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THE OPEN RIDGE AS A VENTILATOR IN LIVESTOCK BUILDINGS

J. M. Bruce

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THE SCOTTISH FARM BUILDINGS INVESTIGATION UNIT
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The open ridge as a ventilator in livestock buildings

J M Bruce, Scottish Farm Buildings Investigation Unit

INTRODUCTION

The open ridge is a ventilator commonly used in cattle buildings. In the UK today it is peculiar to livestock buildings although it has its counterpart in the hole in the roof adopted by primitive societies. It has probably been recognised for thousands of years that an aperture at the highest position on a closed structure resulted in the most efficient ventilation. With the very much increased stocking density of modern livestock buildings the raised tiles and small ridge ventilators used in the past have given way to the necessity for larger openings until the present day when the ridge cover is often eliminated along the entire length of cattle buildings. The Ministry of Agriculture, Fisheries and Food (1) recommended that outlet ventilators should be kept as high as possible and the open ridge is an expression of this same desire.

That efficient ventilation of cattle buildings is of the first order of importance seems indisputable and this has been urgently advocated over the years:

> ".... satisfactory ventilation should be the main factor influencing design" (2)
>
> ".... ventilation is paramount ....." (3)
>
> "The single most important factor in controlling respiratory disease is adequate ventilation." (4)

It is all the more surprising that there is an abundance of poorly ventilated cattle buildings throughout the United Kingdom and so few definitive statements with regard to the open ridge. The open ridge is undoubtedly the most important single element contributing to the ventilation of modern cattle buildings. The purpose of this report is to review the literature on open ridges and to give the results of some wind tunnel studies.

REVIEW

Before beginning the review it is appropriate to outline the areas of uncertainty associated with the open ridge and to identify the important characteristics. It seems that there are essentially three types of open ridge (Fig 1): the plain open ridge, the open ridge with upstands and the open ridge with upstands and cap. There are many variations of these basic types. For example, there are sloped upstands, upstands withheld from the opening, caps with downstands and complex combinations of upstands and caps to produce tortuous airways. Some designs lie between the closed ventilated ridge and the fully open ridge.

Apart from the very significant differences in type there are differences in the recommended proportions of W, H, A and B (5). A 'problem' also exists regarding weatherproof characteristics and how the various designs detract from or augment the ventilation.

A well-documented field investigation was carried out by Findlay (6) on the effectiveness of an open ridge. The number of animals housed in his test buildings was small and the stocking density much lower in 1948 than in present day enterprises. His main conclusions were that an adjustable open ridge giving an area not less than 144 in^2 (0.093 m^2) per cow was probably the best form of outlet. It is significant to note that no mention is made of precipitation entering at the ridge although down-draughting, when the air entered through the ridge, was reported. Findlay's ridges had hinged upstands by means of which the width was varied, but no cap was fitted.

Mitchell (5, 7) has reviewed open ridge design and gives the details of many designs. Reproductions of photographs from Kloeppel (8) by Mitchell (5), which show flow patterns observed using a water table and two-dimensional models of buildings with open ridges, suggest that the final opening to the atmosphere should be in the horizontal plane to encourage air extraction. This conclusion may be invalid as the models of Kloeppel (8) did not adhere to the rule of geometric similitude.

Mitchell (5) states: "Each design is based either on experience gained in practice or the personal whim of the designer concerned." The present review would support this view while, at the same time, it appears that little evolutionary design has occurred through experience. This is understandable when the practical rule of 'safety first' dictates a cautious and not too adventurous outlook on the part of the designer when he has authoritative statements which he can follow blindly, but little quantitative data on which to operate to produce an economical and effective design.

From his review of open ridges Mitchell (5) did not form any conclusions but on the basis of his own model studies (9) he concluded that:

1 Open ridges without upstands or caps can act as air outlets and inlets

2 Sloped upstands appear to reduce entry of air

3 Ridge caps tend to increase air entry and should be omitted where driven snow is a problem.

However Mitchell's models were not complete models. They modelled only the ridge and adjacent roof areas with the external flow perpendicular to the longitudinal axis of the ridge. There was therefore no net air movement through the ridge vent. His conclusions on this evidence may not then be accepted as the final statement.

