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STALDVENT – SOFTWARE TOOL FOR DESIGNING LIVESTOCK FACILITIES IN DIFFERENT CLIMATE ZONES

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ABSTRACT StaldVent is a decision support PC-program for designing ventilation and heating (or cooling) systems for livestock buildings, and for analyzing the indoor thermal climate and energy consumption. Using StaldVent simplifies the design optimization process for ventilation and indoor climate management, which can lead to an improved working environment, better animal welfare, and reduced energy consumption. StaldVent allows environmental footprint prediction using annual-basis simulation of gas emissions, air cleaner efficiency, and energy use. StaldVent can be used as a neutral standard for comparing different ventilations systems – including mechanical, natural, tunnel, and combi-tunnel – on the basis of selected criteria. It can be used for design in any global climate, whether heating or cooling dominant, and for many livestock species. StaldVent allows the input of market-available ventilation components as a reference file to produce a parts list, which makes it useful for both consulting professionals and ventilation equipment supply companies when designing and quoting jobs. The simulation module makes it an effective tool for troubleshooting ventilation problems with installed equipment, which can improve time efficiency when on site for technical follow up.

Keywords: Animal Heat Production, Heat and Mass Balance, Ventilation, Heating and Cooling Systems, Prediction of Indoor Climate, Simulation of Energy Consumption and Gaseous Emissions. Mechanical, Natural and Tunnel Ventilation for Different Climate Zones.

INTRODUCTION Designers of livestock facilities use models to predict heat and moisture production from livestock and then consider the interaction of climate, over the production period(s), on ventilation strategies to maintain healthy indoor conditions for the production animals. Different ventilation strategies may be employed depending on the species of livestock, the dominant climate (heating or cooling), and even government

regulations that may apply (such as to limit ammonia emissions, which exist in countries like Denmark, Netherlands, and Germany) among other considerations.

StaldVent software is a commercially available livestock facility ventilation design program that uses published standard design models and incorporates them into a thorough calculation tool with a straight-forward user interface. StaldVent allows the sizing of the facility's mechanical systems (ventilation, heating, cooling) but also provides a simulation tool that can be used to compare between various building designs, ventilation strategies, and management parameters (such as set points, floor wetness, etc.). The StaldVent software also provides a mechanism to allow troubleshooting of existing livestock facilities. StaldVent is available in professional- and educational-licensed versions, and the interface is available in multiple languages, so it can be used by a variety of industry participants from designers, equipment suppliers and technicians, to technical training colleges and universities.

MATERIALS AND METHODS At the heart of the StaldVent program algorithm is the calculation of animal heat production units (hpu), based on one of three user-selectable methods: Strøm and Feenstra (default), CIGR 2002, and DIN 18910. Users will input data on the livestock species, the building construction details, and the local climate. The full capability of the StaldVent program within all its available calculation modules include: ventilation; heating; cooling; ammonia and odour emissions (air cleaner module); simulation (including energy use optimization); heat exchanger sizing; central exhaust from multiple production units; incorporation of incoming solar radiation levels and wind effects; and water consumption from production, cooling and cleaning systems; as well as alternative heating and cooling source via groundwater heat exchange.

Input data

Livestock species information Users may select from the data entry templates for many livestock species, including pigs, chickens, turkeys, dairy cattle, beef cattle, horses, goats, sheep, and rabbits, or they may choose to enter their own customizable heat production using the Hpu tab. Additional required details include age and weight of the animals, production length/duration, and notable production system details, such as type of flooring.

Building construction details For calculation of the transmission loss, the building dimensions and insulation values can be read in using a table with detailed construction elements including doors and windows. The overall heat transfer coefficient for different wall material combinations can be evaluated together with the wall temperatures.

Local climate information For calculating the interaction with local climate conditions StaldVent can handle several standard reference weather data formats like TMY2, TMY3, Ref (Danish), csv, and other user-customizable files. The software is complemented by the MeteoNorm® program for estimating climate data for more than 7000 locations worldwide.

