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The recommendations in this leaflet concerning sidewall and chimney sizes, as well as building orientation have been developed using Ontario Ministry of Agriculture, Food and Rural Affairs' new computer software for natural ventilation, NatVent 2.0, which provides quick estimates for design of openings. Performance of five prototypes of naturally ventilated buildings has been simulated for 33 regions across Canada, where meteorological stations are already available. The prototypes of buildings are:

- dairy tie stall barn for 50 cows - 36 x 12 m, using 5 chimneys;
- dairy free stall barn for 100 cows - 36 x 24 m, using 10 chimneys;
- broiler chicken barn for 40 000 birds - 122 x 21 m, using 33 chimneys;
- turkey barn for 8690 birds - 122 x 23 m, using 33 chimneys;
- grower-finisher swine barn for 580 pigs - 36 x 12 m, using 7 chimneys.

If the recommendations in this leaflet are used to size the sidewall and chimney openings, and to orient the building, then natural ventilation should work very well during the summer. In winter, the automatic control system reduces the effective opening as necessary, to control the ventilation.

LIMITATIONS OF THE RECOMMENDATIONS

The recommendations are based on original research and weather station data. In order to achieve similar results, your situation should respect the following:

- buildings are considered to be in an open country situation with no adjacent buildings within reasonable

distances;

- no building annexes, such as T or L shapes;
- gable roofs only;
- the selected weather station is representative of your area;
- the landscape in your area should be similar to the selected meteorological station;
- the recommended opening areas apply to sidewall and chimneys; the addition of end wall openings (doors or windows) would be of further benefit during the summer;
- your building should be similar in size and shape to the prototype barns tested.

It is assumed that chimneys are used, however continuous ridge openings of equivalent size are an alternative.

CHIMNEY DESIGN

There are a variety of chimney designs which will work well with natural ventilation. The typical chimney used with these barn prototypes has a cross-section of 600 mm x 600 mm, is lined with rigid insulation and fitted with a rotating damper. In the fully open position, this chimney has about 0.283 m² of opening area.

In order to determine the number of chimneys needed for summer ventilation, the designer has to evaluate the free opening area for any specific chimney in its fully open position. The control damper is used to restrict the area of the opening during cold weather.

BUILDING ORIENTATION

The building orientation is described as follows: north is 0°, east is 90°, south is 180° and west is 270°. If the

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COMPLETE INSTRUCTIONS

The Canada Plan Service, a Canadian federal/provincial organization, promotes the transfer of technology through factsheets, design aids and construction drawings that show how to plan and build modern farm structures and equipment for Canadian agriculture.

For more information, contact your local provincial agricultural engineer or extension advisor.

proposed orientation is 0°, the end wall faces north and the ridge line runs north-south, based on geographic north. Therefore, when a compass is used to orient the building, the orientation should be corrected according to the magnetic deviation.

The preferred building orientation for a particular building prototype varies from one climate zone to another. In most climatic areas, there is a "prevailing" wind direction. For example, in the Ottawa area, the summer winds come generally from the south-west, but do vary from south to west. From Table 1, the preferred building orientation for a dairy tie stall would be $130 \pm 20^\circ$. This does not mean that the producer should refuse to build if the preferred orientation can not be met, since other options exist, such as adding end wall openings for additional benefit in the summer. This only suggests that better ventilation will be achieved for this dairy tie stall barn in the region of Ottawa if the ridge line is oriented between 110° and 150° .

In some climatological areas, the winds come from all directions. Consequently, the building orientation will have only minimal effect on the natural ventilation performance. For example, in the Waterloo -Wellington area, this same dairy tie stall barn should be oriented at $60^\circ \pm 90^\circ$. If the building is built with the ridge line oriented 60° from north, slightly better natural ventilation can be expected. However, the building orientation could vary from 330° to 150° from north without much difference on performance.

In the Waterloo-Wellington area, the recommended building orientation for poultry buildings (Table 2) and swine buildings (Table 3) is indicated as "ALL". Thus all building orientations would be equally good. Wind speed and direction history show that the winds come equally from every direction with similar speeds.

