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NATVENT: A NATURAL VENTILATION SOFTWARE PACKAGE FOR LIVESTOCK BUILDINGS AND GREENHOUSES

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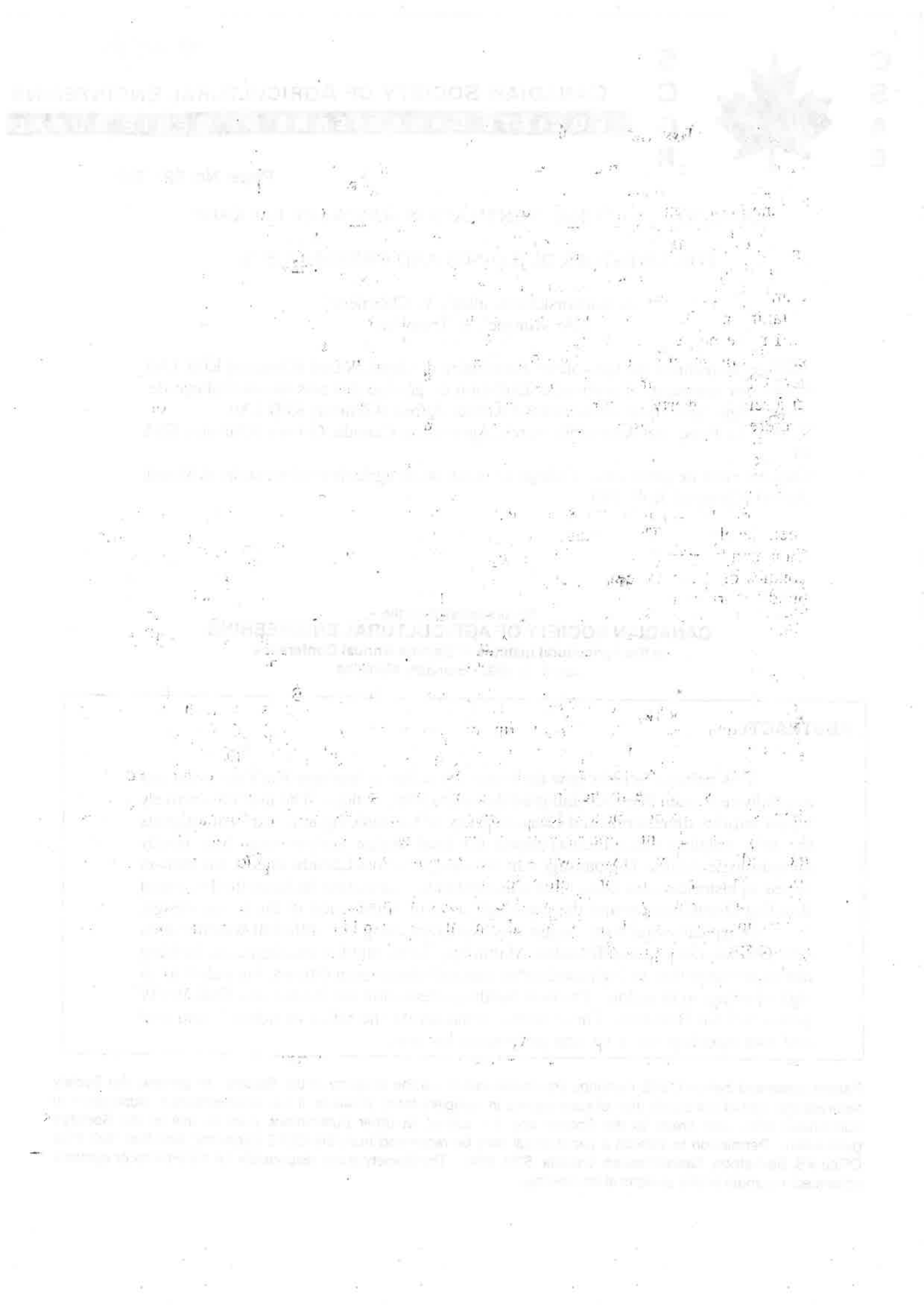
ABSTRACT:

This paper describes how the computer software package NatVent evaluates naturally ventilated livestock and greenhouse building designs. The user interactively inputs various dimensions and characteristics of the building and NatVent suggests the best building orientation(s) based on local design temperatures and hourly meteorological data. The package can test designs across Canada since it has built-in access to historical data from 32 weather stations. The output features the Preferred Building Orientation(s) and the expected Level of Satisfaction of the tested design.

