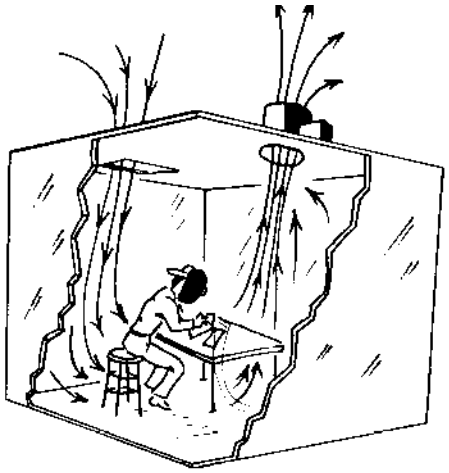

Direct energy consumption,
heat loss through ventilation

Ventilation

Tasks of ventilation:

- Carry fresh air in and remove gases and moisture
- In cattle houses ventilation removes carbon dioxide, moisture, ammonia, hydrogen sulfide, methane
- Cool the building during hot seasons
- Possible to use to deliver heat into the builduing
- Ventilation gives a good living place for animals, good working place for human beings and good circumstances for the structures to remain 'healthy'
- **Minimun ventilation:** Used in cattle houses during cold periods, minimum heat loss through ventilation
- **Maximum ventilation:** Used in cattle houses during hot periods, maximum cooling effect



Ventilation

Fresh air quality

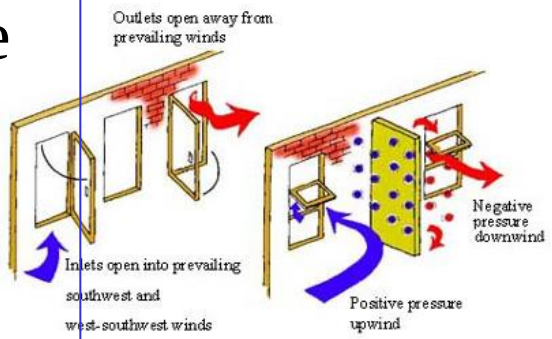
- Animals and human beings need fresh air and they produce carbon dioxide
- Limits for human beings:
  - In working places concentrations of 5000 ppm and more are harmful (8 h exposure)
  - IDLH concentration (Immediately dangerous to life and health, USA) concentration limit is 40 000 ppm over 30 min exposure time
- Recommended value for living houses is 1500 ppm, which corresponds to 0,7 m^3/h fresh air per person
- Another recommendation says that air in a living room should change in every two hours
- For animals the carbon dioxide limit is 3000 ppm

http://www.ttl.fi/internet/ova/hiilidioksidi.html

ppm = part per million
10 000 ppm = 1 %

Significance of cattle house ventilation

- When air quality is good, number of airway deseases is low
- Stalls and passages are dry, utter and claw healthy are good
- Animals are cleaner and easier to clean
- Animals eat better if the feeding place has fresh air
- Increases resting time and improves resistance to deseases
- Decreases stress and improves production
- Bacteria content is decreased and because of low moisture content life time of bacterias is short