Other writers do however lend support to Mitchell's conclusions. Findlay (6) describes his open ridges as acting as air inlets and outlets. Haartsen and Prinsen (10) recommend the sloped upstands. The Ministry of Agriculture, Fisheries and Food (1) states that any attempt to baffle an open ridge by fixing a cap often produces a down-draught when a strong wind is blowing. In contrast, 12 years later, in a leaflet, MAFF (11), show an 8 inch (200 mm) open ridge with no upstands although a cap is mentioned as an alternative. McFarlane (2) found that, where natural ventilation of cattle buildings appeared to be satisfactory, the buildings incorporated one or more of certain features among which he lists an open ridge, preferably with an upstand. The following year McFarlane (12) moderated this to an open ridge, possibly with an upstand. Rogerson (13) concurs with the conclusion of Mitchell but it is likely that his comments are in fact elaborations of Mitchell's conclusions and not based on other evidence. He gives 15 open ridge designs, some of which are asymmetric, which appear to be based on intuition. It is recorded by Johnson (14) that a narrow cover built over an open ridge, with the intention of preventing rain and snow from falling straight down into the building, caught snow blowing along the roof and funnelled it down into the building. Turnbull (15) reports that an insignificant amount of rain and snow was admitted by an outlet ridge slot. Runcie and Watson (16) are in agreement with this when they say that their experience shows very little weather gets through the normal open ridge. However they do say that under severe conditions weather penetration might be a nuisance and that it may be desirable to construct a raised capping over the ridge. This last statement is in contradiction to Mitchell's and Johnson's findings. Graee's intention (17) was to produce a ridge design which would reduce precipitation entry and he produced many designs with baffles within ridge upstands but no caps. A cap was thought by Brevik (18) to be undesirable. He felt that it could restrict ventilation or cause the opening to become choked with an accumulation of frost. Fig 2 (19) shows a capped ridge partially blocked by snow. Mitchell (7) observed on his experimental climatic calf house both capped and uncapped open ridges and found snow penetrated to a much greater extent with the capped ridge - Fig 3 (19).

