and, 3) cold air reaching a floor register. IRTA was contracted by the Research division of CMHC to evaluate the mixing of return air with outside air from a fresh air intake duct.

IRTA first looked at fresh air intakes in a number of different homes. It was found that most ducting is constructed in such a way that mixing is accomplished: corners are not rounded; and branch ducts are connected to the main return air duct, very close to the furnace. This made it impossible to test the efficiency of mixing devices in such settings. It was therefore decided to investigate fresh air stratification and mixing devices in a laboratory setting. Two approaches were taken:

1) Cold air was introduced in such a way as to maintain its stratification. This stratification was largely maintained on straight sections but was mostly lost at 90° corners. The fan used for these tests completed the mixing. Test results proved that if stratification occurs it can be maintained in straight sections of ducts. It is also more likely to persist in well designed, low-pressure-drop ducting built to HRAI rules.

2) On horizontal and vertical ducts, cold air was introduced alternately flush to the surface, and through mixing devices. It was found that practically no stratification was maintained in the vertical duct, with or without mixing devices. Stratification was partially maintained in the horizontal duct, when using a flush fresh air intake. The sliced cylinder mixing device, when installed in the centre of the horizontal duct, broke up the stratification within less than 2 metres. The X-funnel mixer created almost perfect mixing in just over 1 metre.

Essais de mélangeurs d'air frais

Résumé

Le Code National du Bâtiment de 1995 exigera des prises d'air extérieur plus grandes dans les édifices résidentiels. Trois genres de problèmes peuvent survenir si de l'air froid, non mélangé, atteint l'échangeur de chaleur du générateur d'air chaud: 1) de la condensation, 2) de la contrainte des métaux et 3) la possibilité qu'une partie de cet air atteigne une bouche d'air après un réchauffement insuffisant.

L'IRTA a d'abord examiné des entrées d'air frais dans différentes maisons. Il s'avère que la plupart des conduits de chaleur dans ces maisons sont construits de façon à favoriser le mélange: les coins ne sont pas arrondis, les embranchements sont raccordés très près du générateur d'air chaud. Ces conditions rendant impossible l'essai de mélangeurs d'air frais, il fut décidé de conduire les essais en laboratoire en poursuivant deux approches:

1) Stratification forcée. De l'air froid fut introduit dans des conduits de façon à favoriser sa stratification. Il a été possible de maintenir en bonne partie la stratification dans les sections droites de conduits mais presqu'impossible après les coudes de 90°. Le ventilateur de distribution utilisé dans ces essais complétait le mélange. Selon ces essais les couches d'air stratifiées se mélangent peu dans des sections droites. Cette stratification se maintiendra probablement, même après des coudes, dans des conduits conçus selon les règles de HRAI, offrant peu de perte de pression.

2) Configurations favorisant le mélange. Des connections d'air frais furent pratiquées dans des sections de conduits horizontales et verticales, soit à l'égalité de la surface du conduit de retour, soit à travers un mélangeur. Les résultats démontrent que très peu de stratification persiste dans les essais sur le conduit vertical, avec ou sans mélangeur. Par ailleurs, sur un conduit horizontal, une stratification partielle se maintient si le raccordement d'air frais est à l'égalité de la surface. Un mélangeur cylindrique simple, installé au centre du conduit, mêle les strates d'air en moins de 2 mètres. Par contre, le mélangeur x-conique assure une quasi uniformité de température dans l'espace d'un peu plus d'un mètre.

CMHC SCHL

Helping to house Canadians

Question habitation, comptez sur nous

National Office
700 Montreal Road
Ottawa, Ontario
K1A 0P7

Bureau National
700 chemin Montréal
Ottawa (Ontario)
K1A 0P7

Puisqu'on prévoit une demande restreinte pour ce document de recherche, seul le sommaire a été traduit.

La SCHL fera traduire le document si la demande le justifie.

Pour nous aider à déterminer si la demande justifie que ce rapport soit traduit en français, veuillez remplir la partie ci-dessous et la retourner à l'adresse suivante :

> Le Centre canadien de documentation sur l'habitation
> La Société canadienne d'hypothèques et de logement
> 700, chemin de Montréal, bureau C1-200
> Ottawa (Ontario)
> K1A 0P7

TITRE DU RAPPORT : ______________________________

____

Je préférerais que ce rapport soit disponible en français.

NOM ______________________________

ADRESSE ______________________________
rue app.

____
ville province code postal

No de télephone (   ) ____________

1946 SCHL 45 CMHC 1991

TESTING OF FRESH AIR MIXING DEVICES

1. Introduction

The new 1195 National Building Code will call for larger and more effective fresh air intakes in residential buildings. Three types of problems could arise if unmixed cold air reached a furnace heat exchanger: i) condensation; ii) metal stress; and iii) cold air reaching a floor register. IRTA was contracted by the Research division of CMHC:

1) to demonstrate temperature stratification in return air ducts, when fresh air is passively introduced;
2) to build, test and develop a series of mixing devices which reduce that stratification;
3) and, to document the temperature distribution and configurations tested.

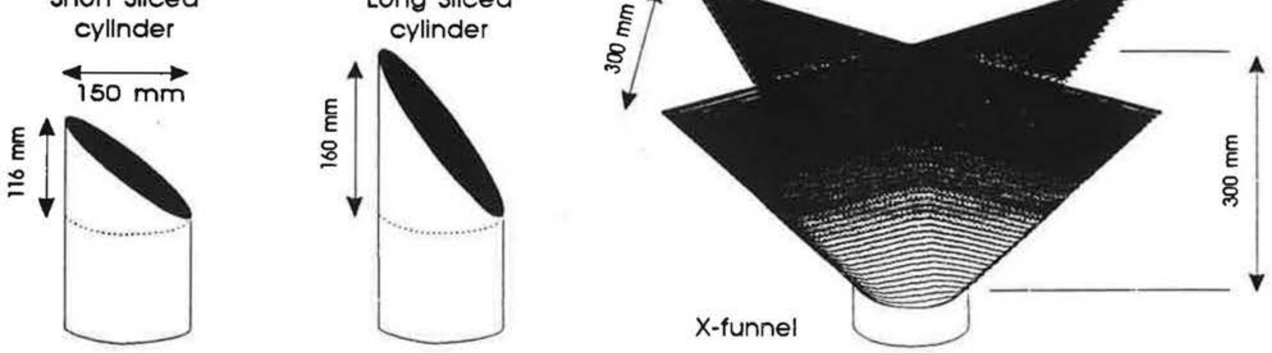
IRTA first looked at fresh air intakes in a number of different homes. Four homeowners answered our initial request for a test house. A visit to these houses revealed heating systems totally unsuited for test purposes. The ducts on all these systems had sharp corners. None of them had long sections free from side connections. Three had Y connections immediately before the return air plenum.

Visits to other houses indicated similar installations. Although the installers had provided good quality workmanship, the ductwork did not appear to have been a priority in the total house design. Installations in older houses were retrofits where furnace location was more a question of circumstance than a question of planning. Ducts in new homes were installed with rectangular 90° sharp-heeled elbows rather than smooth radius elbows. These elbows were not equipped with vanes.

It would have been impossible to test the performance of mixing devices in these duct systems, since they already ensured a high degree of mixing of return air. It was then decided to evaluate stratification and mixing in the laboratory.

The basic principle used in these tests was to establish a known flow of warm air in a duct and to introduce fresh air into this duct at controlled pressure and temperature differences. Mixing was to be established by measuring the temperature of air at different points in the ducts. It should be recognized, however, that the laboratory conditions under which these tests were done cannot be considered as duplicating house conditions.