Temperature and ventilation

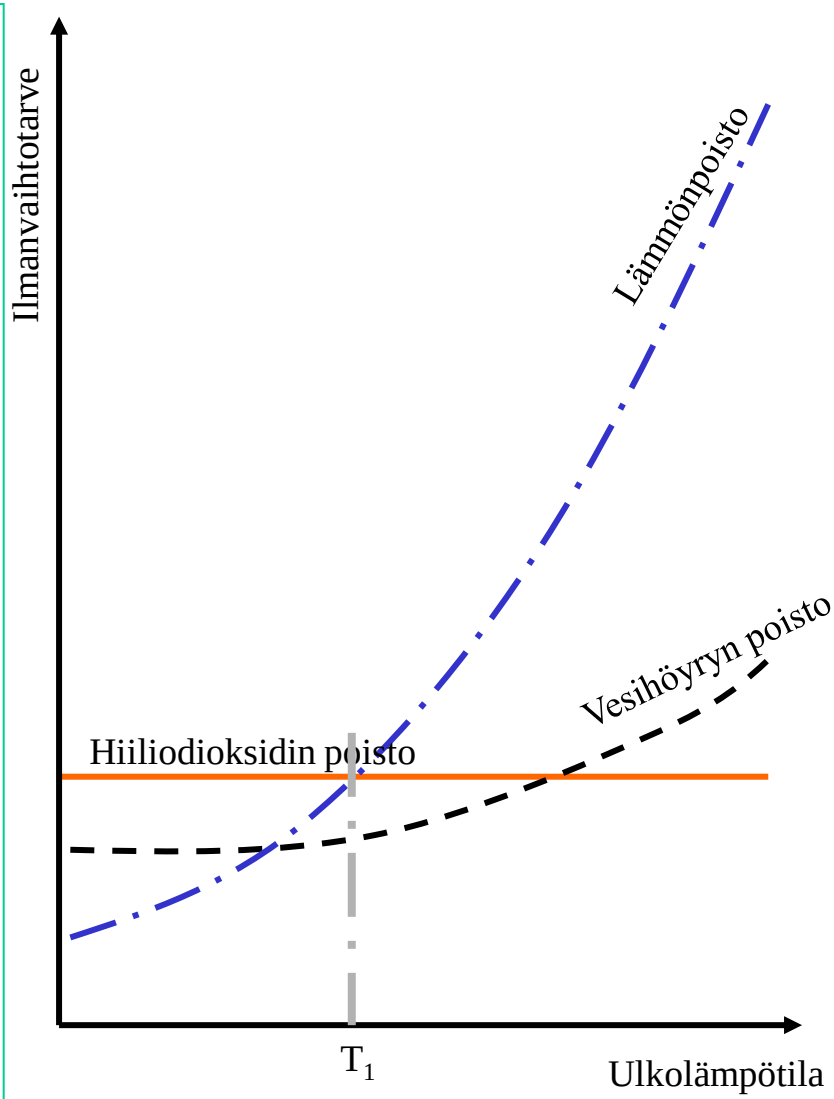
- Cold weather
  - If the ventilation rate is very low, there will be more moisture and harmful gases in the cattle house
  - Cold surfaces become wet and this makes the animal feel draught
- Hot weather
  - Maximum ventilation rate is used in order to remove heat from the building
  - High air speed (draught) cools also the animals

Ventilation types

- Ventilation can be natural or forced
- Natural ventilation
  - Good ventilation control is hard to arrange, with modern technics satisfactory control is possible
  - Temperature and wind has an effect on the ventilation rate
  - Cheap and reliable system
  - Suits best for cows because they can tolerate well cold weather
- Forced ventilation
  - Ventilation is done with fans
  - Good micro climate control
  - Even fresh air distribution
  - Expensive and consumes energy continuosly

Ventilation sizing

- Animals and human beings
  - Welfare is guaranteed with good ventilation
  - Sizing or ventilation rate adjustment is done according to:
    - Temperature
    - Moisture content
    - Carbon dioxide
  - Temperature control strategy changes with oudoors temperature
    - During hot weather heat removal is the main thing
    - During cold weather carbon dioxide content is the main thing
- Structures
  - Ventilation prevents moisture condensation on cold structures



Ventilation rate recommondations

Taulukko 2. Kotieläinten lämmön- ja kosteuden tuotanto sekä sille suositeltavat huoneilman talvenaikaiset arvot lämmöneristetyissä kotieläinrakennuksissa.