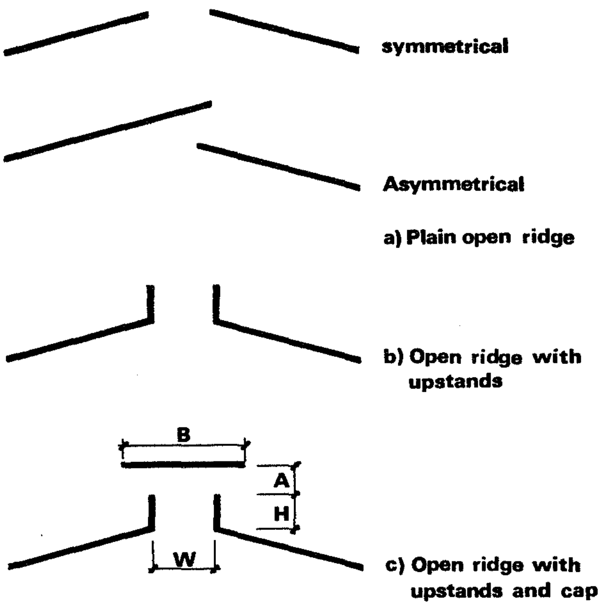


Fig 1 The three characteristic types of open ridge

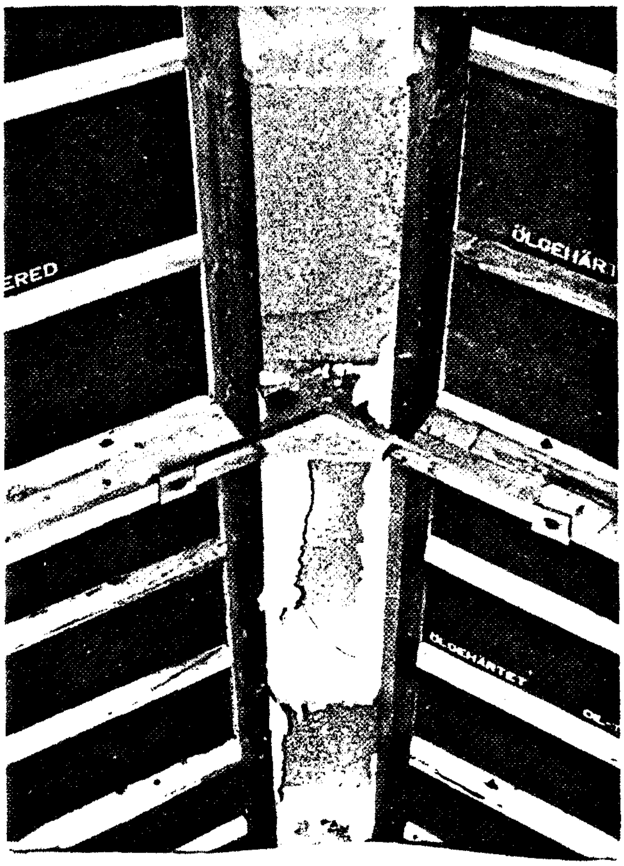


Fig 2 Capped ridge partially blocked by snow

He also verified by measurement that air could move in and out of an uncapped open ridge. He concluded that upstands appear beneficial in preventing entry of precipitation and that capping an open ridge will only prevent direct entry of snow and rain on sheltered sites where the direction of precipitation is directly downwards. Where driven snow is likely, he recommends the cap be omitted from an open ridge. It does appear that, notwithstanding the lack of complete geometric similitude in his models, Mitchell's conclusions (9) are confirmed in practice.

Model studies by Dybwad et al (20) indicate

Fig 3 Snow which had penetrated a capped open ridge lying within a building

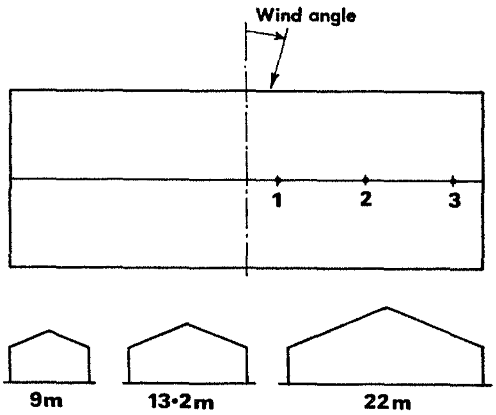


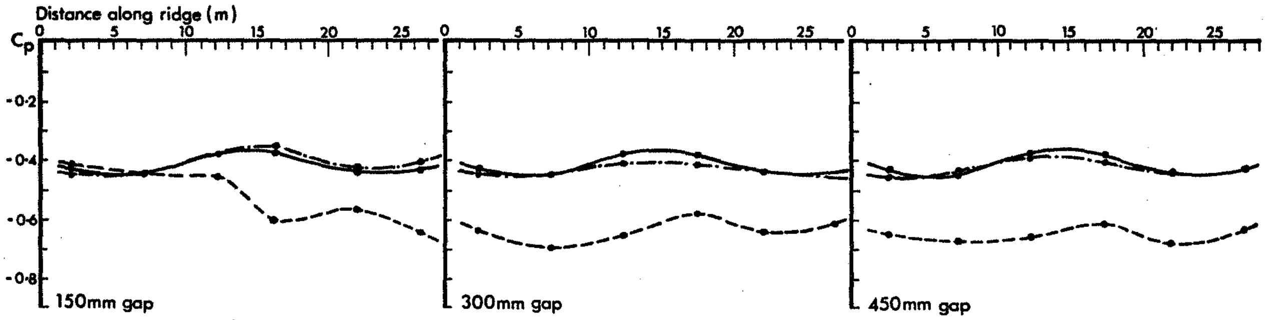
Fig 4 Position of pressure tappings on the model buildings

that ridge vent design has a highly significant effect on outlet air velocity. The greatest air flow was measured with a plain open ridge and the least with a covered ridge vent. This of course means that to obtain an equal volume of flow the covered ridge should have a larger area available for flow than the plain ridge. This measured restriction confirms Brevik's idea (18). The order of decreasing effectiveness measured by Dybwad (20) was: symmetrical plain open ridge, open ridge with upstands, asymmetrical or overlapped open ridge, covered ridge vent. However the anomalous result was obtained that the symmetrical plain open ridge was associated with the highest temperature difference at all but the zero wind condition. This anomaly is not resolved satisfactorily by Dybwad.