A typical swine barn design was evaluated using two different weather data sets: Ottawa, Ontario and Brandon, Manitoba. To be rated as excellent, this building design required 0.91 m high continuous sidewall openings in Ottawa, but only 0.61 m high openings in Brandon. The best building orientation for Ottawa was ESE-WNW versus N-S for Brandon. These results demonstrate the effect of sidewall, end wall and roof openings when varying geographic location.



RÉSUMÉ

Ce document démontre les possibilités du logiciel "NatVent" pour concevoir les étables et serres ventilées naturellement. L'utilisateur introduit les dimensions et l'emplacement géographique du bâtiment et "NatVent" suggère l'orientation préférée ainsi qu'une évaluation du "Niveau de Satisfaction" que le producteur agricole pourra espérer de son système de ventilation naturelle. La conception est basée sur une banque de données météorologiques pour 32 stations au travers du Canada.

À titre d'exemple, le dimensionnement des ouvertures pour la ventilation naturelle d'une porcherie type pour la finition a été effectuée pour Ottawa (Ontario) et Brandon (Manitoba). Dans la région d'Ottawa, cette porcherie a besoin d'une ouverture continue de 0.91 m de hauteur sur les murs de côté pour obtenir un "excellent" niveau de satisfaction comparativement à 0.61 m pour Brandon. Pour la même porcherie, l'orientation préférée sera ONO-ESE pour Ottawa versus N-S pour Brandon. Les résultats illustrent les effets des différentes ouvertures dans les murs, les extrémités et au faîte du toit sur l'orientation préférée ainsi que les niveaux de satisfaction.

INTRODUCTION

A natural ventilation software package for livestock buildings and greenhouses has been developed. The package, called NatVent, uses historical weather data from various Canadian locations to assist in designing these buildings. This paper gives an example of the abilities of the package to verify the effect of sidewall and end wall openings, as well as building orientation, by comparing a typical swine barn design using weather data for Ottawa, Ontario and Brandon, Manitoba.

LITERATURE REVIEW

Wind tunnel studies using a 1:20 scale model of a low-rise agricultural building representing a typical gable roofed swine or dairy barn were performed by Choinière (1991). The studies were used to develop a method to predict wind induced ventilation rates.

Suchorski-Tremblay *et al.* (1991) presented the methodology that incorporated some of the results of these studies into a series of computer programs. Zemanchik *et al.* (1991) then used these programs to study the effect of building orientation and outside temperature on the predicted ventilation rates and its variation for a given weather history. This variation included frequency of events when predicted ventilation would be below some given value for a given number of consecutive hours.

Choinière *et al.* (1992) developed a software package now called NatVent. NatVent determines a building design's natural ventilation by wind induced forces relative to location or site specific weather data.

OBJECTIVES

The NatVent package was used to test a typical finisher swine barn design for 580 pigs, using weather data for Ottawa, Ontario and Brandon, Manitoba. The effects of different continuous sidewall openings heights (0.61 m, 0.76 m and 0.91 m) with either open or closed end wall windows were related to the Preferred Building Orientation (P.B.O.) and the Level of Satisfaction (L.S.) as calculated by NatVent.

METHODS AND PROCEDURE

Table 1 shows the building design layout used in the study. The sizes of the weather data files used were: 30.5 years for Brandon and 34.4 years for Ottawa.

Appendix 1 provides a typical output summary from NatVent. It includes the data the user inputs for the building design and testing criteria, as well as the results of the NatVent analysis.

The building, shown in Figure 1, is a 36.6 m long by 12.2 m wide gable roofed swine barn. The roof has six 0.61 m by 0.61 m chimneys, with an effective opening area of 2.23 m^2. Both end walls have two windows each measuring 1.83 m by 0.91 m, with an effective opening area of 6.68 m^2. The sidewall openings are 31.7 m long, with 14 steel posts measuring 0.15 m wide each. Therefore, the effective opening length is 29.6 m. The effective opening area depends on which opening height is used. The opening heights tested were 0.61 m, 0.76 m and 0.91 m. The total opening area of each test building is given in Table 1. The buildings are symmetrical with respect to all opening placements.

NatVent is capable of calculating the L.S.(%) and P.B.O. for design temperatures equal to or greater than 20°C and for building orientations from 0° to 350° in increments of 10°. For this study, the design temperature used was 20°C and the building orientations used were 0° through 330° in increments of 30°.