Figure A. Mixing Devices



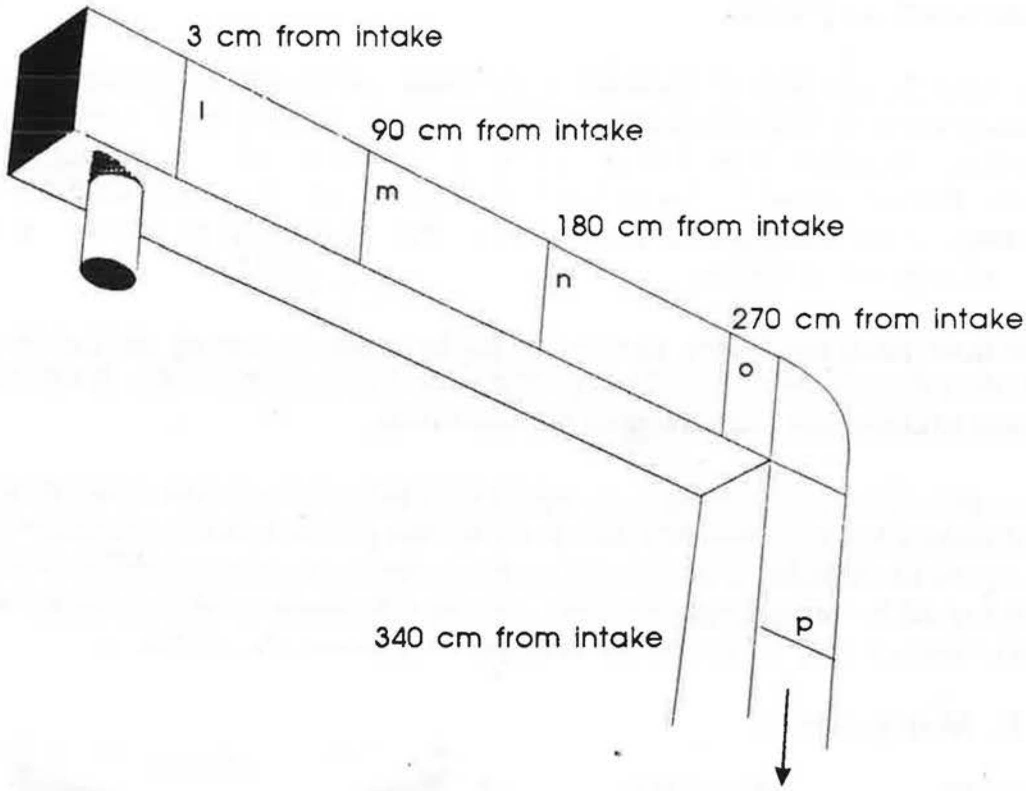
2. Procedure

A 150 mm fresh air intake was used since it is the minimum size called for by the new code proposals.

a) Ducts

i- An existing 300 mm by 300 mm (12 in. by 12 in.) duct was used to develop the methodology and to observe basic phenomena. A 150 mm sheet metal fresh air intake was connected to this duct. The connection was done both on the bottom-side and on the bottom-centre (Figure B).

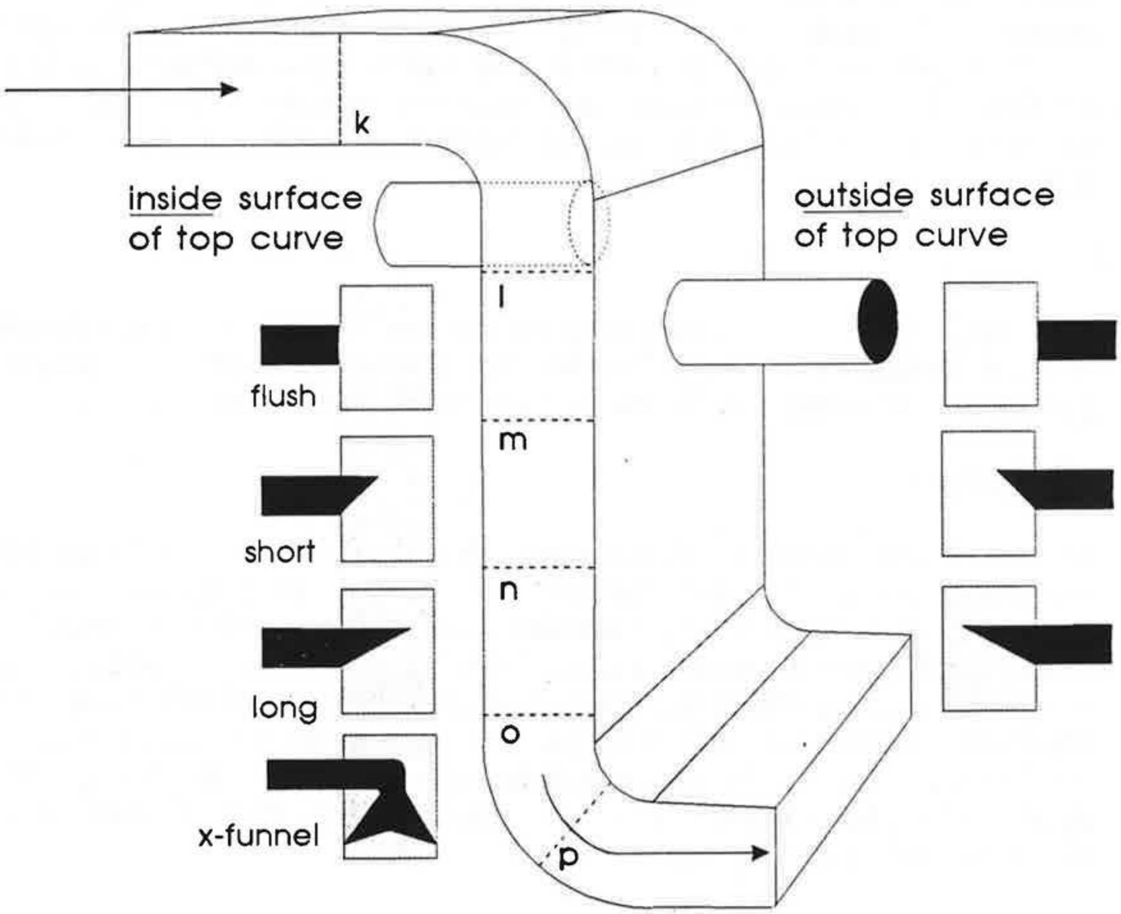
Figure B: 300 mm by 300 mm return air duct with 150 mm fresh air intake. Letters l, m, n, o and p indicate temperature and pressure measurement points along the duct.



ii- A 300 mm by 600 mm (12 in. by 24 in.) return air duct was built to allow measurement of the mixing along a vertical segment. The height of this segment is the same as that found in a house between the joists and the floor-level connection to the furnace fan compartment (figure D).

The 150 mm fresh air duct was connected in two different places. It was first connected to a centrally-located hole, immediately after the elbow, on the inside curve, on the vertical leg of the duct. It was also connected 40 cm down from the elbow on the outside curve. This lower position was chosen to prevent the backflow of warm air into the fresh air duct.

Figure C: 300 mm by 600 mm return air duct with 150 mm fresh air intake. Letters k, l, m, n, o and p indicate pressure and temperature measurement points along the duct.



b) Measurements and methodology

i- Temperatures:

Temperatures were measured at 25 points (5 x 5 grid) at each location, using a single type K thermocouple and a Comark 9050 precision thermocouple reader. A single thermocouple was used to measure all temperatures, thus providing more accurate differential measurements[1]. Actual variations in duct temperatures were far greater than meter errors (less than 0.5° C). These variations were within 1° C in stable conditions and within 3° C in areas of high temperature difference, close to the fresh air intake. Using a single thermocouple for all readings virtually eliminated instrument-induced differentials in temperature measurements.

ii- Pressures:

Differential pressures were measured with an *Airflow* type 5 precision manometer. The low scale of this manometer reads from 0 to 125 pascals in 0.5 Pa divisions. The position of the meniscus can be estimated between these divisions. The manometer was connected to two static pressure sensing probes introduced in the middle of the air flow. Differential pressures were measured between a fixed point (point k, upstream from the fresh air intake, see Figure C) and different positions along the duct.

iii- Flow:

The straight sections of the duct were too short to allow precise flow measurements with a pitot tube. However, a 25-point pitot traverse was used and is considered to provide a good estimate of the average air velocity in the duct.

