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EXPERIMENTAL DETERMINATION OF THE POSITION OF JETS FOR SLOT VENTILATED SPACES

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INTRODUCTION

Perhaps one of the simplest means of ventilation is probably the natural ventilation produced by one slot in 1 or 2 walls of a building, but the understanding and control of the inside air movements is very difficult. Among these difficulties, we find the instability of the flow produced by two-dimensional jets.

During an experimental study of the ventilation of a sheep-fold in a scale model, we have found some manifestation of this problem. As the implementation of the test room was not oriented to this kind of measurement, it was not possible to make a systematic study of this phenomenon, but considering present results we can give some general information about this problem and evaluate the influence of bi-stability in a slot ventilated building.

1.- BI-STABILITY IN TWO-DIMENSIONAL FLOW

Many kinds of instabilities, in two-dimensional flow, are present in the literature and one of the most important is the Bi-stable flow.

Baturin (1) says that when the inlet is in the middle of the model (see fig. 1.), the flow across the space is unstable and the jet is forced against one of the walls. This adhesion of the stream can be avoided only very occasionally and for extremely short periods of time.

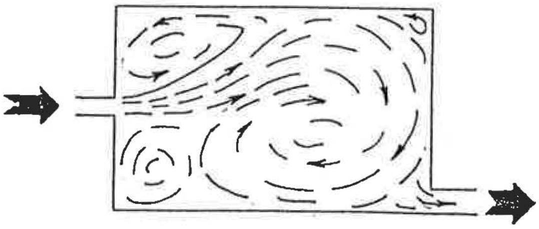

Figure 1.- Adhesion of air jet to wall with inlet at center point of the end wall.

Timmonds (2) found similar results in similar experiences but he added the result of a theoretical study using a computer program to solve the Navier-Stokes equations. He found that for a geometry which causes the flow to be bi-stable, it is possible that the initial conditions in a numerical calculation will cause the jet to remain in its initial position ,However for a stable flow geometry, the initial condition should not affect the final solution.

Favre-Marinet (3) used this bi-stability produced by the Coanda effect, to create oscillating jets and improve the mixing with the ambient fluid.

In all previous cases the bi-stability was produced by only one two-dimensional jet with its inlet placed in the middle of two walls (geometry of fig. 1). In the present work the bi-stability is produced by the interaction of two two-dimensinal jets issued from opposite walls.

2.- TEST FACILITY

Investigations were carried out at the laboratory of thermodynamics of the University of Liege, on a 1/3 scale model of the experimental sheep-fold of the veterinarian school (see fig. 2).

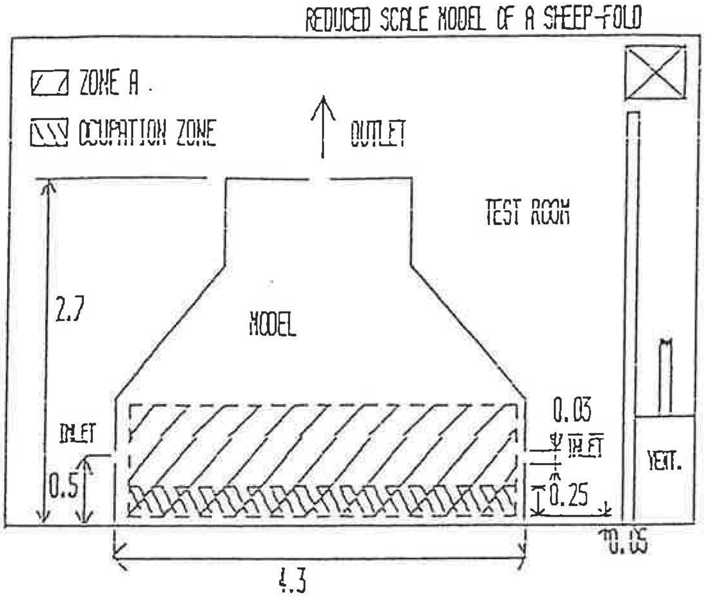

Figure 2. scale model of a sheep-fold

The effect of ventilation, actually produced by wind, is reproduced by 2 ventilators to keep the same pressure inside and outside of the model so as to minimize the infiltration effect.
The heat emission from animals is simulated by heating carpets on the floor of the model.

An omnidirectional probe (TSI model 1620) has been used for measurements of mean velocity of the air . All temperatures were measured with thermocouples type T and voltages with the integrated measurement system Solartron 2510.