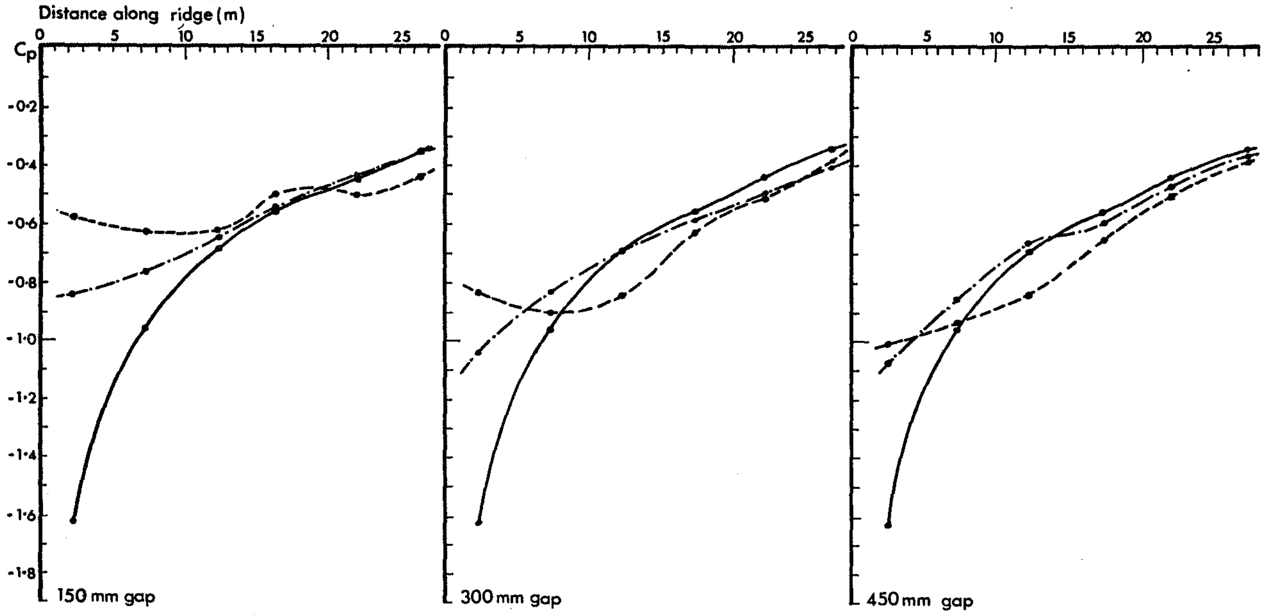
It would be expected, from a knowledge of fluid dynamics, that baffling or capping would result in a higher flow resistance. This implies a lower volumetric flow rate for a given flow potential, ie pressure difference. Dybwad's results do reflect this anticipated trend. More recently model studies similar to those of Dybwad(20) have been carried out by Froehlich et al (21). The important conclusion they draw is that ridge vent design does have a significant effect on outlet velocity but they are not able to distinguish pressure potential and flow resistance effects. Although there was a statistically significant difference in performance between ridge designs there would seem to be little practical difference with the exception of the covered ridge which shows a quite dramatic fall in performance at velocities greater than 20 ft/s (6.1 m/s). However there is no explanation proposed to explain this characteristic and until there is there will be doubt as to the reliability of the result.

In the face of this however we have Addison (22) recommending the use of upstands to improve the ventilation performance by forming a funnel at the ridge. However, like Forsyth (23) he suggests that the roof sheeting be carried beyond the upstands to catch and drain rain running down the inner faces of the upstands. This of course produces an orifice which negates any possible improvement in the resistance characteristic due to the upstands. It is reported (10) that upstands on low pitched roofs prevent the entry of rain blown up the roof surface. Harrison (24) uses the term 'venturi-ridge' and suggests that in windy conditions this outlet will 'cause' the air in the building to rush out tending to keep out rain and snow. The use of the name venturi in this instance is quite wrong and inappropriate to describe an open ridge with upstands. The important characteristics of a venturi tube are a converging entry length, a short parallel intermediate length and finally a slowly diverging (5-15°) exit length. The practical significance of the venturi tube is that it has a low resistance to flow. The single and by far the most important factor providing this low pressure loss characteristic is the gently divergent exit length. Without this gradually expanding section the benefit of the device is completely lost. Harrison also recommends that the roof sheeting be projected into the ridge gap beyond the upstands and advises the use of a cap to prevent rain and snow entering. Without detail he writes that various designs have been proven in heavy rain and snow. From this review it would appear that not a lot of people are aware of them.