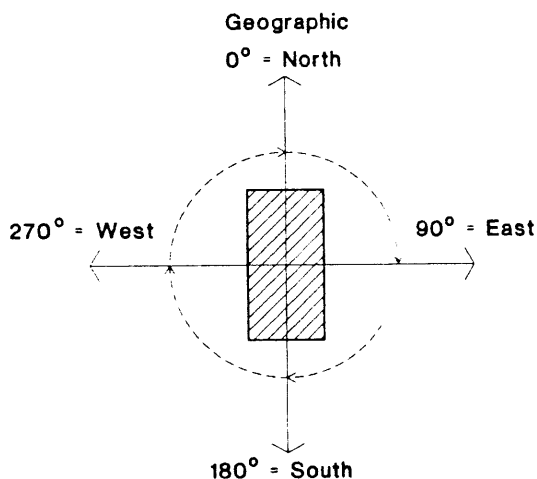


FIGURE 1 ROTATION OF BUILDING FOR ORIENTATION ANGLES

EXAMPLE

At the back of this leaflet is a Design Worksheet example to be used as a guide for calculating the sidewall opening height, number of chimneys and the preferred building orientation. A blank Design Worksheet is also included. The example is as follows:

A turkey producer lives near Winnipeg, Manitoba and wants to build a new 107 x 23 m turkey barn for 7600 birds using natural ventilation, including a series of chimneys. It is known that both continuous sidewall openings are 102 m long, but are partially blocked by a 38 mm wide stud every 0.60 m. This makes for a total of 338 studs ($102 \text{ m} / 0.60 \text{ m} \times 2 \text{ sides} - 2$).

From Table 2, moving down to Winnipeg, Manitoba and across to turkeys we see that the recommended total opening area per 100 birds is 2.96 m^2 , the sidewall opening area is 2.85 m^2 , and the preferred building orientation is 90° from north $\pm 50^\circ$. Thus the ridge line should run east-west (90° - 270°), but little difference in performance would be expected for up to 50° variation from this orientation.

As indicated by the calculations, the sidewall opening height should be 1.13 m, the number of chimneys should be 30, and they should therefore be spaced 3.5 m apart.

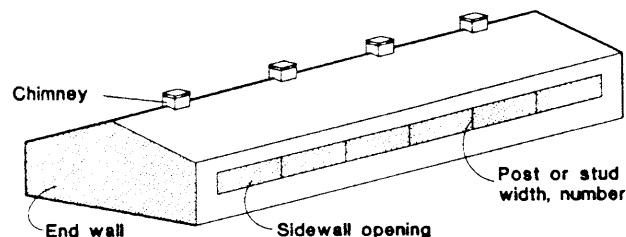


FIGURE 2 DESCRIPTIVE DEFINITIONS

PRACTICAL CONSIDERATIONS

The recommendations in the tables provide very specific sidewall and ridge opening areas. However, in practice, natural ventilation equipment for sidewall openings is sold by 150 mm increments. It is recommended to enlarge the sidewall openings by adjusting the side height to the next modular size to fit the equipment. The same principle applies for selecting number of chimneys. Always round up the number to the next unit, e.g. if 29.7 chimneys are recommended, use 30. Also consider the building frame; often chimneys are most conveniently located every 2.4 m, 3.2 m or some other distance according to the truss spacing. Rounding up the number of chimneys to fit this space requirement is recommended.

Some risk will be taken if the sidewall or ridge opening sizes

are reduced. It is important to realize that the natural ventilation performance may be impaired.

If you choose to use a continuous ridge opening instead of chimneys, it is still recommended to use the same size of sidewall opening shown in Tables 1, 2 or 3. The ridge opening area should be equal to the equivalent area of the recommended number of chimneys.

WIND BREAK PANEL

It is strongly recommended to use a wind break panel over the top part of the sidewall opening to reduce drafts in winter. However, most producers leave the wind break panel hanging in place during the summer, thereby reducing the effective opening height. It is then recommended to add 150 mm to the opening height (Item Q, Worksheet) to obtain equally good natural ventilation during the summer.