Equipment performance data and prices (optional) The StaldVent program provides overall ventilation and heating design (including sizing) with built-in generic components. If the user has their own equipment with performance data available, they may format it as a StaldVent database, and the StaldVent program is capable of taking this user-provided equipment to generate a detailed design with component listings. Additionally, equipment price lists can be generated if the pricing data is entered for the components, and some companies already use StaldVent to develop quotations for their clients.

Calculation algorithm

Heat production units The StaldVent software is based on the standard heat production unit concept (hpu) where the animal sensible heat and latent heat varies with the indoor temperature as shown in Figure 1. Several models including Strøm/Feenstra, GIGR 2002 and DIN 18910 can be selected.

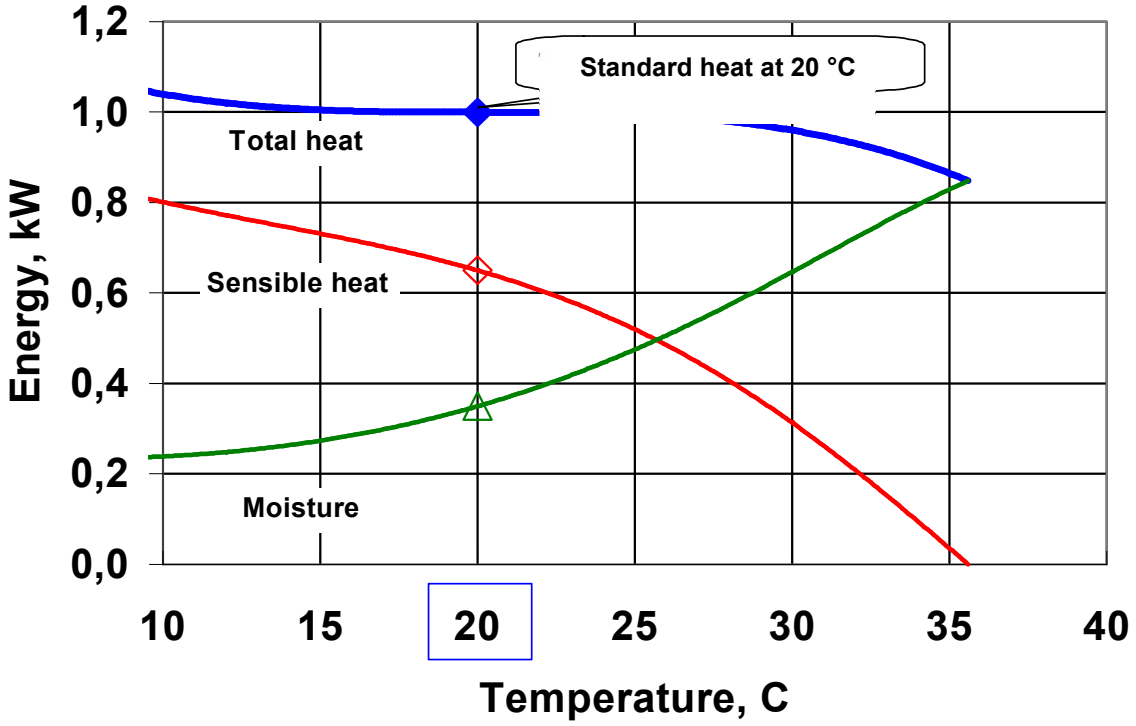

Figure 1. Strøm/Feenstra Heat Production Model.

The hpu model is universal for most animal groups and depends on the animal mass, growth rate, milk production etc. Based on the number of heat production units the

production of CO_2 is predicted with a production rate of 180 liters per hour per hpu (180 l/h/hpu). The moisture production can be calculated from the latent heat production. Ammonia production modelling is based on both the CO_2 production (from hpu) as well as considering the interaction with the flooring system as inputted by the user.

Energy balance With the animal production and building construction specified the heat and mass balance can predicted. The hot weather design condition will determine the maximum ventilation rate while the cold weather design condition will determine the maximum heating requirement as illustrated in Figure 2.