Eläin	Paino kg	Eläinten ikä, Kk (vrk)	Suositus-lämpötila °C	Suht. Kost:n max-%	Lämmön-luovutus W/el.	Kosteuden luovutus g/h	Ilmanvaihto m^3/h min.	Ilmanvaihto m^3/h max.
Lypsylehmä	400..500		12	85	700	400	55	310
- " -	600		12	85	800	450	65	330
- " -	700		12	85	850	500	70	360
Hieho ja ummessa oleva lehmä	500		12	85	600	400	50	240
Nuorkarja, uudistus	400	18	12	85	500	300	40	200
- " -	300	9	12	85	400	250	30	150
- " -	150	5	12	85	250	150	20	100
Vasikka	75	2	12	85	100	75	10	55
Lihakarja	600	20	12	80	600	750	110	250
- " -	500	16	12	80	550	500	80	230
- " -	300	10	12	80	400	450	55	180
- " -	200	6	12	80	350	350	50	150
- " -	100	3	12	80	250	200	30	100
Emakko + pikkuporsaat,(7kpl)	200+10x7		16(32)	80	550	450	35	250
Joutilas emakko	200		12	80	350	100	20	150
Karju	200	12	12	80	350	100	20	150
Nuoremakko, uudist.	<200	<3	16	80	150	75	20	150
Pikkuporsas	20	3	20	80	60	60	5	30
- " -	10	1	22	80	30	40	3	30
Tuotannossa oleva emakko (Kaikki eläimet samassa tilassa - emakot, pikkuporsaat, karjut)			16	80	480	220	35	260
Lihotussika, jatkuva tuotanto	30...110	3...7	16	80	110	100	10	70
Lihotussika, kierroskasvatus	110	5...7	16	80	200	150	15	100
- " -	90	3...5	16	80	150	120	13	80
- " -	60	2...3	16	80	100	90	10	60
- " -	30	1...2	18	80	75	70	7	40
Kana	2	>5	18	70	10	5	0.5	6.0
Broileri	1.7	35 vrk	21	75	10	5	0.8	5.0
- " -	1.0	25 vrk	23	75	10	5	0.5	3.0
- " -	0.5	16 vrk	27	75	5	2.5	0.3	2.5
- " -	0.1	5 vrk	31	75	1	1	0.1	0.5
- " -	0.05	1 vrk	34	70				
Lammas	<100	>2	10	80	150	80	10	50
- " -	10	<2	10	80	50	20	2	15
Hevonen (työ)	500		10	80	650	200	30	240
- " - (kilpa)	500		14	80	650	220	35	350

Suurin sallitun ilman virtausnopeus eläinten oleskeluvyöhykkeellä talven aikana on 0.25 m/s. Lämpimänä vuodenaikana sallitaan suurempi virtausnopeus.

Air moisture contents

Relative humidity expresses how near air is to saturation, 100 % = saturation

$$s = \frac{p_h}{p'_h}$$

s = relative humidity
p_h = water vapour partial pressue
p'_h = water vapour partial pressue at saturation