iv- Test conditions

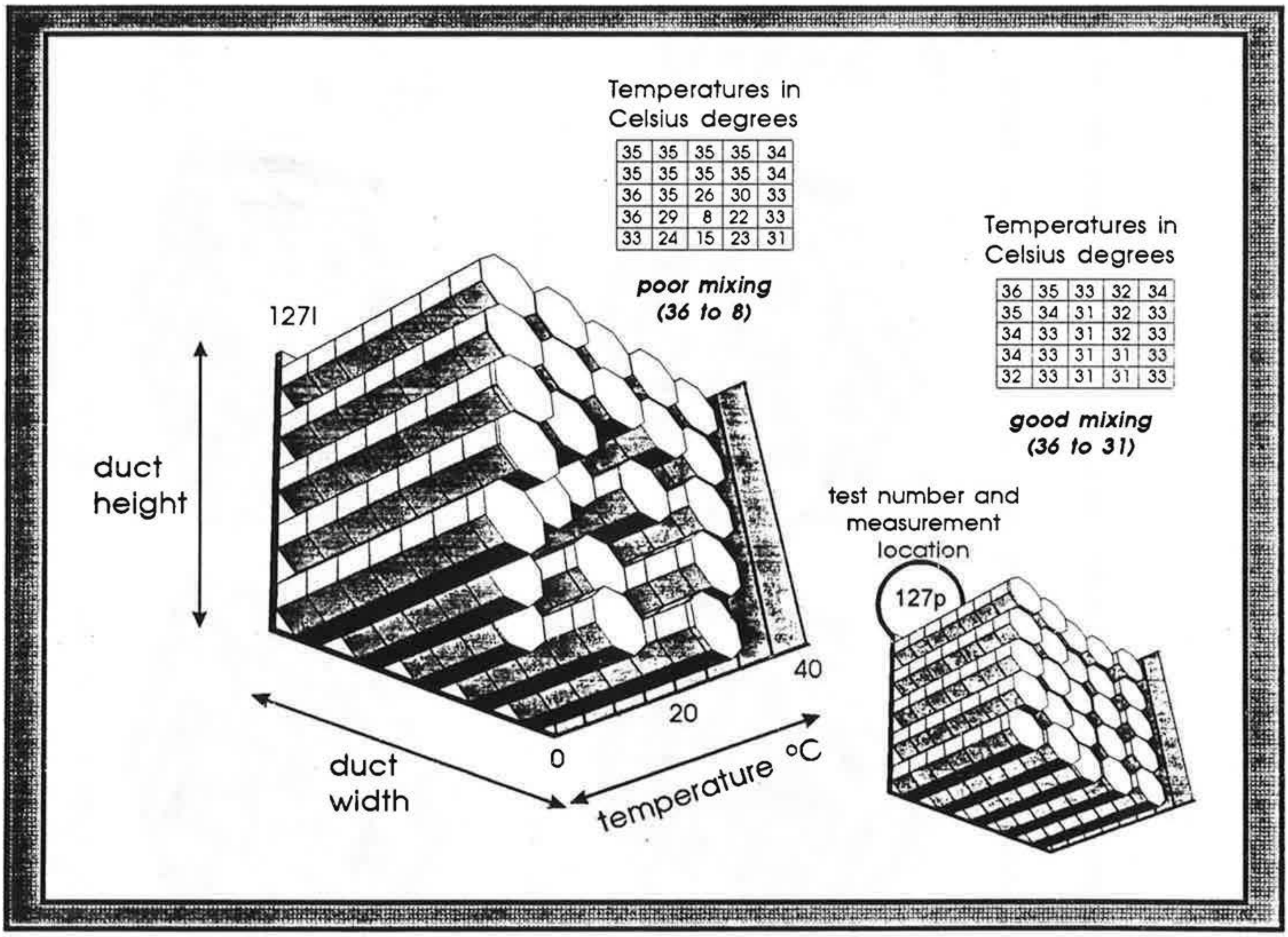
In actual heating season conditions, return air is usually in the 20°C range. Fresh air may dip as low as -30°C, for differentials of 50°. For test purposes, a temperature differential of 40° to 50°C was maintained between return-air and fresh-air. Since outside air temperatures were not controllable, "return air" was heated to maintain the needed temperature difference. Tests were done during the daytime and outside air was taken from the south side of the building; outside temperatures, however, varied rapidly on a sunny day. Temperature differentials were, therefore, not maintained as steady as had been hoped. Flow velocities of 3 m/s (550 l/s flow rates) were maintained in the vertical duct.

[1] A permanent thermocouple array would have accelerated reading but would have influenced mixing and flow.

3. Results

Temperature data are graphed in such a way as to allow a visual evaluation of mixing. Note that distances between the fresh air intake and the temperature measurement points vary from one fresh air intake configuration to another. Mixing should be compared for similar distances.

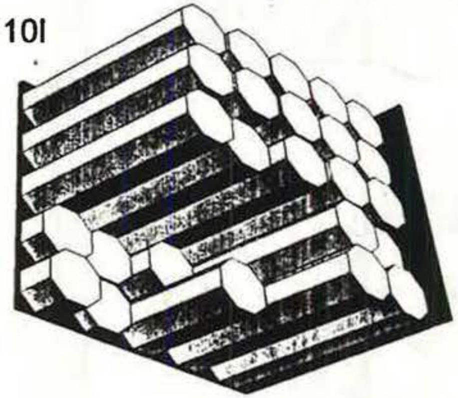
Figure D: Key to the interpretation of the fresh air mixing graphs.



a) 300 mm by 300 mm horizontal duct. This duct was used for preliminary testing; data collection was not as complete as for the vertical duct.

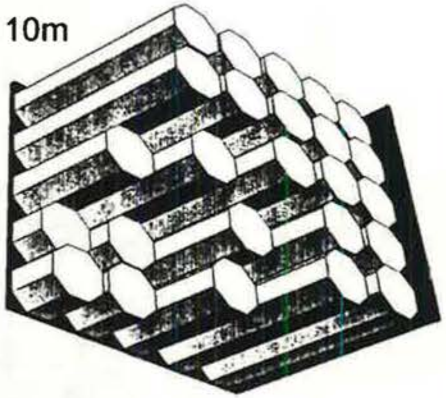
i- Forced stratification of fresh air intake by the use of flow straighteners: stratified cold air remains stratified.