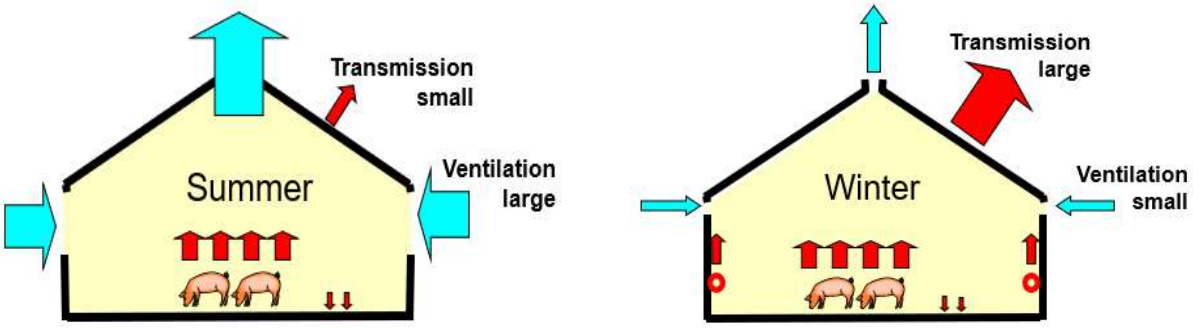

Figure 2. Heat and mass balances for summer and winter condition.

System design output

Ventilation system Based on the actual climate conditions the required air flow rate and pressure difference can be calculated when an acceptable temperature difference between indoor and outdoor temperatures has been specified. The air flow rate at minimum ventilation rate depends on the acceptable CO_2 concentration in the barn, or on the acceptable limits of relative humidity, with the governing design parameter selected by the user.

Heating system With the maximum and minimum ventilation rate calculated, the required heating capacity can be determined. Normally indoor temperature and humidity is used for controlling the indoor climate, but CO_2 control can be used as well. Water-based heating and direct (unvented) combustion systems can be evaluated. Heat recovery via heat exchangers (air-to-air) can also be modelled within the regular heating module.

Cooling system If satisfactory temperature conditions cannot be achieved through ventilation alone it is possible to add a cooling system that is operated within given limits for setpoint deviation and indoor humidity. Different systems like spray cooling, PAD-

cooling and mechanical cooling can be modelled. If even more cooling is necessary, tunnel ventilation with chill effect can be introduced.

Emissions control The StaldVent program has built-in models for prediction of ammonia production from pigs and broilers. With these models it is possible to calculate the ammonia concentration within the building and emissions to the surrounding environment. The effect of partial or full air cleaning can be simulated in general as well as with systems based on air extraction through the floor area/manure pits.

Simulation With the main system design in place it is possible to make a simulation of all parameters on an annual hourly basis to validate the performance of the chosen system. The simulation module can handle up to 10 individual simulations which makes it easy to compare different systems and settings, such as fan control strategy, heating source, type of cooling system and capacity, among others.

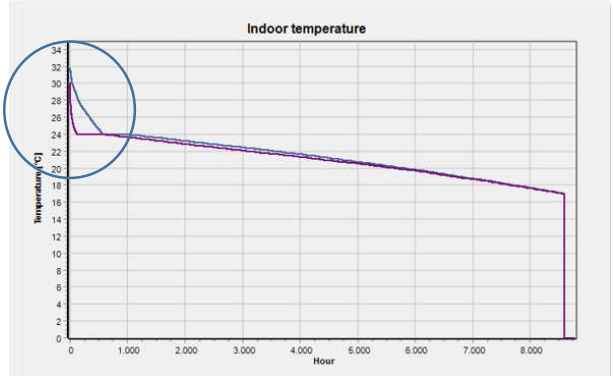

Figure 3. Annual duration temperature profile for swine house in Quebec with and without spray cooling. The circled area highlights the temperature effect (reduction in hours at higher temperatures) of using evaporative cooling.

RESULTS In addition to being a user-friendly modelling interface to facilitate the calculation of many important design parameters, StaldVent also provides useful graphical output to assist in the interpretation of the design values and in presenting these design and troubleshooting values to clients and other stakeholders.

CONCLUSION The StaldVent livestock facility ventilation design tool is a useful tool for designers, equipment suppliers and technicians, and educators in the animal production industry across many different climate zones.

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