END WALL OPENINGS

The addition of end wall openings are strongly suggested. They could for example be large end doors or windows, to be opened during the warm period of the year. Adequate control can be achieved manually.

MANAGEMENT INFORMATION

See CPS leaflet M-9760 for detailed information concerning the selection and operation of a natural ventilation system for your building.

NATVENT 2.0 SOFTWARE

If further detail is required regarding the use of this software, please contact your provincial agricultural office, or the first author of this leaflet, Mr. Y. Choiniere.

TABLE 1 OPENING AREAS FOR DAIRY CATTLE BARNs

Province and station location	Tie stall (per head)			Free stall (per head)		
	Total opening area,m ²	Sidewall opening area,m ²	Building orientation, degrees	Total opening area,m ²	Sidewall opening area,m ²	Building orientation, degrees
BRITISH COLUMBIA						
Hope	.94	.91	150 ± 30	.51	.49	160 ± 20
Kamloops	2.43	2.41	20 ± 30	1.04	1.01	20 ± 20
Penticton	.99	.96	90 ± 10	.60	.57	90 ± 30
Vancouver	.80	.77	160 ± 30	.64	.61	170 ± 40
ALBERTA						
Calgary	.67	.64	90 ± 80	.54	.51	80 ± 90
Edmonton	1.14	1.11	30 ± 90	.74	.71	30 ± 50
Grande Prairie	.97	.94	50 ± 30	.69	.66	30 ± 20
Lethbridge	.65	.62	0 ± 90	.48	.45	0 ± 90
Red Deer	.80	.78	90 ± 50	.64	.61	90 ± 90
SASKATCHEWAN						
Estevan	.56	.54	40 ± 90	.42	.39	40 ± 20
Prince Albert	.84	.81	ALL	.51	.49	0 ± 90
Regina	.58	.55	40 ± 90	.42	.39	40 ± 20
Saskatoon	.61	.58	60 ± 90	.45	.42	60 ± 90
MANITOBA						
Brandon	.73	.70	10 ± 20	.52	.49	0 ± 50
Winnipeg	.62	.60	80 ± 30	.46	.44	80 ± 50
ONTARIO						
Barrie	1.18	1.15	40 ± 20	.89	.86	50 ± 20
London	.88	.85	70 ± 60	.63	.60	100 ± 40
North Bay	.67	.64	140 ± 30	.50	.47	130 ± 20
Ottawa	1.01	.98	130 ± 20	.70	.68	130 ± 20
Saint Catharines	.54	.52	100 ± 90	.49	.46	100 ± 90
Simcoe	.71	.68	120 ± 30	.59	.56	130 ± 30
Toronto	.82	.79	100 ± 20	.59	.56	80 ± 50
Trenton	.80	.77	130 ± 20	.53	.50	120 ± 20
Waterloo-Wellington	.94	.91	60 ± 90	.59	.57	40 ± 90
Windsor	.81	.78	130 ± 20	.57	.54	120 ± 10
QUEBEC						
Montreal	.94	.91	120 ± 30	.61	.58	120 ± 30
Quebec	1.19	1.16	150 ± 20	.64	.61	150 ± 20
Riviere du Loup	.61	.58	130 ± 20	.49	.46	120 ± 30
Sherbrooke	1.40	1.37	150 ± 20	.91	.88	150 ± 20
NEW BRUNSWICK						
Moncton	.47	.44	120 ± 30	.44	.41	120 ± 40
PRINCE EDWARD ISLAND						
Summerside	.42	.39	120 ± 20	.31	.28	120 ± 20
NOVA SCOTIA						
Truro	.63	.60	150 ± 20	.45	.43	140 ± 20
NEWFOUNDLAND						
Stephenville	N/A	N/A	N/A	.71	.68	150 ± 20

N/A = not available, barn designs should be checked with the NatVent software.

ALL = all angles can be used equally, no preferred building orientation.