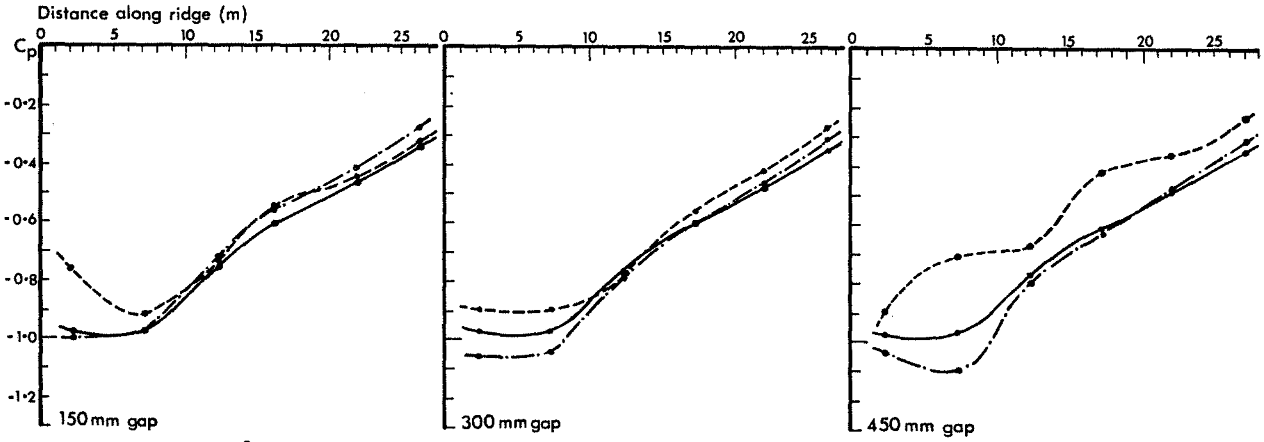
In the popular farming press it is common to find commendations of capped ridges and also to read of implied and usually vague benefits to the ventilation. Farm buildings' manufacturers seem happy to conform to this conception and will even imply some superiority in their advertising literature. The brochure of a leading farm building manufacturer states: "while a specially adapted crown-crank ridge is fitted to extract