110l



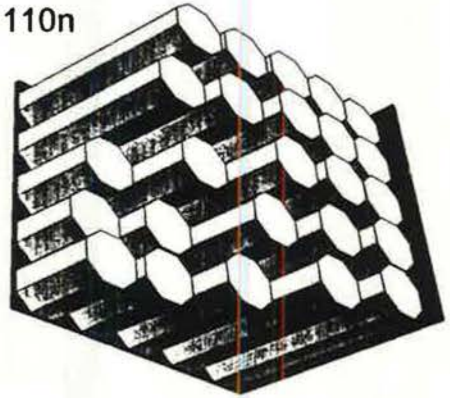
3 cm from intake

110m



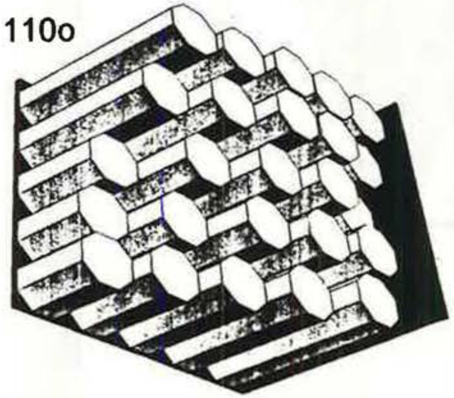
90 cm from intake

110n



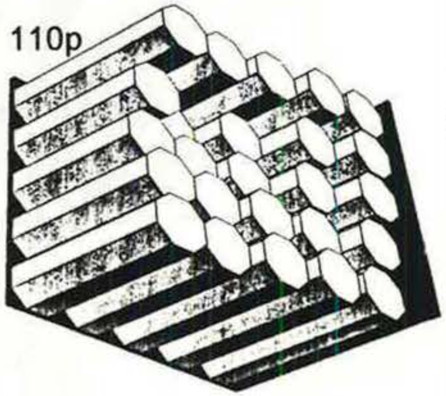
180 cm from intake

110o

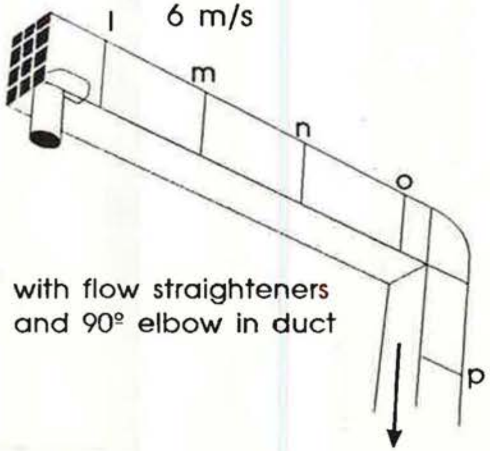


270 cm from intake

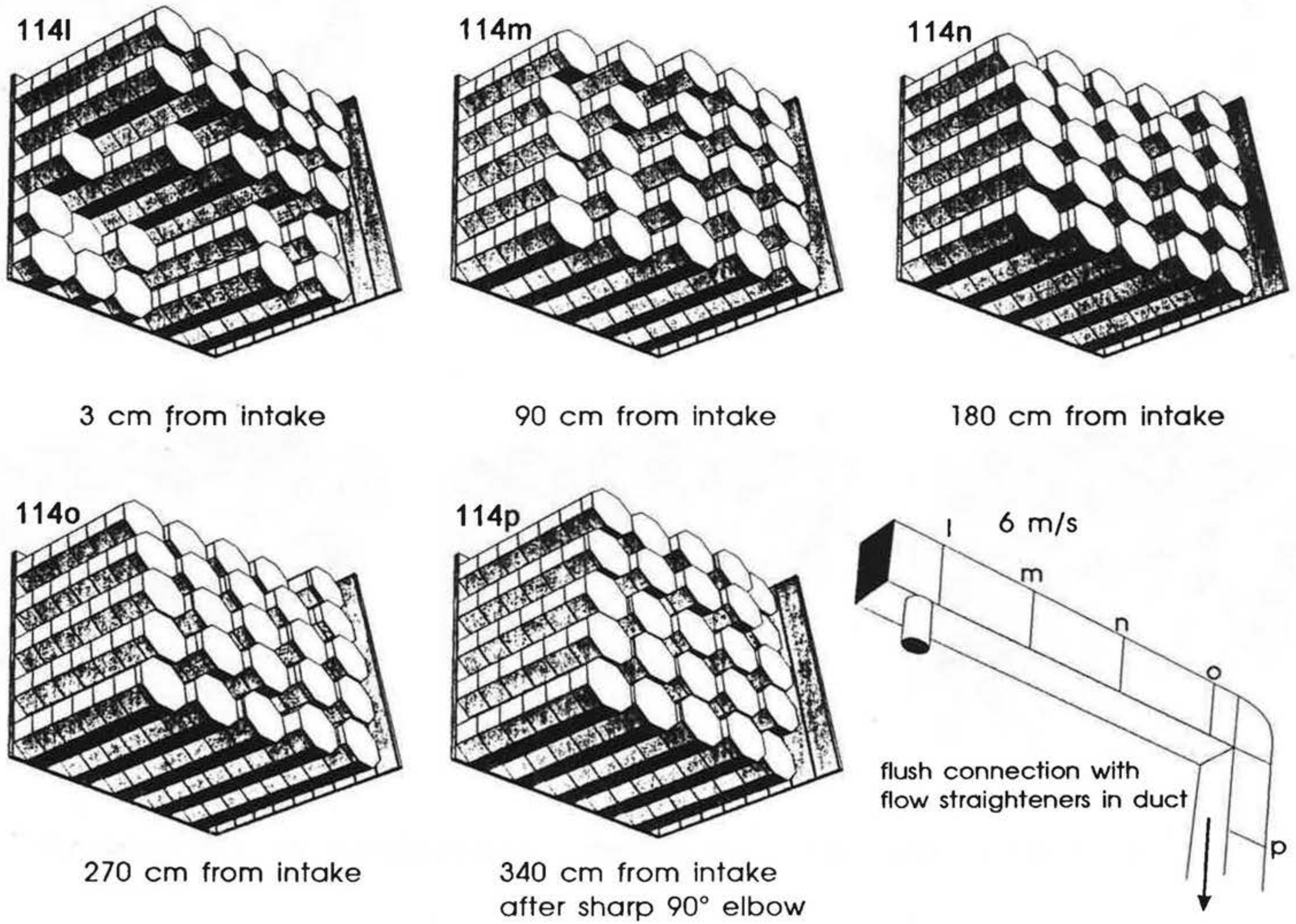
110p



340 cm from intake
after sharp 90° elbow

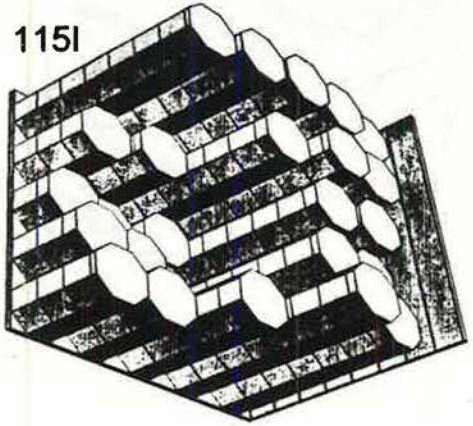


ii- Flush connection on the bottom (at the side); partial stratification is maintained for more than 270 cm.



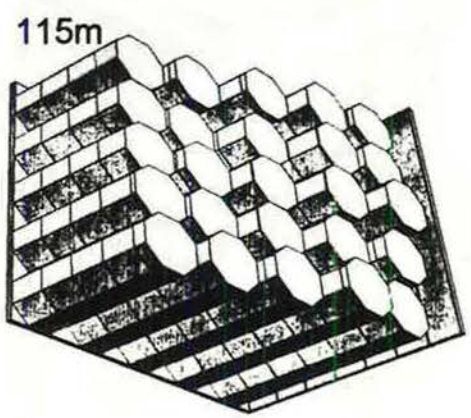
iii- Short mixing device on the bottom (at the side); partial stratification is maintained for more than 270 cm.

115l



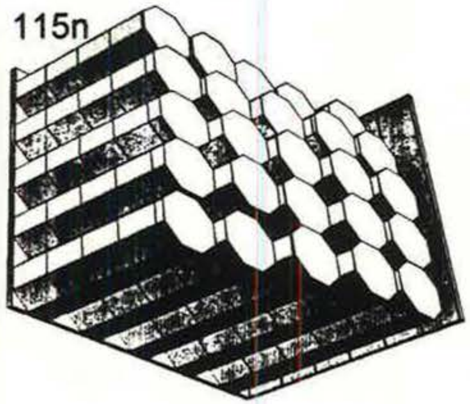
3 cm from intake

115m



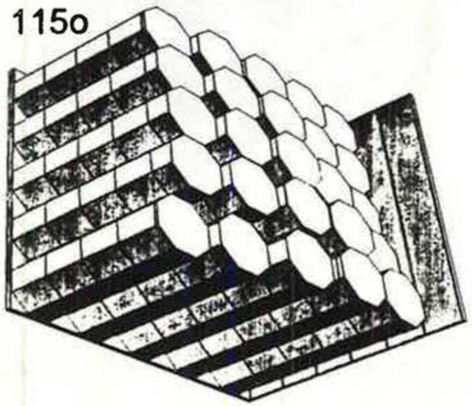
90 cm from intake

115n

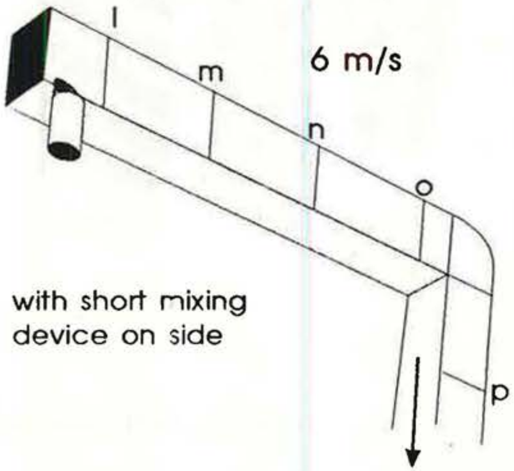


180 cm from intake

115o

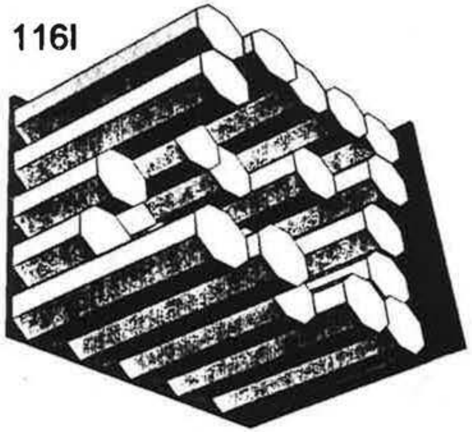


270 cm from intake



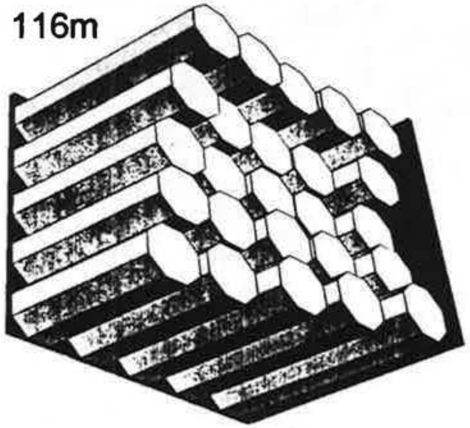
iv- Short mixing device on the bottom (at the centre); this device breaks stratification in less than 2 metres.