TABLE 2 OPENING AREAS FOR POULTRY BARNs

Province and station location	Broiler chickens (per 1000 birds)			Turkeys (per 100 birds)		
	Total opening area, m ²	Sidewall opening area, m ²	Building orientation, degree	Total opening area, m ²	Sidewall opening area, m ²	Building orientation, degree
BRITISH COLUMBIA						
Hope	4.73	4.49	160 ± 20	2.47	2.36	160 ± 10
Kamloops	9.64	9.41	10 ± 10	<i>N/A</i>	<i>N/A</i>	<i>N/A</i>
Penticton	5.98	5.74	90 ± 10	3.16	3.05	90 ± 20
Vancouver	7.26	7.02	0 ± 20	3.36	3.25	0 ± 20
ALBERTA						
Calgary	5.62	5.38	70 ± 30	2.83	2.72	70 ± 40
Edmonton	8.07	7.84	10 ± 40	3.83	3.71	30 ± 20
Grande Prairie	7.78	7.54	30 ± 30	3.88	3.77	30 ± 20
Lethbridge	5.62	5.38	170 ± 30	2.80	2.69	170 ± 40
Red Deer	6.67	6.43	80 ± 30	3.53	3.42	80 ± 30
SASKATCHEWAN						
Estevan	4.62	4.38	40 ± 20	2.36	2.25	40 ± 10
Prince Albert	5.85	5.62	30 ± 30	3.15	3.04	30 ± 30
Regina	4.56	4.32	30 ± 20	2.34	2.23	40 ± 20
Saskatoon	4.87	4.64	80 ± 30	2.62	2.51	60 ± 20
MANITOBA						
Brandon	5.86	5.63	10 ± 20	2.99	2.88	0 ± 20
Winnipeg	5.07	4.84	80 ± 30	2.96	2.85	90 ± 50
ONTARIO						
Barrie	8.73	8.49	50 ± 10	4.49	4.38	50 ± 20
London	8.07	7.84	90 ± 90	3.83	3.72	100 ± 50
North Bay	6.03	5.79	120 ± 20	2.87	2.76	120 ± 20
Ottawa	7.92	7.68	130 ± 20	4.28	4.17	130 ± 20
Saint Catharines	5.21	4.98	130 ± 50	2.78	2.66	140 ± 40
Simcoe	6.46	6.23	120 ± 20	3.53	3.42	120 ± 20
Toronto	7.26	7.02	90 ± 20	3.72	3.60	80 ± 30
Trenton	5.91	5.67	120 ± 20	3.08	2.97	120 ± 10
Waterloo-Wellington	7.09	6.85	10 ± 50	3.90	3.79	<i>ALL</i>
Windsor	6.54	6.30	130 ± 20	3.53	3.42	120 ± 20
QUEBEC						
Montreal	7.02	6.78	120 ± 20	3.72	3.60	110 ± 10
Quebec	7.26	7.02	150 ± 20	3.47	3.35	140 ± 10
Riviere du Loup	4.59	4.35	120 ± 20	2.34	2.23	120 ± 10
Sherbrooke	9.59	9.35	150 ± 10	<i>N/A</i>	<i>N/A</i>	<i>N/A</i>
NEW BRUNSWICK						
Moncton	4.04	3.80	130 ± 20	2.40	2.29	130 ± 30
PRINCE EDWARD ISLAND						
Summerside	3.53	3.29	120 ± 10	2.02	1.91	120 ± 20
NOVA SCOTIA						
Truro	5.21	4.98	140 ± 20	2.78	2.66	140 ± 40
NEWFOUNDLAND						
St. John's	7.66	7.43	140 ± 10	3.77	3.66	140 ± 10

N/A = not available, barn designs should be checked with the NatVent software. ALL = all angles can be used equally, no preferred building orientation.