Humidity ratio (absolut humidity) expresses how much the air has water in

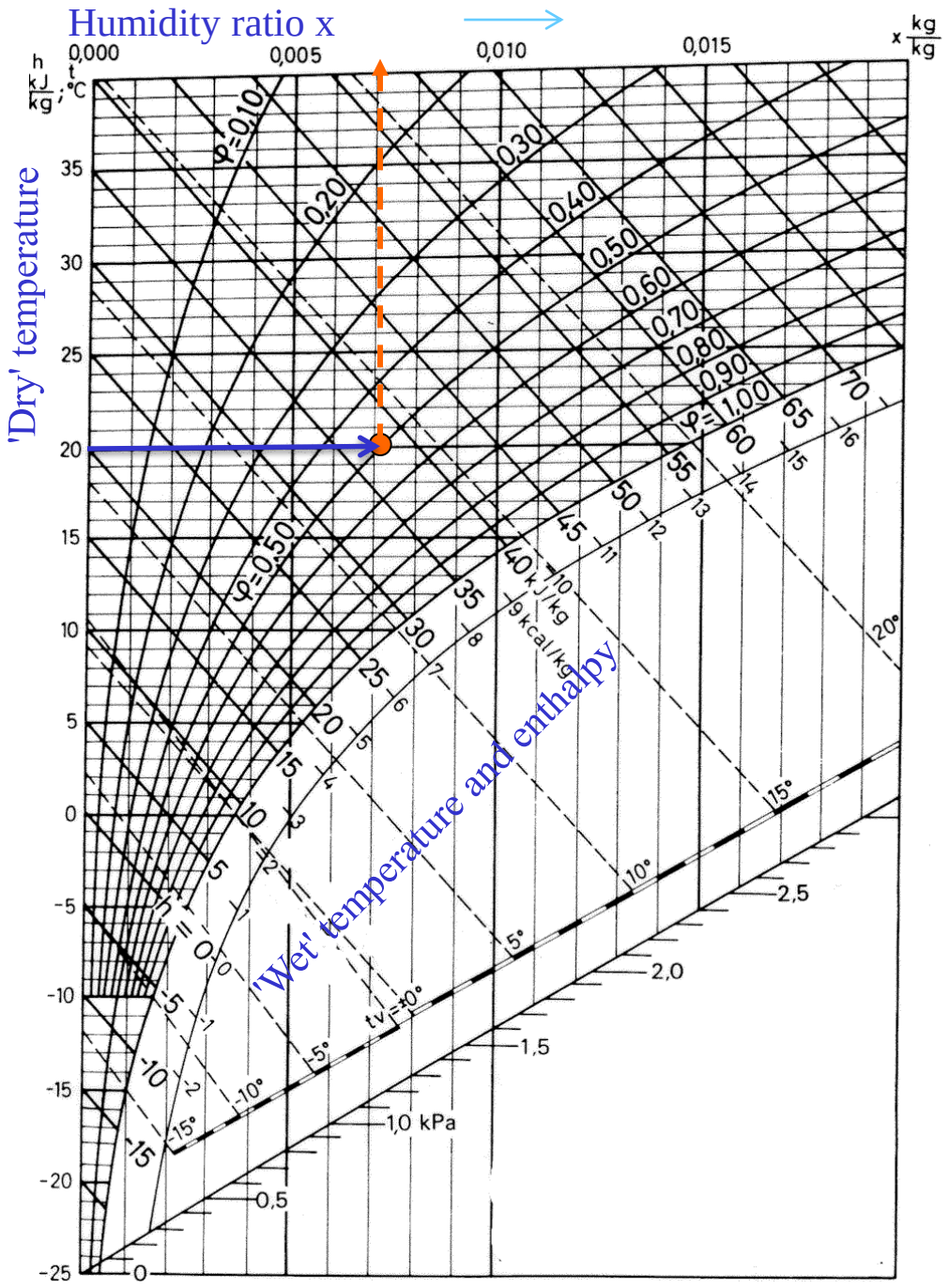
$$x = \frac{m_h}{m_i}$$

x = humidity ratio
m_h = mass of water
m_i = mass of dry air

Mollier

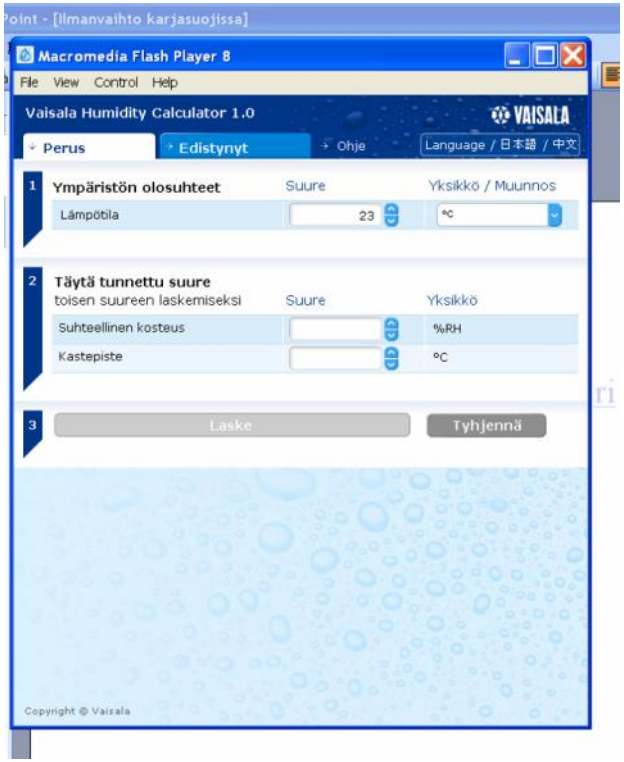
- Mollier diagram is humid air 'map'
- When two condition points are known the other points can be read from the diagram
- Nowadays 'Psychrometric calculators' can be used for the same purpose

Example: Air temperature is 20 C and humidity 50 %, enthalpy of air is 38 kJ/kg and humidity ratio is 0,007 kg of water in every dry air kg



Calculators

- Psychrometris calculators
- http://www.vaisala.fi/kosteuslaskuri



Sizing of ventilation

Heat removal:

$$\dot{V}_l = \frac{\Phi_{iv}}{\rho_i c_i (T_s - T_u)}$$

Moisture removal:

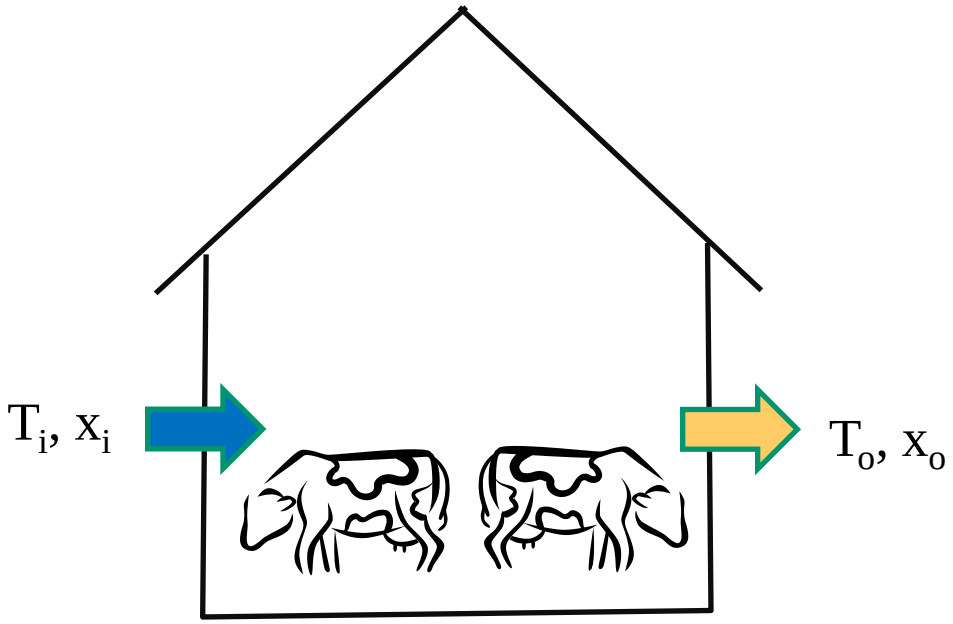
$$\dot{V}_v = \frac{\dot{V}_{H_2O}}{\rho_i (x_s - x_u)}$$

CO_2 removal:

$$\dot{V}_h = \frac{\dot{V}_{CO_2}}{s - s_u}$$

V_l	ventilation rate needed to remove heat
V_v	ventilation rate needed to remove moisture
V_h	ventilation rate needed to remove CO_2
φ_{iv}	removed heat power
ρ_i	air density (1,20 – 1,27 kg/m^3)
c_i	air heat capacity, 1,006 kJ/kg
T_s	inside temperature
T_u	outside temperature
V_{H2O}	Animal moisture production
x_s	humidity ratio in the building
x_u	outdoor humidity ratio
V_{CO2}	animal carbon dioxide production
s	allowed carbon dioxide content
s_u	outdoor corbon dioxide content (~300 ppm)

Air heating power



$$P_k = \dot{V}_i \rho c_i \Delta T = \dot{V}_i \rho c_i (T_o - T_i)$$

c_i	air heat capacity, n 1,006 kJ/kgK
V	air volume flow
ρ	air density
ΔT	temperature change

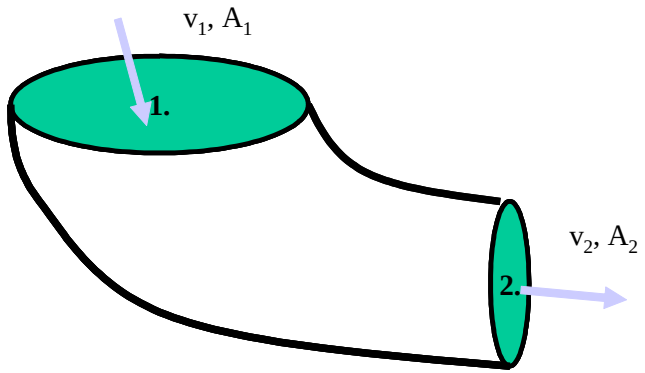
This is an approximate way to calculate ventilation heat loss

Example

- Piggery indoor temperature is 15 C and outdoor temperature is -15 C. Minimum ventilation rate is 13 m3/h. How much heat is lost through ventilation?

Air speed

- When known ventilation flow goes through an opening, the air velocity can be calculated with the equaton beside
- During cold weather the macimum recommnded air speed for animals is 0,25 m/s