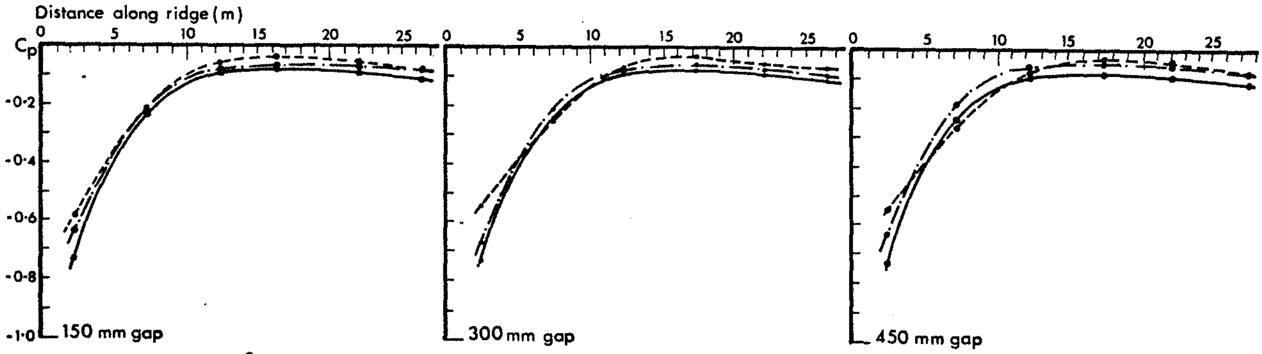
13·200m span, 0° Wind angle



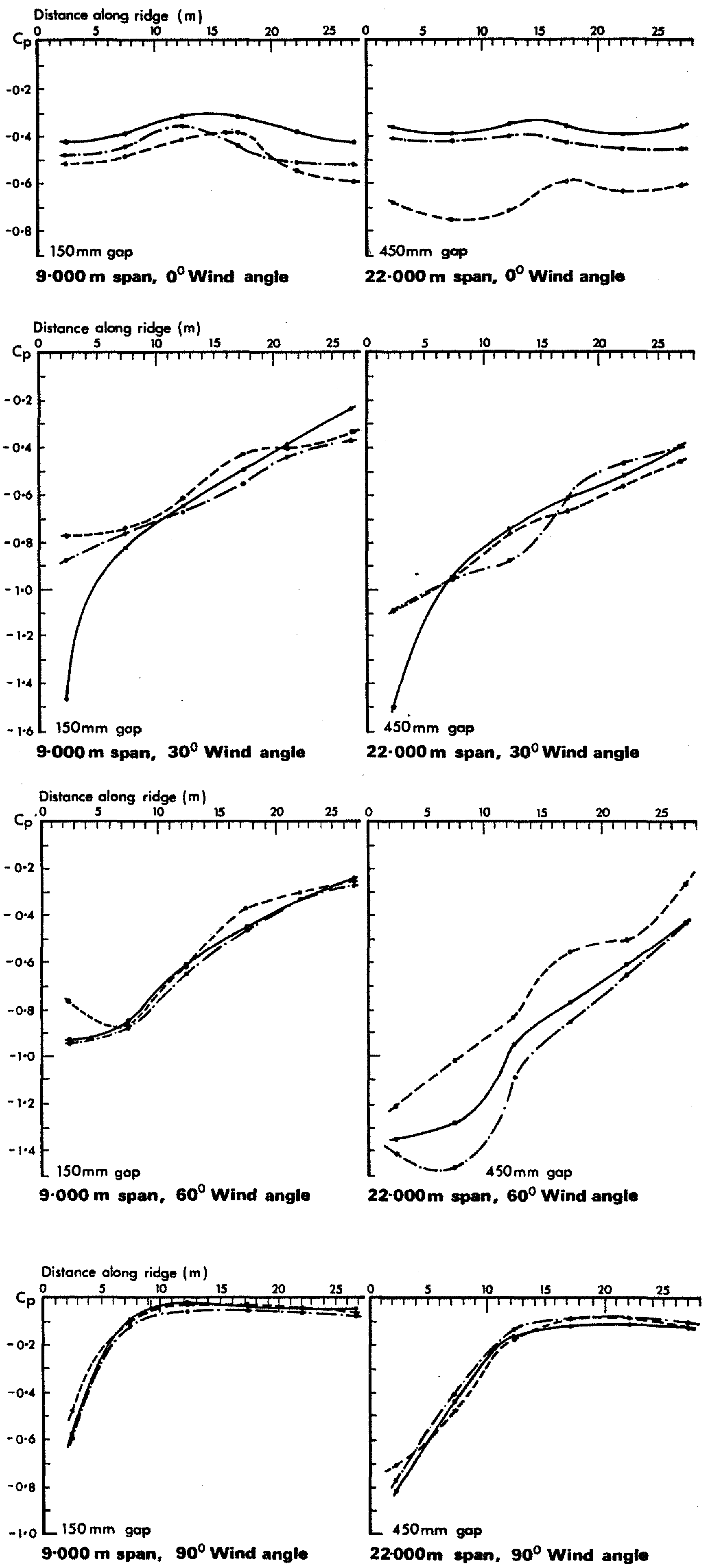
13·200m span, 30° Wind angle



13·200 m span, 60° Wind angle



13·200 m span, 90° Wind angle



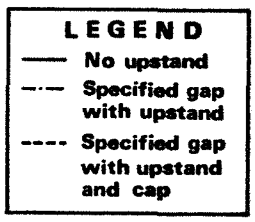


Fig 5 Pressure coefficients measured at the ridge of three model buildings at various wind angles

stale air." It is tempting to assert that their special ridge will perform worse than a simple plain open ridge in the most important operational function of providing ventilation.

SUMMARY OF REVIEW

There is outright disagreement between some of the sources referenced. When faced with this confused situation careful attention has to be paid to the basis for the remarks and recommendations offered in order to sift the truth. Who said what, and what evidence was produced, must be considered. There is a definite preoccupation in the literature with preventing rain and snow from entering an open ridge, but it is not entirely clear why. There is no justification for great concern where entering precipitation may be regarded only as a transient inconvenience, especially when designing towards this factor prejudices the ventilation system. It does appear however that a cap over an open ridge creates the greatest entry of wind driven precipitation and should be avoided. Whether upstands are beneficial in this respect is not certain although it is reported that upstands on low pitched roofs prevent the entry of rain blown up the roof.