116l



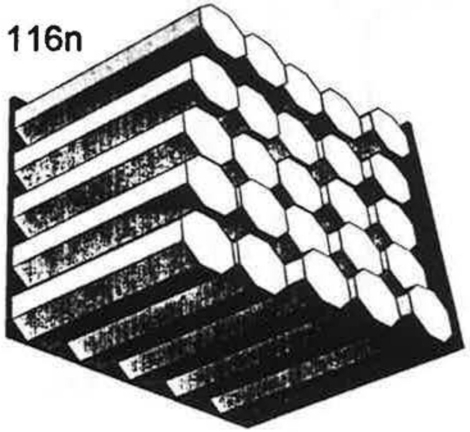
3 cm from intake

116m



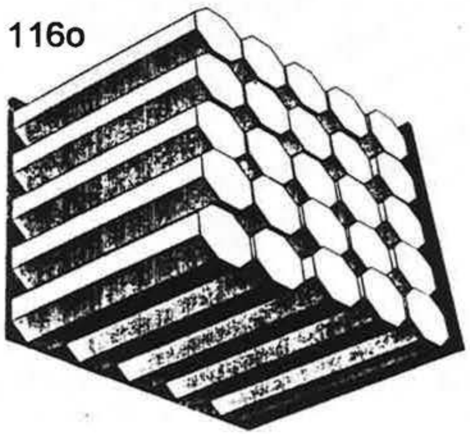
90 cm from intake

116n

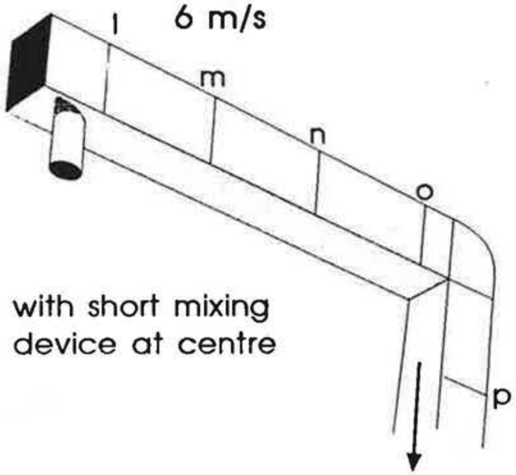


180 cm from intake

116o



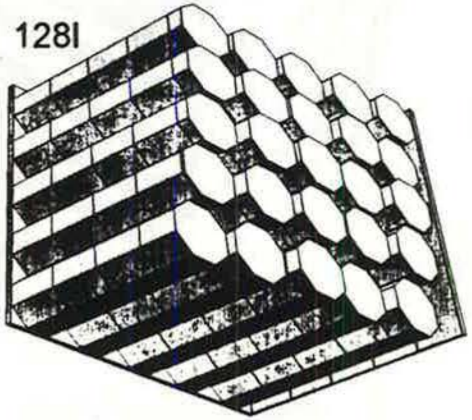
270 cm from intake



b) 300 mm by 600 mm vertical duct (a set of data for this duct can be found in table A).

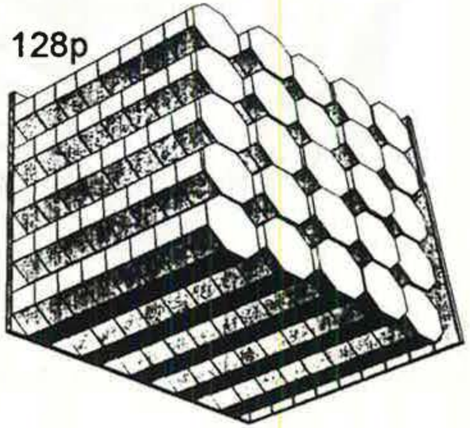
i- Temperature distribution without a fresh air intake.

128l

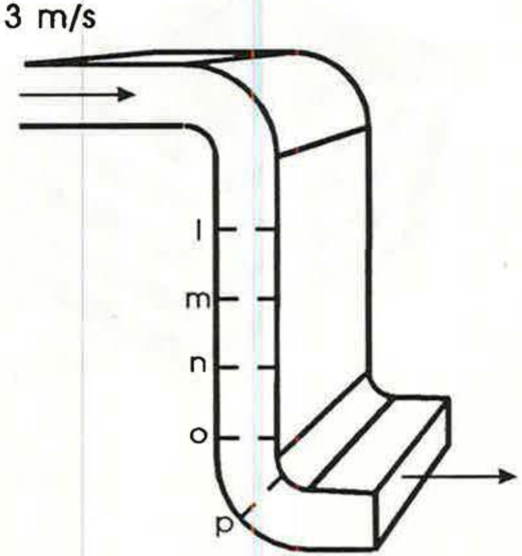


at point l

128p

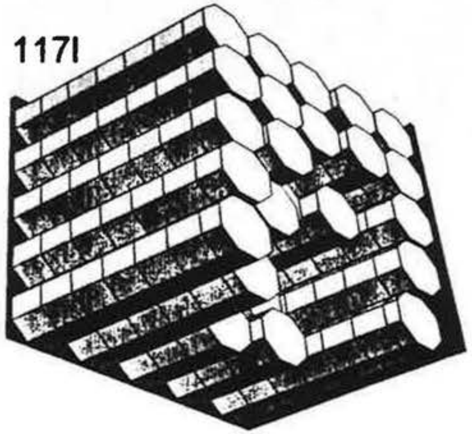


at point p



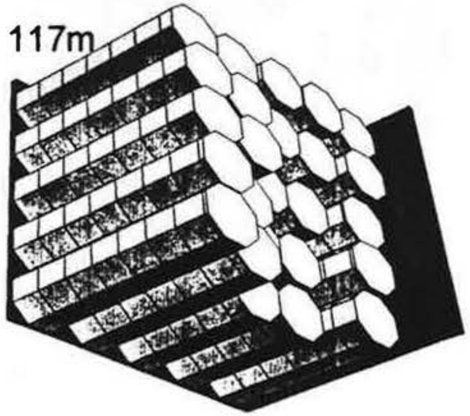
ii- Flush, on the inside surface. First test: 3 m/s.

117l



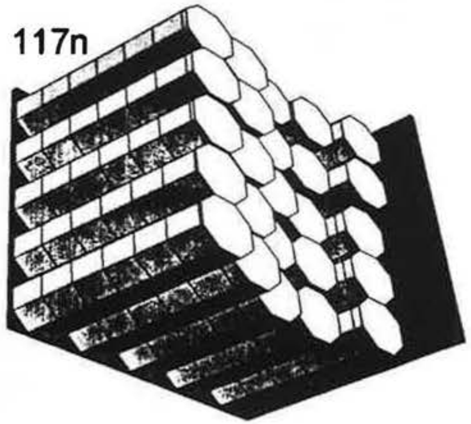
3 cm

117m



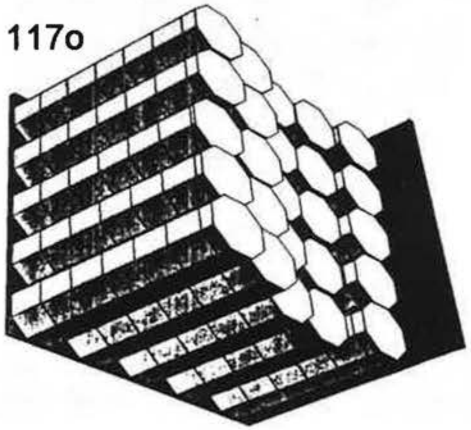
43 cm

117n



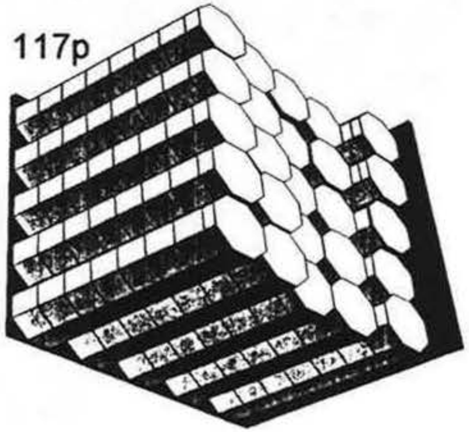
83 cm

117o

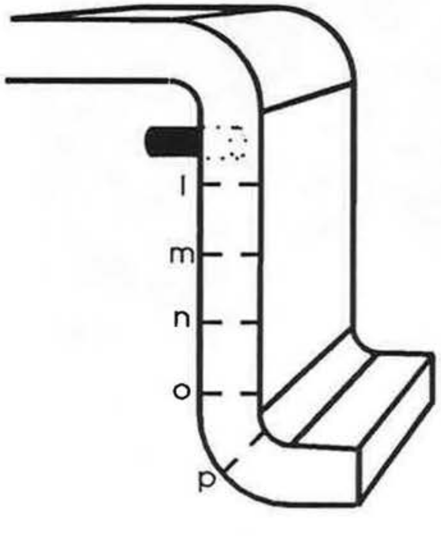


123 cm

117p

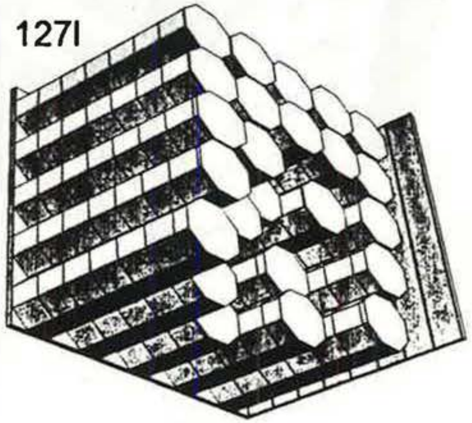


163 cm



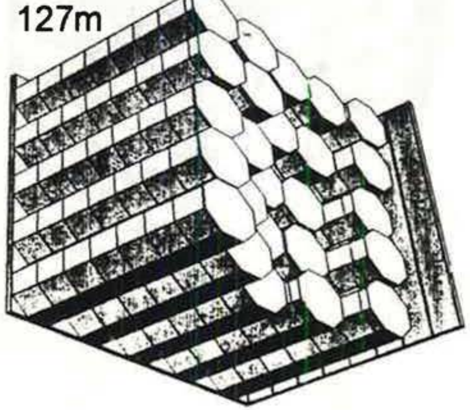
ii- Flush, on the inside surface. Second test: 6 m/s.
(Notice that the pattern is the same as in the first test at 3 m/s.)