RESULTS AND DISCUSSION

The results from the 12 tests are listed in Table 2. Data from both sites show an effect of sidewall opening height on both P.B.O. and L.S.; as the sidewall height increases, the L.S.(%) increases, and the P.B.O. varies. Also the L.S.(%) is always better for buildings having openings in the end walls. The P.B.O. varies depending upon sidewall opening size and existence of end wall openings, but the relationship is not clear.

Table 3 shows that the addition of end wall openings become relatively less important to ventilation as sidewall openings increase in size.

By comparing the results in Table 2, for Ottawa and Brandon, the minimum opening area required to achieve an excellent building design differs. For Ottawa, an excellent level of satisfaction is achieved with a sidewall opening size of 0.91 m and closed end walls, while for Brandon, a 0.61 m high sidewall opening and openings in the end wall are required. If both buildings had closed end walls, the Brandon building would require a 0.76 m high sidewall opening. In Brandon, the P.B.O. for open end wall designs is consistently S-N (180°), but for closed end wall designs, the value fluctuates from NNE-SSW (30°) to N-S

(0°). The building located in Ottawa behaves differently. The smallest sidewall opening size with open end walls prefers a building orientation of ESE-WNW (300°) while with closed end walls NNW-SSE (150°). With the largest sidewall openings, the P.B.O. changes to WNW-ESE (120°) with either open or closed end walls. Each design tested had a different response depending upon the building design as well as the local climate.

SUMMARY AND CONCLUSION

There are some general conclusions that can be drawn from the testing of a typical swine building in these two different locations: Ottawa, Ontario and Brandon, Manitoba. They are:

1) As sidewall opening size increases, the Level of Satisfaction (L.S.(%)) also increases.
2) Given the same sidewall opening size, openings in the end wall provide a greater Level of Satisfaction (L.S.(%)) than a closed end wall.
3) The Preferred Building Orientation varies according to the sidewall opening size, the presence of end wall openings and local climate.
4) Both the Preferred Building Orientation and the Level of Satisfaction are different for Brandon versus Ottawa.

From this study, it appears that the sizes of the sidewall and end wall openings are site specific and can only be determined based on local weather data.

RÉSUMÉ ET CONCLUSION

Les effets de différentes ouvertures dans les murs et les extrémités d'une porcherie type ventilée naturellement dans la région d'Ottawa et Brandon peuvent être résumés comme suit:

1) Un agrandissement de l'aire des ouvertures dans les murs cause une augmentation du niveau de satisfaction.
2) L'utilisation de deux ouvertures aux extrémités du bâtiment augmente les niveaux de satisfaction.
3) L'orientation préférée pour cette porcherie type varie selon l'aire des ouvertures dans les murs, l'utilisation d'ouvertures aux extrémités ainsi que l'emplacement géographique.
4) Les niveaux de satisfaction et les orientations préférées varient pour Ottawa versus Brandon.

Les résultats de cette étude confirment que le dimensionnement des ouvertures pour la ventilation naturelle ainsi que l'orientation préférée pour le bâtiment doit être fait avec les données climatologiques locales.

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Table 1. Experimental building design layout.

Test	Sidewall Opening Height (m)	Site	End Wall Windows	Total Opening Area (m^2)
a	0.76	Ottawa	open	52.98
b			closed	46.29
c	0.76	Brandon	open	52.98
d			closed	46.29
e	0.61	Ottawa	open	43.34
f			closed	36.65
g	0.61	Brandon	open	43.34
h			closed	36.65
i	0.91	Ottawa	open	62.64
j			closed	55.95
k	0.91	Brandon	open	62.64
l			closed	55.95

Table 2. Preferred Building Orientation and Level of Satisfaction results.

	Site:	Ottawa, Ontario			Brandon, Manitoba		
Sidewall Opening Height (m)	End Wall Windows	Pref. Building Orient.	Level of Sat.	L.S. (%)	Pref. Building Orient.	Level of Sat.	L.S. (%)
0.61	open	300° WNW-ESE	Good	74.0	180° S-N	Excellent	83.5
0.61	closed	150° SSE-NNW	Fair	68.5	30° NNE-SSW	Very Good	78.4
0.76	open	120° ESE-WNW	Very Good	79.3	180° S-N	Excellent	87.4
0.76	closed	150° SSE-NNW	Very Good	76.4	30° NNE-SSW	Excellent	83.9
0.91	open	120° ESE-WNW	Excellent	83.2	180° S-N	Excellent	89.8
0.91	closed	120° ESE-WNW	Excellent	80.6	0° N-S	Excellent	87.8

Table 3. Comparing L.S.(%) for end walls with and without openings for both Ottawa and Brandon.