Visualization of air flow has been made by smoke tubes.

By an automatic positioning system, probes can be placed anywhere in the model and 70 fixed temperatures on the walls and in the air are recorded many times during a test.

3.- RESULTS

Present results are based mainly on smoke visualization tests.

DESCRIPTION OF AIR FLOW

ONE TWO-DIMENSIONAL JET

Initially the development of the jet is in straight line. When one part of the jet makes contact with the floor (see fig. 3.), the entrainment of the jet produces a low pressure zone between the jet and the floor. This low pressure zone cause a deflection of the center line of the jet and produces a reversing of flow in the low velocity zone.

When the temperature of the jet in the inlet is lower than the mean temperature in the room, the deflection of the center line is more important (4).

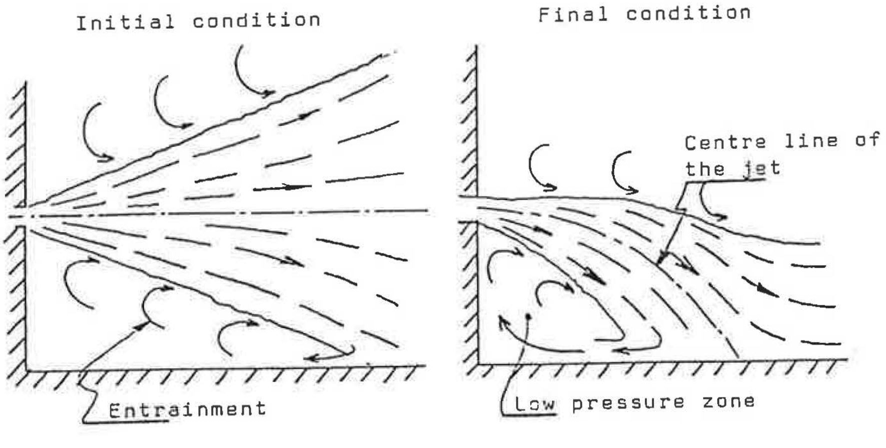

Figure 3.- Development of one two-dimensional jet in a model of sheep-fold.

TWO TWO-DIMENSIONAL JETS

When two jets of air exist, 3 different phases can be present during the development of jets.

Phase A : Each jet beginning their development independently to the other, and we find the air flow pattern showed in figure 4.

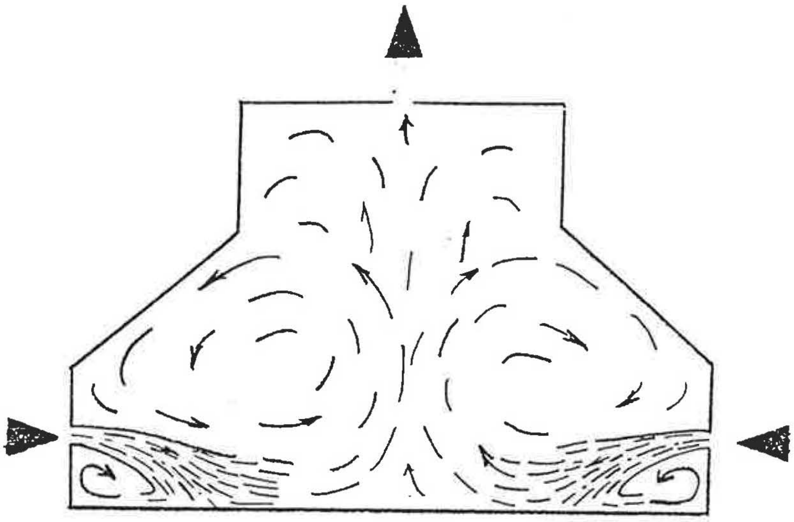

Figure 4.- Air flow pattern produced in phase A of the development of two two-dimensional jets

Phase B : After some time one of the jets is located below the other.
Phase C : The second jet take place near the roof and a new low pressure zone is created between the jet and the roof (see fig. 5). This Coanda effect between the jet and the roof is not necessary to produce the bi-stable phenomenon. Indeed, for some cases of bi-stable flow this effect is not present.

Results show that the phase C is the most stable phase because we never found a transition from this phase to phase A.

DURATION OF EACH PHASE

The duration of phase B is very short and it does not seem necessary to perform further study of this phase; but phase A , depending of the conditions of the test, can be present for a long time.