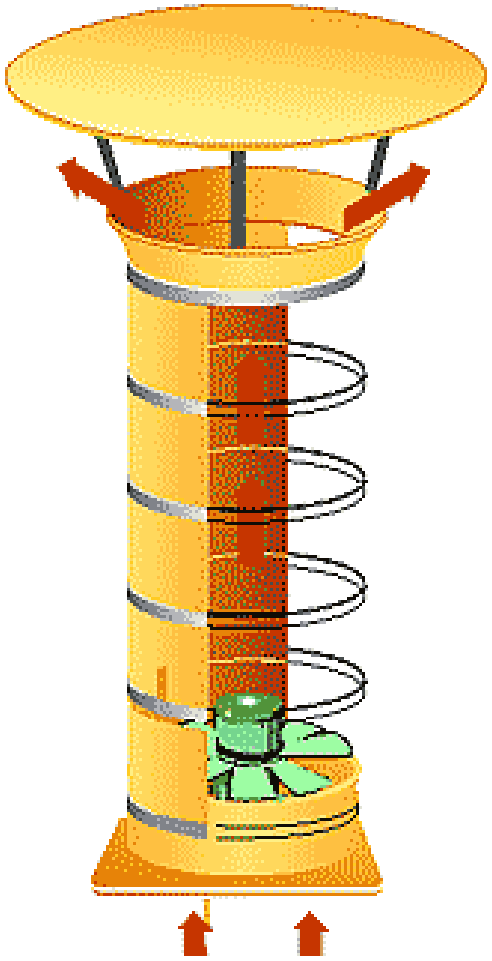


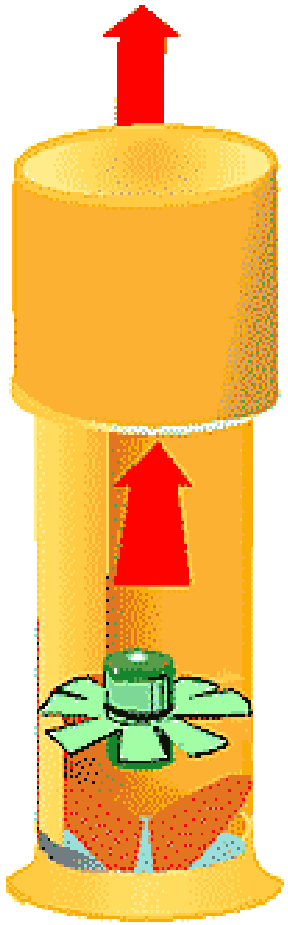
$$q = vA$$

$$v_1 A_1 = v_2 A_2$$

Examole

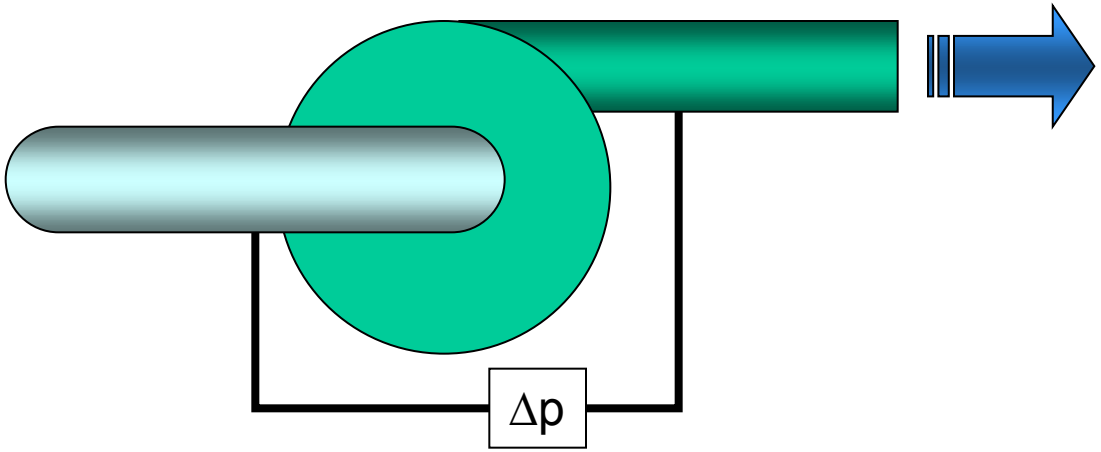
- Minimum ventilation rate for a pig is 13 m3/h and velocity 0,25 m/s. How large is the opening in personal ventilation?