EXPERIMENTAL OBJECTIVE

When a ventilation opening experiences a pressure differential, air movement will occur through it. The movement will be in the direction of decreasing pressure. The basic equation which describes the process is:

$$\Delta P = k \tfrac{1}{2} \rho U^2 \qquad \ldots 1$$

Combining this with the equation for volumetric flow rate:

$$V = AU \qquad \ldots 2$$

gives:

$$V = A \left[\frac{2 \Delta P}{k \rho} \right]^{\frac{1}{2}} \qquad \ldots 3$$

It is now seen that the volumetric flow rate or ventilation rate increases as A and ΔP increase and as k decreases. For our purposes ρ, the air density may be considered constant. For a ridge vent of a given area the ventilation rate will be influenced as described by the pressure difference developed across the opening and its resistance factor.

Dybwad (20) and Froehlich et al (21) presented quantitative evidence on the ventilating characteristics of four ridge designs. What is not available from their data are the separate effects of the ridge designs on firstly the flow resistance and secondly the interaction with the wind to produce the flow potential.

The experimental work to be reported was designed to show whether or not the ridge design could influence the pressure coefficient when subject to wind.

EXPERIMENTAL METHOD

When the wind blows over an obstacle, such as a building, regions of low and high pressures are produced related to the speeding up and slowing of the wind. It is usual to describe this effect in terms of pressure coefficients (25). The pressure coefficient is a measure of the pressure at a point expressed as a fraction of the kinetic pressure of the wind in the free stream. Thus the pressure at a point is given as:

$$P = C_p \tfrac{1}{2} \rho U_{10}^2 \qquad \ldots 4$$

The pressure difference across the shell of a building at any point would be found by subtracting the above pressure, P, from the internal pressure of the building which is a complicated function of the wind direction and strength and the arrangement of openings in the building (25). The pressure difference does not lend itself to a generalised quantitative statement but the external pressure or pressure coefficient does so as it is not dependent on anything but the wind and the external geometry of the building and its surroundings.

Models of three buildings 9.0, 13.2 and 22.0 m wide were made of clear acrylic sheet to a scale of 1:50. The buildings were all 29 m, long, 2.4 m to the eaves with a roof pitch of 22.5°. Pressure tappings, 1.6 mm diameter, were located at the ridge apex (Fig 4). Tappings were necessary in only one half of each model because the models were mounted on a turntable and advantage was taken of symmetry. Pressures were measured using a micromanometer with an accuracy of ± 0.02 mm water. The wind tunnel (26) used had a cross section of 1.5 x 1.0 m and a one-sixth power velocity profile was generated to simulate flow over fairly open rural areas. The maximum nominal velocity was 10 m/s and this was the speed used for all the reported measurements.

All the models were tested firstly with no additions at the ridge to provide a reference set of data. Upstands 150 mm high were added to the models at various spacings with and without caps as shown in Fig 1c. The cap width, B, was always twice the gap, W, and the cap was raised $\tfrac{1}{2}$W above the top of the upstands. The various combinations tested are given in Table 1.

NOTATION

A	area of opening
C_p	pressure coefficient
k	resistance coefficient
P	pressure
ΔP	pressure difference
U	air velocity
U_{10}	air velocity at 10 m height
V	volumetric flow
ρ	air density

Table 1

Open ridge combinations tested

Model width (m)	Gap size (mm) 150	300	450	With cap	Without cap
9.0	•			•	•
	•			•	•
13.2		•		•	•
			•	•	•
22.0			•	•	•

RESULTS

All the results are shown in Fig 5 in terms of the pressure coefficient C_p as defined in equation 4. The asymmetry indicated in the 0^{o} curves particularly for the capped ridges is indicative of the fact that it is difficult to build a perfectly symmetric model of the ridge. The difference between the three points on the left hand end of the graphs which were obtained at 0^{o} wind angle and the right hand three points obtained at 180^{o} highlight this difficulty.

DISCUSSION OF RESULTS

A clear result of the model study is that there is no practical difference in the pressure coefficients generated at the ridge of a building whether there are no upstands, upstands or upstands with caps. For a 0^{o} wind upstands have almost no effect on the pressure coefficients along the ridge, but the placing of a cap has a marked effect on the magnitude of the pressure coefficients. As the wind swings round to 90^{o} there is a tendency for the capping to reduce the pressure coefficient but only on the leading portion of the model. At 90^{o} there is no difference due to ridge design. The measurements at the ridge show a small increase in pressure coefficient as the width - and the height - of the models increase.