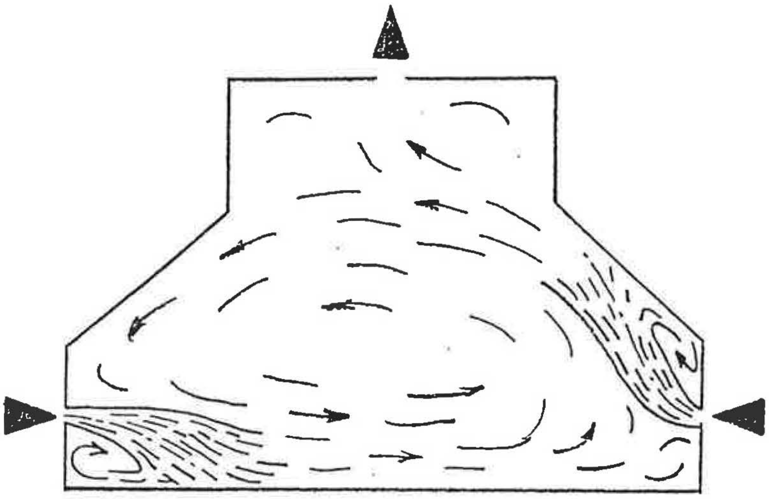

Figure 5.- Air flow pattern produced in phase C of the development of two two-dimensional jets

Main parameters who influence the duration of the phase A are, the Archimedes number and the velocity factor Fv, defined by:

Fv = Uo1 / Uo2
Where Uo1 and Uo2 are inlets velocities and Uo1>Uo2.

Table 1 in appendix shows different experimental tests classified in 3 groups.

In group I, we find tests where the duration of phase A is long compared to the frequency of wind velocity variations. In this case we can consider the flow stable in their phase A.

The group II presents a real unstable flow, where it is very difficult to predict the air flow pattern obtained when we work in this range of Ar and Fv.

In the group III, the duration of the phase A is very short and we arrive, in a few seconds to the phase C. In this case, this phase is very stable.

Figure 6 shows the classification of tests in function of Fv and Ar. (for this graphic we take the lower Ar number in each test). Tests with high Ar and high Fv are not considered in this study, because this situation is not present in natural ventilation of agricultural buildings.

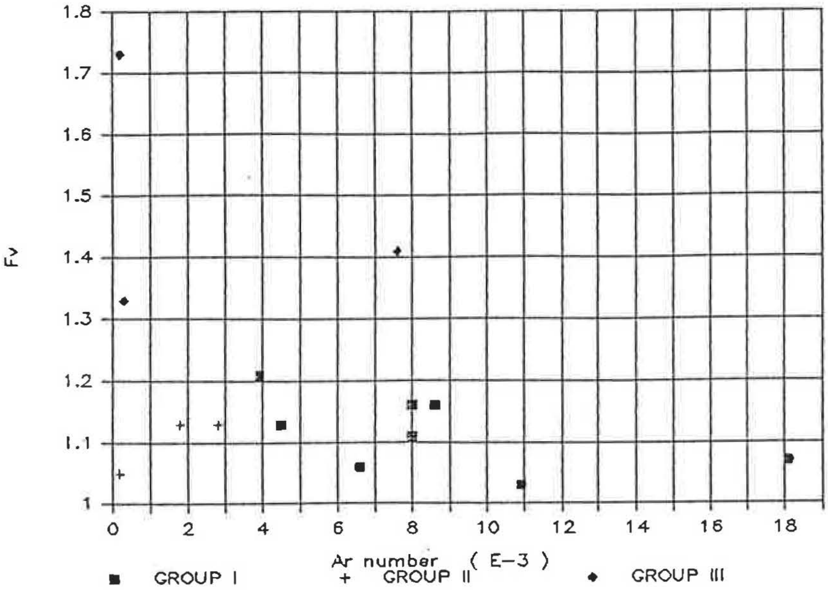

Figure 6.- Air flow pattern obtained in the model in function of Ar and Fv.

IDENTIFICATION OF EACH JET DEFLECTED

In a general way, we can say that the jet deflected to the roof is the jet with lower velocity at the inlet, but two exceptions to this rule can be established.

The first corresponds to the points in group II . Due to low Fv of these tests, sometimes the jet deflected to the roof is the jet with higher velocity at the inlet .
For each test of this group we repeat many times an identical protocol to start the ventilators, and we find that 75% of the time, the jet with lower velocity is deflected to the roof. The deflection to the roof of the jet with higher velocity is verified 25% of the time.