Blower

- A blower moves (blows) air from one place to another
- The power in the flow depends on volume flow and pressure
- Pressures in ventilation are quite low, normally < 100 Pa
- Blower efficiencies are 40 – 60 %



v

$$P_f = \dot{V}\,\Delta p$$

$$P_a = \frac{P_f}{\eta}$$

Example

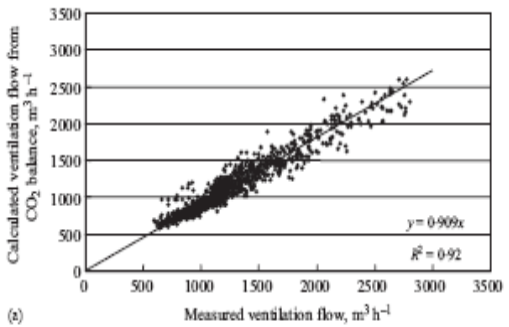
- How much electrical power does a blower in cow house need during maximum ventilation rate?

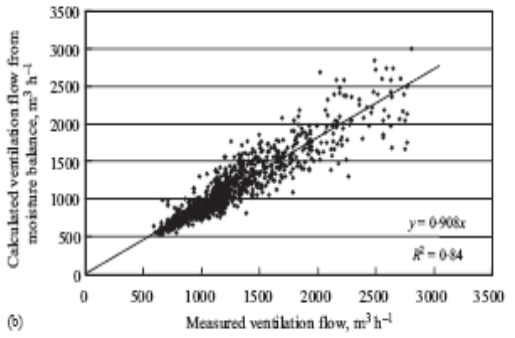
Example of blowers

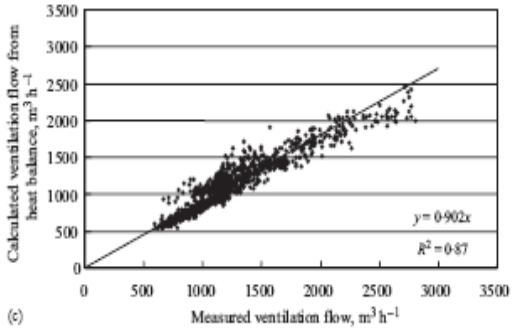
	teho	virta	ilmam. 0Pa	ilmam. 30Pa
Pellon 404H	0,26 kW	1,2 A	4730 m3/h	4400 m3/h
Pellon 520H	0,51 kW	2,3 A	8000 m3/h	7400 m3/h
Pellon 520S	0,28 kW	1,6 A	5300 m3/h	4800 m3/h
Pellon 640S	0,60 kW	2,7 A	12500 m3/h	11500 m3/h
Pellon 820H	1,5 kW	7,4 A	23000 m3/h	21500 m3/h

Flow measurement

- Forced ventilation
  - Whole flow goes through blowers
  - Flow can be measured from air ducts or an estimated flow can be taken from manufacturer specifications (if available)
    - Remember that long and dusted air ducts can make extra pressure drops, what is the proper pressure in specifications?
  - Flow measurement from blower free flow is uncertain, because during outblow flow divides up and the speed changes with measuring point and distance
- Natural ventilation
  - Ventilation can be measured with CO_2 balance method
  - CO_2 measurement as well as the number of animals in the building must be known