	Site:	Ottawa, Ontario	Brandon, Manitoba
Sidewall Opening Height (m)	% Difference of Total Opening Area*	Difference of L.S.(%)**	Difference of L.S.(%)**
0.61	15.4	5.5	5.1
0.76	12.6	2.9	3.5
0.91	10.7	2.6	2.0

* % Difference of Total Area Opening = $\frac{\text{(Total Opening Area of design with end walls open - Total Opening Area of design with end walls closed)}}{\text{Total Opening Area of design with end walls open}} \times 100$

e.g. For a sidewall opening of 0.61 m, $(43.34\ m^2 - 36.65\ m^2)/43.34\ m^2 \times 100 = 15.4\%$

** Difference of L.S.(%) = (L.S.% of a design with end walls open - L.S.% of a design with end walls closed)

e.g. In Ottawa, Ontario, for a sidewall opening of 0.61 m, (74.0% - 68.5%) = 5.5%.

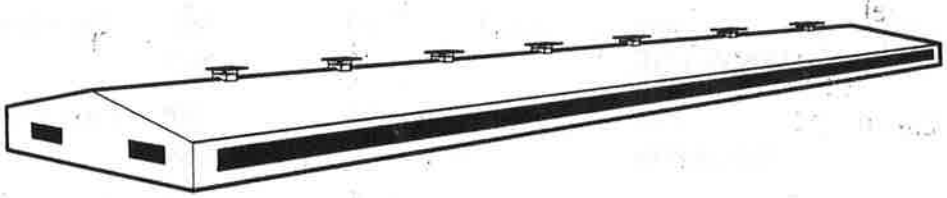

Figure 1. Typical gable roofed swine barn tested using NatVent.

3	60
4	90
5	120
6	150
7	180
8	210
9	240
10	270
11	300
12	330

The building is to be located in Manitoba.

The building is to be located near the Brandon station.

For temperatures greater or equal to 20C...
Weight of average ventilation rate: 0 %
Weight of average proximal ventilation rate: 33.34 %
Weight of frequency of single hour events: 33.33 %
Weight of frequency of 3 consecutive hour events: 33.33 %
Weight of duration of maximum event: 0 %

Weight of design temperature of 20½C: 100 %

NOTICE OF RESPONSABILITY:
OMAF, Canadian Electrical Association and Ontario Hydro do not assume any liability for any loss caused by the use of any information contained in this package and do not in any way warrant or guarantee that it meets the user's needs, local climatic conditions or applicable building regulations.

AVIS DE RESPONSABILITE
MAAO, Association canadienne de l'électricité et Hydro Ontario ne sont pas responsables d'aucune perte résultant de l'utilisation des renseignements contenus dans ce logiciel et n'atteste ni ne garantit d'aucune façon que ledit logiciel répond aux besoins de l'usager, aux conditions climatiques locales ou aux règlements en matière de bâtiment.

Authorized for release by:

_____

Ag. Eng. or other knowledgeable person

Date: _____

Distance from left corner to center: 18.288 m.
Distance from floor to center: 1.981 m.
Number of post(s) in opening: 14
Width of a post: 15.2 cm.

SIDEWALL 4 has a continuous opening.

SIDEWALL 4 opening's width: 31.699 m.
SIDEWALL 4 opening's height: 61 cm.
Distance from left corner to center: 18.288 m.
Distance from floor to center: 1.981 m.
Number of post(s) in opening: 14
Width of a post: 15.2 cm.

ROOF has chimneys.

There are 6 chimneys on the ROOF.

Opening Number	Length of opening (cm)	Width of opening (cm)	Distance from END WALL 1 to center of opening(m)
1	61	61	3.048
2	61	61	9.144
3	61	61	15.24
4	61	61	21.336
5	61	61	27.432
6	61	61	33.528

Livestock type to be housed: Grower-finisher hogs.

Animal Type	Number of Animals	Ventilation Rate L/s/animal
grower-finisher hogs	580	35

The required ventilation rate is 20300 L/s.

The chosen ventilation rate is 20300 L/s.