TABLE 3 OPENING AREAS FOR SWINE BARNs

Province and station location	Growing-finishing swine (per 10 pigs)		
	Total opening area, m ²	Sidewall opening area, m ²	Building orientation, degree
BRITISH COLUMBIA			
Hope	.64	.61	170 ± 30
Kamloops	1.12	1.09	10 ± 10
Penticton	.74	.71	90 ± 20
Vancouver	.90	.87	0 ± 20
ALBERTA			
Calgary	.65	.61	60 ± 50
Edmonton	.87	.83	20 ± 30
Grande Prairie	.87	.84	30 ± 20
Lethbridge	.73	.70	0 ± 90
Red Deer	.78	.75	70 ± 40
SASKATCHEWAN			
Estevan	.58	.54	40 ± 90
Prince Albert	.69	.66	40 ± 40
Regina	.57	.53	40 ± 90
Saskatoon	.59	.56	60 ± 50
MANITOBA			
Brandon	.70	.66	10 ± 30
Winnipeg	.63	.59	80 ± 30
ONTARIO			
Barrie	1.08	1.04	50 ± 50
London	.88	.84	100 ± 50
North Bay	.70	.66	130 ± 20
Ottawa	.94	.90	130 ± 30
Saint Catharines	.59	.56	140 ± 40
Simcoe	.77	.73	130 ± 20
Toronto	.90	.87	70 ± 60
Trenton	.70	.66	120 ± 20
Waterloo-Wellington	.83	.80	ALL
Windsor	.90	.87	120 ± 40
QUEBEC			
Montreal	.83	.80	120 ± 30
Quebec	.78	.74	150 ± 20
Riviere du Loup	.59	.55	120 ± 30
Sherbrooke	1.11	1.08	150 ± 20
NEW BRUNSWICK			
Moncton	.51	.48	120 ± 20
PRINCE EDWARD ISLAND			
Summerside	.56	.52	110 ± 40
NOVA SCOTIA			
Truro	.73	.70	140 ± 20
NEWFOUNDLAND			
Stephenville	.84	.81	150 ± 20

ALL = all angles can be used equally, no preferred building orientation.

Natural Ventilation Design Worksheet Example (Turkeys)

Building Dimensions: 107 x 23 m

Location of weather station near building site			Winnipeg Manitoba	
Type of production			Turkey	
A	Number of animals or birds		7600 birds	
B	Length of sidewall 1 opening (m)		102	m
C	Length of sidewall 2 opening (m)		102	m
D	Total length of sidewalls (m)	B + C =	204	m
E	Total number of studs or posts in sidewalls		338	
F	Width of a sidewall stud or post (mm)		38	mm
G	Width blocked by studs or posts (m)	E x F / 1000 =	12.8	m
H	Remaining length of opening (m)	D - G =	191.2	m
I	Length of the roof (m)		107	m
J	Area of one chimney opening (m ²)		0.283	m ²

Based on the type of production and station location, use the total opening area, sidewall opening area and the building orientation found in tables 1, 2 or 3.

K	Total opening area per bird or animal (m ²) =		2.96 /100	m ²
L	Sidewall opening area per bird or animal (m ²) =		2.85 /100	m ²
M	Building orientation (degrees) =		90 ± 50°	

N	Total opening area (m ²)	A x K =	225.0	m ²	7600 x 2.96/100
O	Total sidewall opening area (m ²)	A x L =	216.6	m ²	7600 x 2.85/100
P	Sidewall opening height (m)	O / H =	1.13	m	216.6/191.2
Q	If adding a wind break, increase by 0.15 m	P + .15 m =	1.28	m	1.13 + 0.15
Fi	Total roof opening area (m ²)	N - O =	8.4	m ²	225.0 - 216.6
S	Number of chimneys (round up answer)	R / J =	30		8.4/0.283
T	Distance between chimneys (m)	I / (S + 1) =	3.5	m	107/31

Natural Ventilation Design Worksheet

Building Dimensions:

	Location of weather station near building site		
	Type of production		
A	Number of animals or birds		
B	Length of sidewall 1 opening (m)		m
C	Length of sidewall 2 opening (m)		m
D	Total length of sidewalls (m)	B + C =	m
E	Total number of studs or posts in sidewalls		
F	Width of a sidewall stud or post (mm)		mm
G	Width blocked by studs or posts (m)	E x F / 1000 =	m
H	Remaining length of opening (m)	D - G =	m
I	Length of the roof (m)		m
J	Area of one chimney opening (m ²)		m ²

Based on the type of production and station location, use the total opening area, sidewall opening area and the building orientation found in tables 1, 2 or 3.