127l



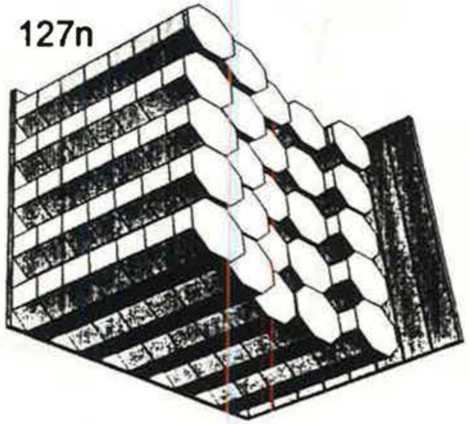
3 cm

127m



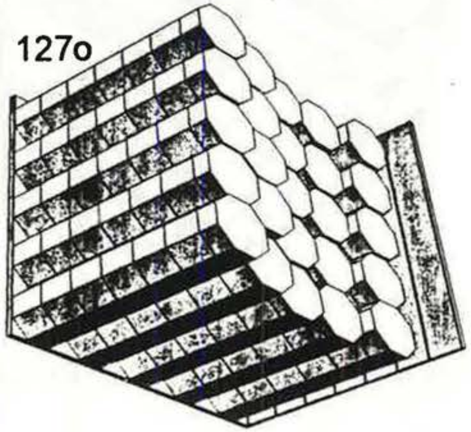
43 cm

127n



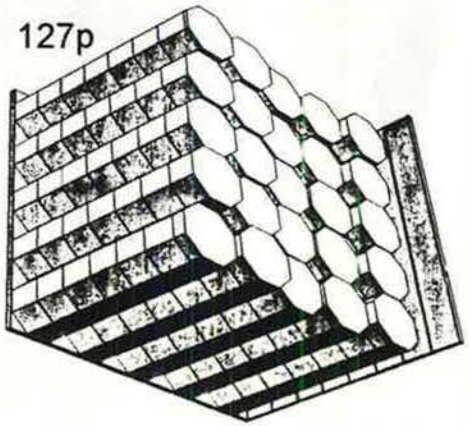
83 cm

127o

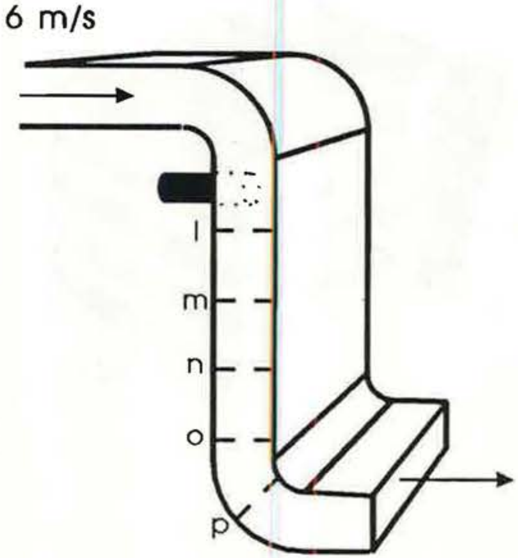


123 cm

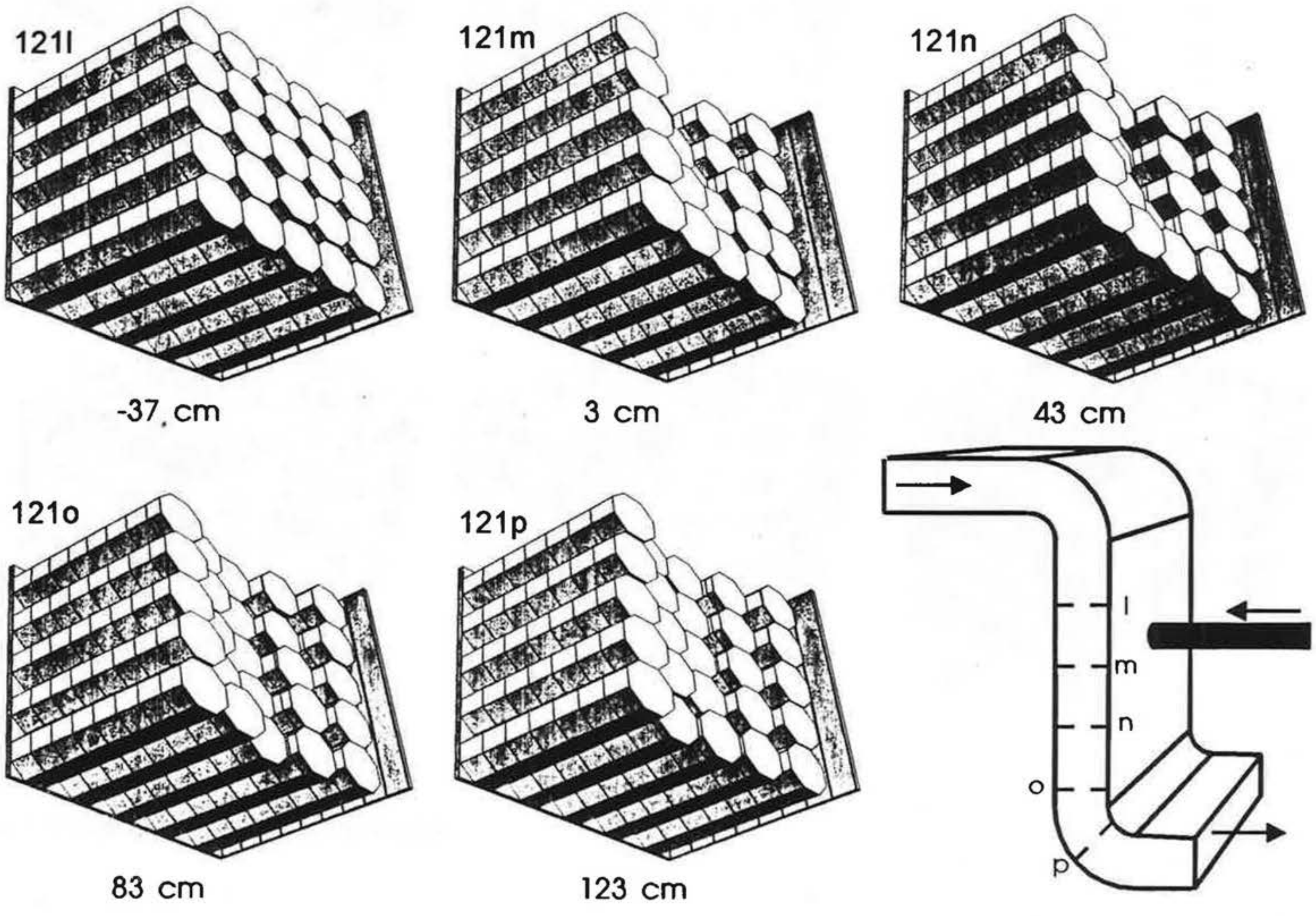
127p



163 cm

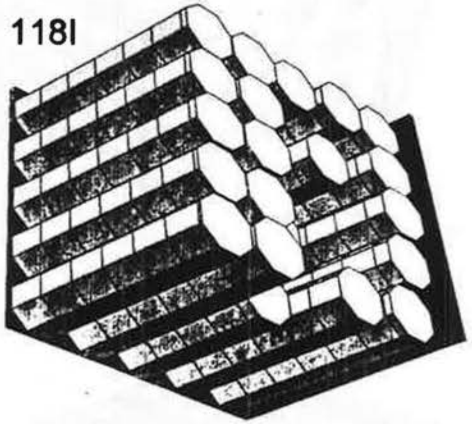


iii- Flush on the outside surface.



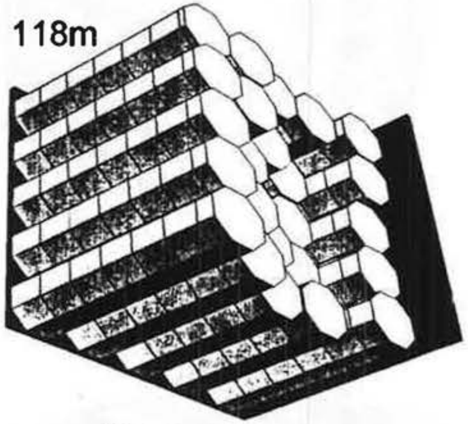
iv- Short mixing device, on the inside surface.