The second exception of the general rule is when the jet with higher velocity occurs in a previously established air flow pattern.
Figure 7a shows an air flow pattern produced by one jet; when the second jet with higher velocity starts (fig 7b), the previous air flow causes the deflection of the higher velocity jet to the roof

4.- IMPACT OF BI-STABILITY PHENOMENON IN THE NATURAL VENTILATION OF THE SHEEP-FOLD

The fluctuations of the direction and velocity of the wind produce, in the sheep-fold, the successive existence of all the air flow pattern described in this paper. To determine what is the frequency of the occurrence of each individual air flow pattern it is necessary to know the characteristic of wind fluctuation for every particular site. Anyway we can give some general trends.

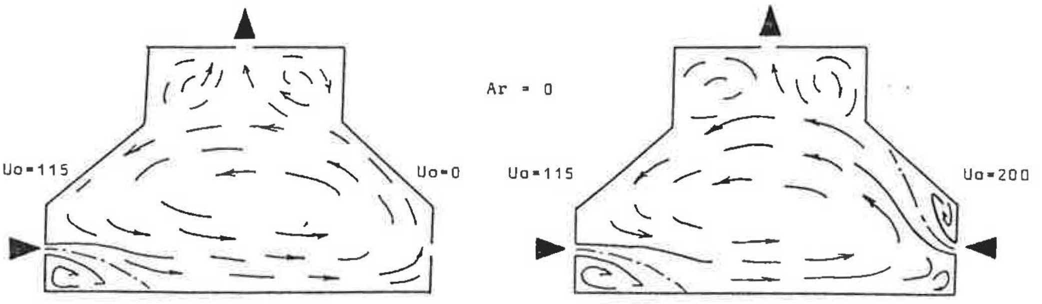

FIGURE 7a.

FIGURE 7b.

Figure 7.- sketch of the air flow pattern produced when a jet developing in a previous air flow pattern.

The experience shows that the Ar number is determined mainly by the wind velocity. If the wind velocity is low, Ar is high and we find a flow pattern where the phase A is stable (group I). when the wind velocity increase, Ar decreases but Fv increases and we find an air flow pattern stable in the phase C. This means that only few times during a day we have conditions yielding an air flow pattern like flows of group II.

5.- CONCLUSIONS

A bi-stable flow can be present if we have some interaction between two two-dimensional jets issued from opposite walls, and when the Coanda effect is important.

For the geometry in study and for high Ar numbers, we have an air flow pattern were the two jets are deflected to the floor.

For low Ar numbers and high differences between velocities in every inlet, the air flow pattern with two jets deflected to the floor is unstable and the jet with lower velocity at the inlet, is deflected to the roof.

When low Ar numbers and low Fv are present, we are in a very unstable zone and the prediction of the flow in this case is very difficult, but this case is not frequently present in natural ventilation of agricultural buildings.

REFERENCES

1.- V.V. Baturin, Fundamentals of industrial ventilation. Pergamon, Oxford (1972)

2.- M. B. Timmons, Experimental and numerical study of air movement in slot-ventilated enclosures. PhD Thesis, Cornell University, USA (1979).

3.- M. Favre-Marinet et al. , Generation of oscillating jets. Journal of Fluids Engineering , Vol. 103 , pp 609-614, December 1981.

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APPENDIX

TABLE 1

Classification of air flow pattern obtained in the model in function of Ar number and Fv.

Ar1 E-3	Ar2 E-3	Uo1 (cm/s)	Uo2 (cm/s)	Fv	GROUP
8.0	13.8	94	81	1.16	I
8.0	9.1	104	94	1.11	I
6.0	6.9	113	107	1.06	I
18.1	19.4	73	68	1.07	I
13.0	10.9	99	96	1.03	I
8.6	9.9	105	90	1.16	I
4.5	5.6	123	109	1.13	I
3.9	5.3	145	120	1.21	I
2.8	3.2	162	144	1.13	II
1.8	2.1	189	168	1.13	II
0.1	0.0	144	137	1.05	II
0.0	0.0	199	115	1.73	III
7.6	13.2	108	77	1.40	III
0.1	2.0	112	84	1.33	III

Ar = g L (T - To)/(T * Uo^2)
Fv = Uo1/Uo2
Where :
L : Characteristic length (high of the slot)
T : Outlet temperature
To : Inlet temperature
Uo : Velocity at the inlet