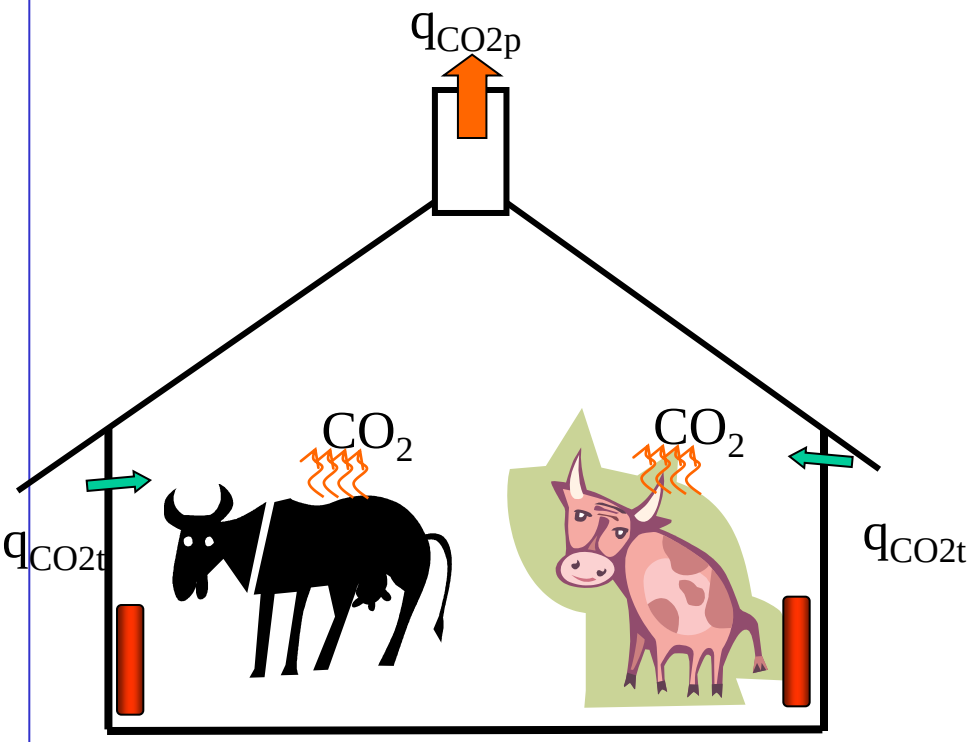




Carbon dioxide balance

- In CO_2 balance method the CO_2 flows in and out of the building are recorded
- The CO_2 content of the ventilation air increases because of animal breathing
- When number of animals, mean animal CO_2 production and CO_2 concentrations are known the volume flow can be calculated

$$\dot{V}_{CO_2} = \frac{q_{CO_2} \cdot N}{C_{CO_2 p} - C_{CO_2 t}}$$



CO_2 production

Animal	Heat production W	Moisture production g/h	CO_2 production l/h
Pig	180 – 220	90 – 120	35
Farrow	60 – 100	30 – 50	10 – 16
Milking cow	900 – 1100	400 – 485	150 – 180
Calf	120 – 180	60 – 90	20 – 30
Horse	650 – 860	250 – 290	110 – 140
Sheap	70 – 150	20 – 70	10 – 30
Hen	10 – 15	4 – 6	2 -6
Broiler	1 – 12	0,5 – 6	0,2 -2

Example

The size of the cow house is 12m x 30m x 3 m. There are 40 cows and 10 calves in the building, the outside CO_2 content is 300 ppm and the outlet content is 780 ppm. What is the ventilation rate?

What is the heat loss through ventilation if outdoor temperature is – 15 and indoor temperature is + 15 C ?

Lähdetietoa

http://www.mmm.fi/maatalous_maaseudun_kehittaminen/maaseudun_rakentaminen/rakentamisohjeet/

MMM:N ASETUS TUETTAVAA RAKENTAMISTA KOSKEVISTA RAKENTAMIS-MÄÄRÄYKSISTÄ JA SUOSITUKSISTA (100/01)
Liite 1: MMM-RMO C1, Maatalouden tuotanto- ja varastorakennukset yleiset suunnitteluperiaatteet
Liite 2: MMM-RMO C1.2.1, Kotieläinrakennukset, lypsykarjarakennukset
Liite 3: MMM-RMO C1.2.2, Kotieläinrakennukset, lihakarjarakennukset
Liite 4: MMM-RMO C1.2.3, Kotieläinrakennukset, sikatalousrakennukset
Liite 5: MMM-RMO C1.2.4, Kotieläinrakennukset, siipikarjarakennukset
Liite 6: MMM-RMO C1.2.5, Kotieläinrakennukset, lampolat ja vuohelat
Liite 7: MMM-RMO C1.2.6, Kotieläinrakennukset, hevostallit
Liite 8: MMM-RMO C1.2.7, Kotieläinrakennukset, turkistarhat
Liite 9: MMM-RMO C2.1, Maatilan lämpöhuolto, asuinrakennusten lämmitys ja ilmanvaihto
Liite 10: MMM-RMO C2.2, Maatalouden tuotantorakennusten lämpöhuolto ja huoneilmasto
Liite 11: MMM-RMO C3, Kotieläinrakennusten valaistus
Liite 12: MMM-RMO C4, Kotieläinrakennusten ympäristöhuolto
Liite 13: MMM-RMO C5, Maatalousrakennusten paloturvallisuus
Liite 14: MMM-RMO F3, Ennakkohyväksyntä, yleiset sovellutusohjeet
Navetan ilmanvaihto. Maidontuotannosta huipputeknologiaa – hanke. http://teknotiimi.maasyke.fi
CIGR Handbook of Agricultural Engineering Volume II: Animal Production & Aquacultural Engineering
Lypsylehmän ruokinta. Tietoa tuottamaan 82.
Tuotantoeläinten hyvinvointi. Tietoa tuottamaan 81.

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