There is 1 design temperature chosen.

Temperature Number	Design Temperature (½C)
1	20

There are 12 orientation angles chosen.

Angle Number	Orientation Angle (½)
1	0
2	30

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NATVENT - A NATURAL VENTILATION PACKAGE FOR AGRICULTURAL BUILDINGS

NATVENT - UN LOGICIEL POUR LA VENTILATION NATURELLE DES BATIMENTS AGRICOLES

VERSION: 1.0; 1991-10

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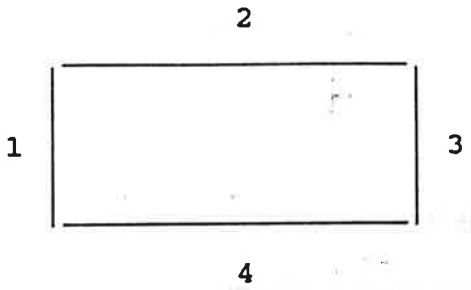
Client's name: Swine barn run g. Date: November 22 1991.

Run's title: Chimney - end wall open - Brandon.

Building's total length: 36.576 m.
Building's width: 12.192 m.
Building's sidewall height: 2.438 m.
Building's roof angle: 18.4 degrees.



END WALL 1 has intermittent openings.

There are 2 openings in END WALL 1.

Opening Number	Width of opening (cm)	Height of opening (cm)	Distance from left corner to center of opening(m)	Distance from floor to center of opening(m)
1	182.88	91.44	3.048	1.524
2	182.88	91.44	9.144	1.524

END WALL 3 has intermittent openings.

There are 2 openings in END WALL 3.

Opening Number	Width of opening (cm)	Height of opening (cm)	Distance from left corner to center of opening(m)	Distance from floor to center of opening(m)
1	182.88	91.44	3.048	1.524
2	182.88	91.44	9.144	1.524

SIDEWALL 2 has a continuous opening.

SIDEWALL 2 opening's width: 31.699 m.
SIDEWALL 2 opening's height: 61 cm.

Appendix 1

Typical Summary Output from NatVent

Temperature = 20½C

Build. Orient. Angle (½)	Average Vent. Rate (L/s)	R	Average Pr. Vent. Rate (L/s)	R	Single Hour Event (%)	R	Three Hour Event (%)	R	Max. Dur. (h)	R	Overall Ranking R
180	34422	9	17860	12	27.6	11	9.8	12	18	11	11.7
0	34422	10	17860	11	27.6	11	9.8	12	16	12	11.3
30	34794	11	17834	10	27.5	12	9.8	11	18	11	11.0
210	34794	12	17834	9	27.5	12	9.8	11	21	10	10.7
150	32522	5	17703	8	29.7	10	10.7	10	21	10	9.3
330	32523	6	17703	7	29.7	10	10.7	10	21	10	9.0
300	31575	2	17688	6	29.8	9	10.7	9	18	11	8.0
120	31575	1	17688	5	29.8	9	10.7	9	16	12	7.7
240	33246	8	17657	4	30.3	8	11.1	8	18	11	6.7
60	33245	7	17657	3	30.3	8	11.1	8	21	10	6.3
270	31893	4	17649	2	30.6	7	11.2	7	21	10	5.3
90	31892	3	17649	1	30.6	7	11.2	7	21	10	5.0

CAUTION: NATVENT REQUIRES INTERPRETATION BY AN ENGINEER OR OTHER PERSON WITH A THOROUGH KNOWLEDGE OF THE PRINCIPLES OF NATURAL VENTILATION.

Best Orientation Angle for Building for Design Temperature 20½C and Level of Satisfaction

Building Orientation Angle (½)	Overall Rank	Percent Success	Level of Satisfaction
180	11.7	83.5	Excellent
0	11.3	83.5	Excellent
30	11.0	83.5	Excellent
210	10.7	83.5	Excellent
150	9.3	82.3	Excellent
330	9.0	82.3	Excellent
300	8.0	82.2	Excellent
120	7.7	82.2	Excellent
240	6.7	81.9	Excellent
60	6.3	81.9	Excellent
270	5.3	81.7	Excellent
90	5.0	81.7	Excellent

CAUTION: NATVENT REQUIRES INTERPRETATION BY AN ENGINEER OR OTHER PERSON WITH A THOROUGH KNOWLEDGE OF THE PRINCIPLES OF NATURAL VENTILATION.