K	Total opening area per bird or animal (m ²) =		m ²
L	Sidewall opening area per bird or animal (m ²) =		m ²
M	Building orientation (degrees) =	±	°

N	Total opening area (m ²)	A x K =	m ²
O	Total sidewall opening area (m ²)	A x L =	m ²
P	Sidewall opening height (m)	O / H =	m
Q	If adding a wind break, increase by 0.15 m	P + .15 m =	m
R	Total roof opening area (m ²)	N - O =	m ²
S	Number of chimneys (round up answer)	R / J =	
T	Distance between chimneys (m)	I / (S + 1) =	m

NATURAL VENTILATION OPENING SIZES AND BUILDING ORIENTATION

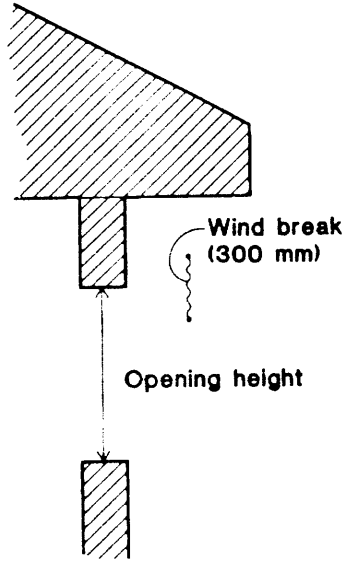


FIGURE 3 SIDEWALL OPENING HEIGHT

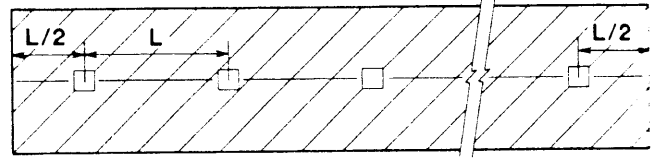


FIGURE 4 DISTANCE BETWEEN CHIMNEYS

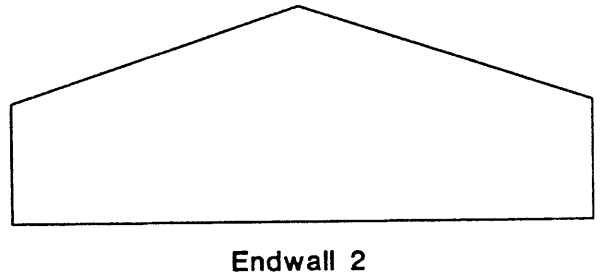
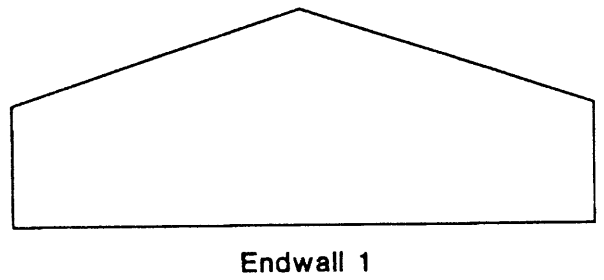


FIGURE 6 FILL IN WITH APPROPRIATE END WALL OPENINGS

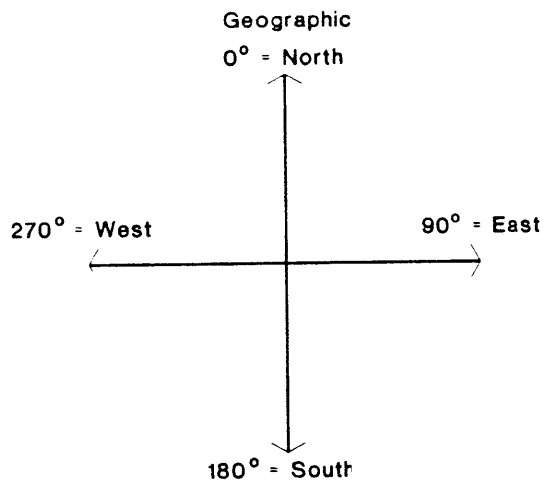


FIGURE 5 ORIENT THE BUILDING AND PROVIDE RANGE OF ANGLES