118l



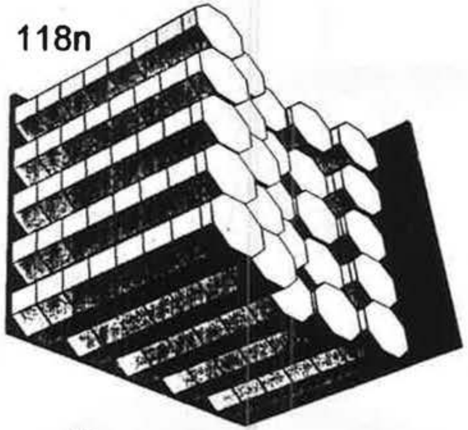
3 cm

118m



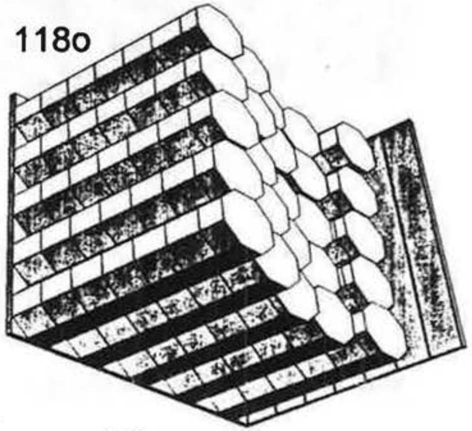
43 cm

118n



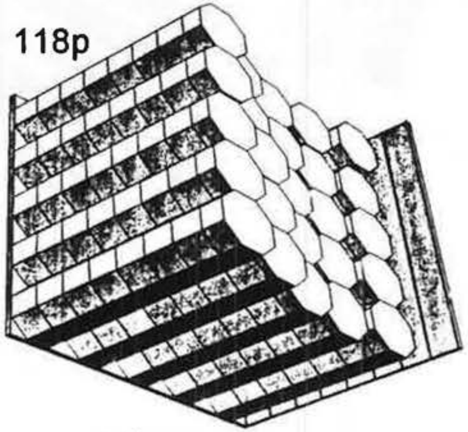
83 cm

118o

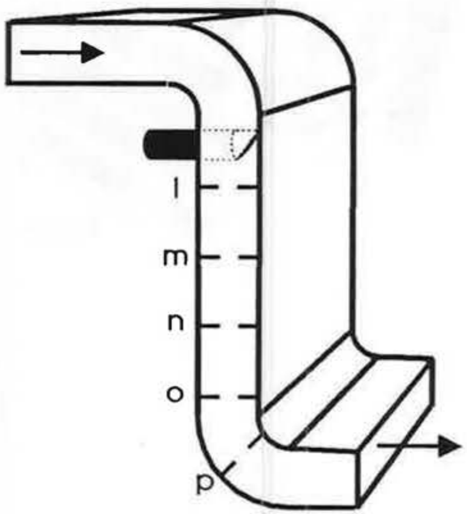


123 cm

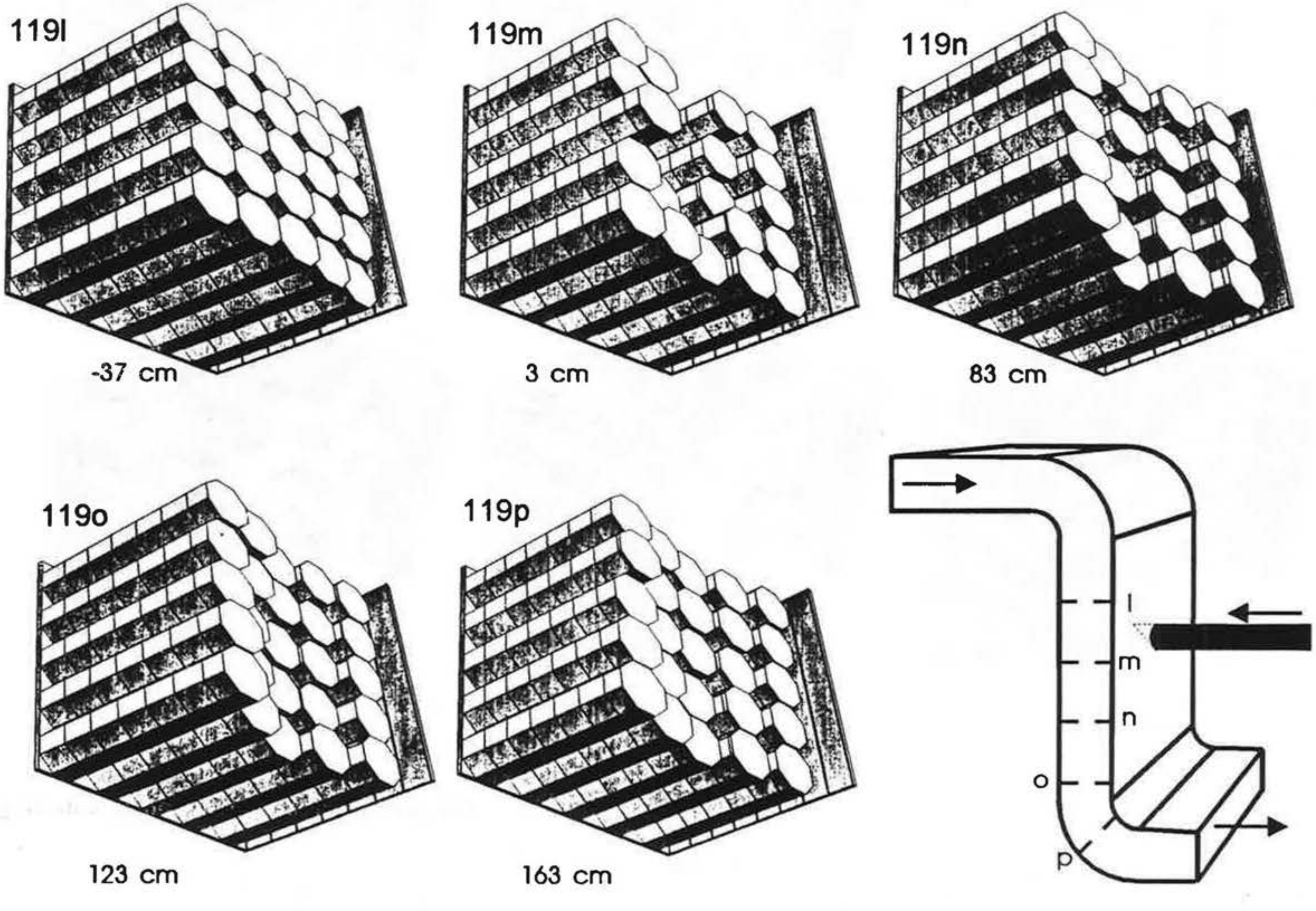
118p



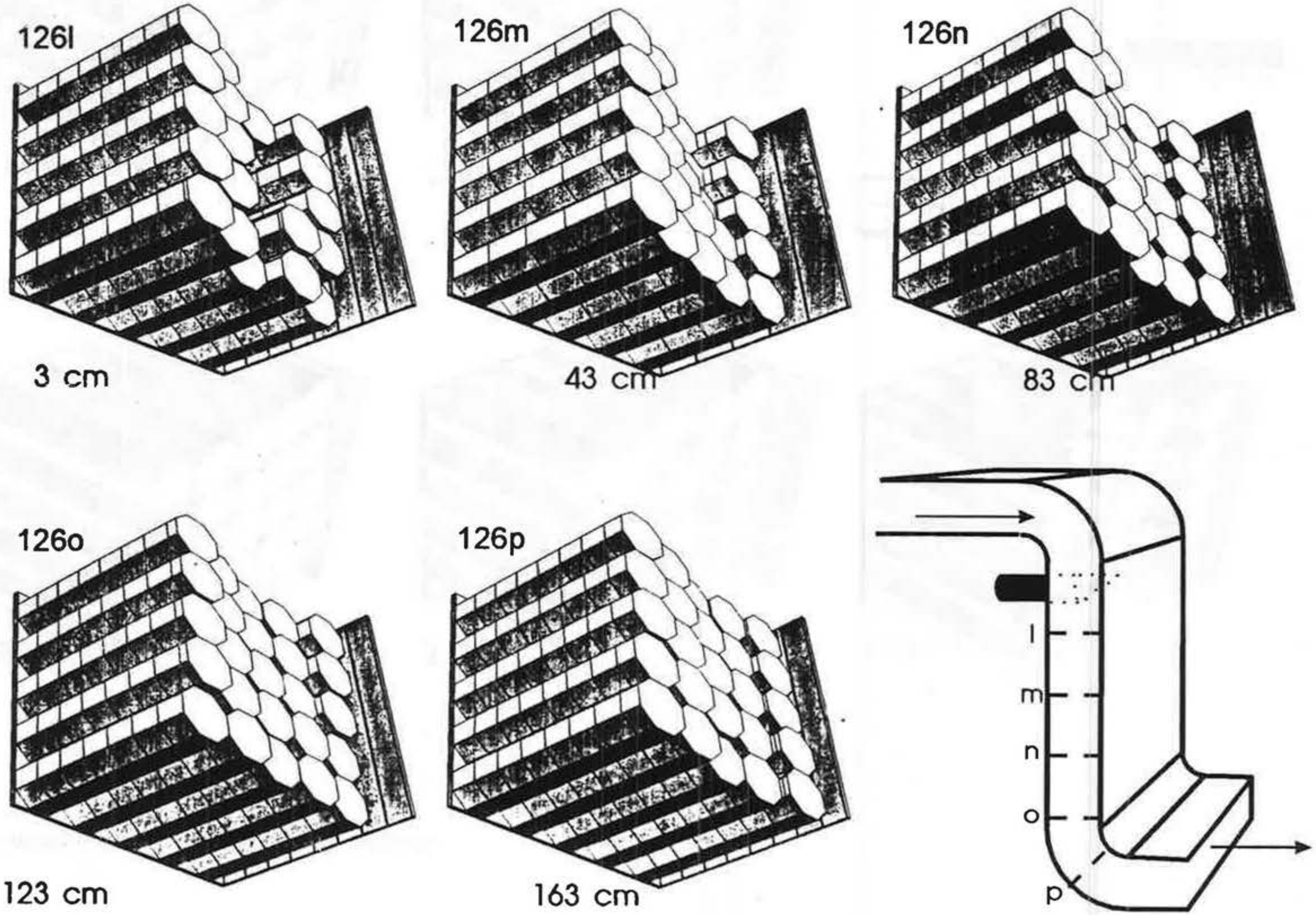
163 cm



v- Short mixing device, on the outside surface.

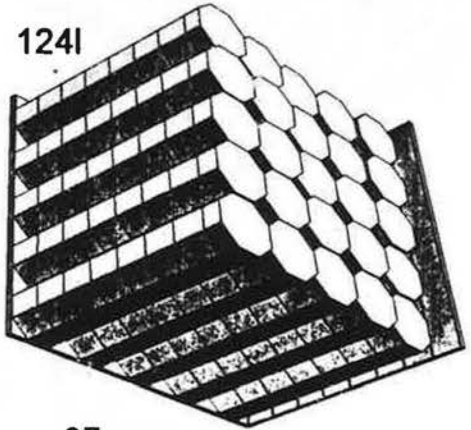


vi- Long mixing device, on the inside surface.



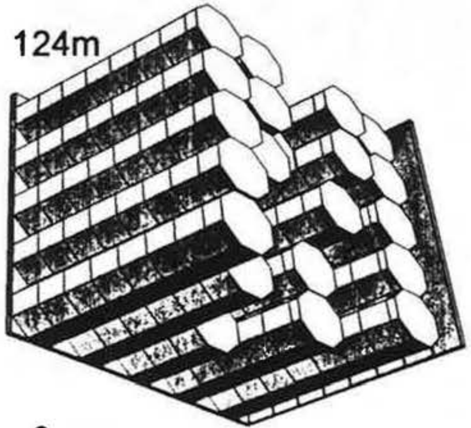
vii- Long mixing device, on the outside surface.

124l



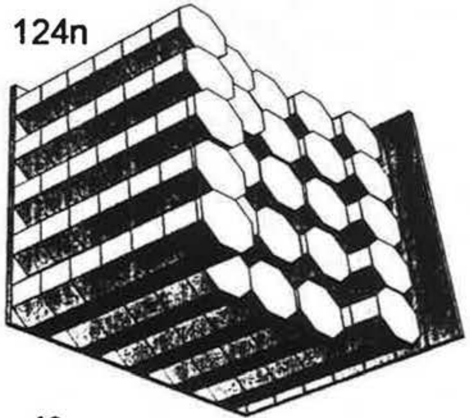
-37 cm

124m



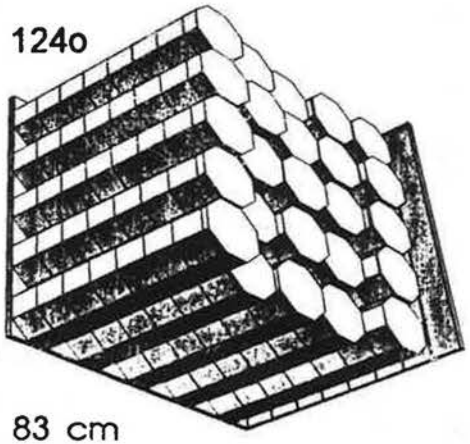
3 cm

124n



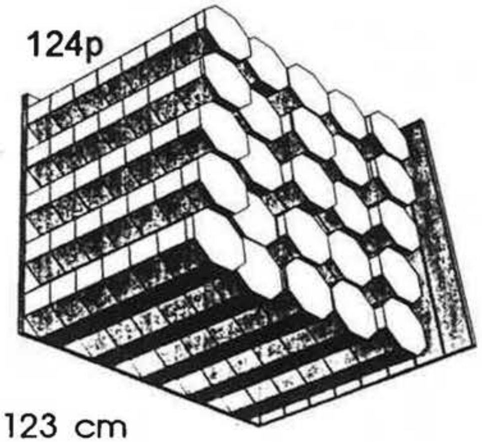
43 cm

124o

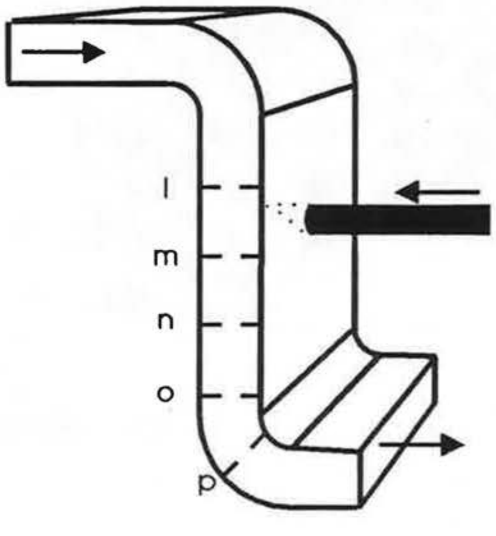


83 cm

124p



123 cm



d) Costs

Costs are estimated for new houses and do not include the supplementary labour required for retrofits.

a) The sliced cylinder mixing devices take 5 to 10 minutes more to install than a flush fresh air intake (approx. $10). The mixing device itself would cost less than $10 to fabricate. The total cost, including installation, would be in the order of 20$.

b) The X-funnel mixing device takes 20 to 30 minutes to install (approx. $30). Once production becomes a routine, it is estimated that it would cost in the order of $40 to fabricate. The total cost, including installation, would be in the order of $70.

4. Conclusions

a) All of the houses visited had poorly designed ductwork that would probably provide high mixing from a fresh air intake at 3 meters upstream from the heat exchanger. It can likely be inferred that poorly designed ductwork seldom maintains stratification. However, as duct and fan design is improved to be more energy efficient, the probability of stratification will increase.