CONCLUSIONS

1 There is an increased flow resistance factor as the ridge design becomes more complex. The simpler the design the less resistance experienced.
2 Upstands may help in reducing entry of precipitation through an open ridge particularly on low-pitched roofs.
3 Caps increase the probability of entry of wind driven precipitation and may lead to choking of the opening with snow and therefore should be avoided. Caps do however prevent entry of precipitation in calm conditions.
4 The experimental work described showed no practical effect on pressure coefficient at the ridge due to the ridge designs considered. There is therefore no effect on wind induced suction.

REFERENCES

(1) MINISTRY OF AGRICULTURE, FISHERIES & FOOD Ventilation and insulation Fixed equip fm leafl (35) London HMSO 1958

(2) McFARLANE D The intensive housing of beef cattle RASE & CLA Beef housing conf Kenilworth 9 Nov 1965

(3) PRESTON T R WILLIS M B Intensive beef production Oxford Pergamon press 1970

(4) GUSS S B GROUT A R Effects of housing on the health of dairy cows National dairy housing conf Publ ASME SP-01--73 Feb 1973 120-127

(5) MITCHELL C D Open ridges for natural ventilation - a review Fm bldg prog (29) Jul 1972 11-14

(6) FINDLAY J D Experiments on the ventilation of cattle byres J of agric sci 38 411-424 (received 12 June 1948)

(7) MITCHELL C D Climatic calf housing PhD thes Univ Aberdeen 1975

(8) KLOEPPEL R The air inside an animal building Section II Ventilation and ventilation (Stallklima II) RATIONALISIERUNGSKURATORIUM FÜR LANDWIRTSCHAFT, PREETZ 1969

(9) MITCHELL C D Open ridge designs Fm bldg prog (29) July 1972 15-18

(10) HAARTSEN P I PRINSEN L Conclusions and suggestions on the insulation and ventilation of cubicle buildings for cattle INSTITUUT VOOR LANDBOUWBEDRIJFS-GEBOUWEN, WAGENINGEN Meded (28) 1968

(11) MINISTRY OF AGRICULTURE, FISHERIES & FOOD Housing of beef cattle Fixed equip fm leafl (50) London HMSO 1970

(12) McFARLANE D The intensive housing of cattle for beef production FARM BUILDINGS CENTRE June 1966

(13) ROGERSON P D An approach to the design of low cost cattle housing SCOTTISH FARM BUILDINGS INVESTIGATION UNIT Int rep Aug 1972

(14) JOHNSON D W Survey of feeding beef cattle inside sheds ASAE Winter meeting Chicago 8-11 Dec 1970 Paper 70-905

(15) TURNBULL J E Engineering for intensive housing of livestock Canadian Dept of Agric Publ (1503) 1973

(16) RUNCIE K V WATSON G A L Bad ventilation can lead to death and distress Scott fmr 19 Jan 1974

(17) GRAEE T Open ridges NORGES LANDBRUCKSHØGSKOLE INSTITUUT FOR BYGNINGSTEKNIKK Saertrykk (157) Byggmestern (10) 1972

(18) BREVIK T J To avoid condensation in free stall barns Hoard's dairyman Oct 1971

(19) MITCHELL C D Personal communication 1975

(20) DYBWAD I R HELLICKSON M A JOHNSON C E MOE D L Model study of ventilation characteristics of an open front building ASAE Annual meeting Lexington, Kentucky 17-20 June 1973 Paper No 73-405

(21) FROEHLICH D P HELLICKSON M A YOUNG H G Ridge vent effects on model ventilation characteristics ASAE Annual meeting Stillwater, Oklahoma 23-26 June 1974 Paper 74-4055

(22) ADDISON J N Beware of condensation Dairy fmr suppl Dec 1972

(23) FORSYTH R J Condensation in farm buildings Scott agric Autumn 1958

(24) HARRISON P Adequate natural ventilation Fm bldgs dig 8 (3) Autumn 1973 7-9

(25) BRUCE J M Wind tunnel investigation of a model livestock building SCOTTISH FARM BUILDINGS INVESTIGATION UNIT April 1974

(26) BRUCE J M ROSS P A ROGERSON P D The design, construction and calibration of a low speed wind tunnel for studies in architectural aerodynamics SCOTTISH FARM BUILDINGS INVESTIGATION UNIT Feb 1974

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