b) Stratified air tends to remain stratified in straight runs, especially in corners. Stratification is partially retained around elbows. In this particular test installation, no stratification remained after the blower.

c) Flush fresh air intakes behave differently depending on their position on the duct surface. In some cases, they ensure good mixing within the 3 meter distance; in others, the mixing is barely adequate within that distance. The sliced cylinder mixing devices installed did not improve mixing in cases where a flush fresh air intake worked well (e.g. on the inside of the down leg, just after the corner). In other cases, the slice cylinder mixers produced a large difference. These mixers caused little pressure drop at 3 m/s air velocity.

The X-funnel mixer provided the best mixing in short distances. However, it was responsible for a substantially greater pressure drop.

APPENDIX

Calculation for determining air velocity (V) and flow rate (Q) from velocity pressure

$$V = C\sqrt{\frac{h}{\rho}}$$

where:

V = velocity, m/s
h = velocity pressure, Pa
ρ = density of air, kg/m^3
C = 1.412

Example:

test #117: readings of velocity pressure in Pa				
4.3	3.8	3.3	2.5	4.3
4.3	4.8	3.5	2.8	5.0
5.0	5.5	3.5	3.5	5.8
5.5	6.0	4.5	4.3	7.0
5.8	6.0	6.0	6.5	7.5
square root of velocity pressure:				
2.062	1.936	1.803	1.581	2.062
2.062	2.179	1.871	1.658	2.236
2.236	2.345	1.871	1.871	2.398
2.345	2.449	2.121	2.062	2.646
2.398	2.449	2.449	2.550	2.739
average square root:			2.175	

Using air density ρ = 1.16 kg/m^3 and cross-sectional area (A) = 0.186 m^2

$$V = \frac{1.412 \times 2.175}{\sqrt{1.16}} = 2.85\ m/s$$

$$Q = V \times A = 2.85 \times 0.186 = 530\ l/s$$