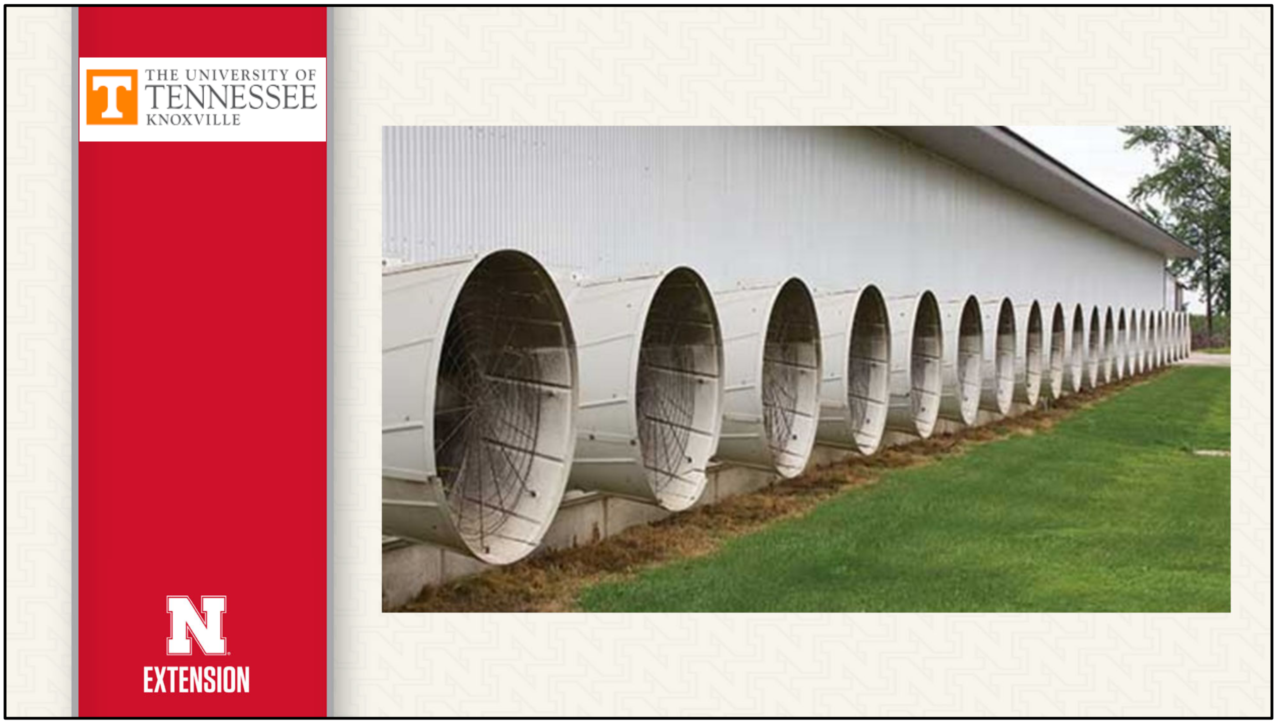
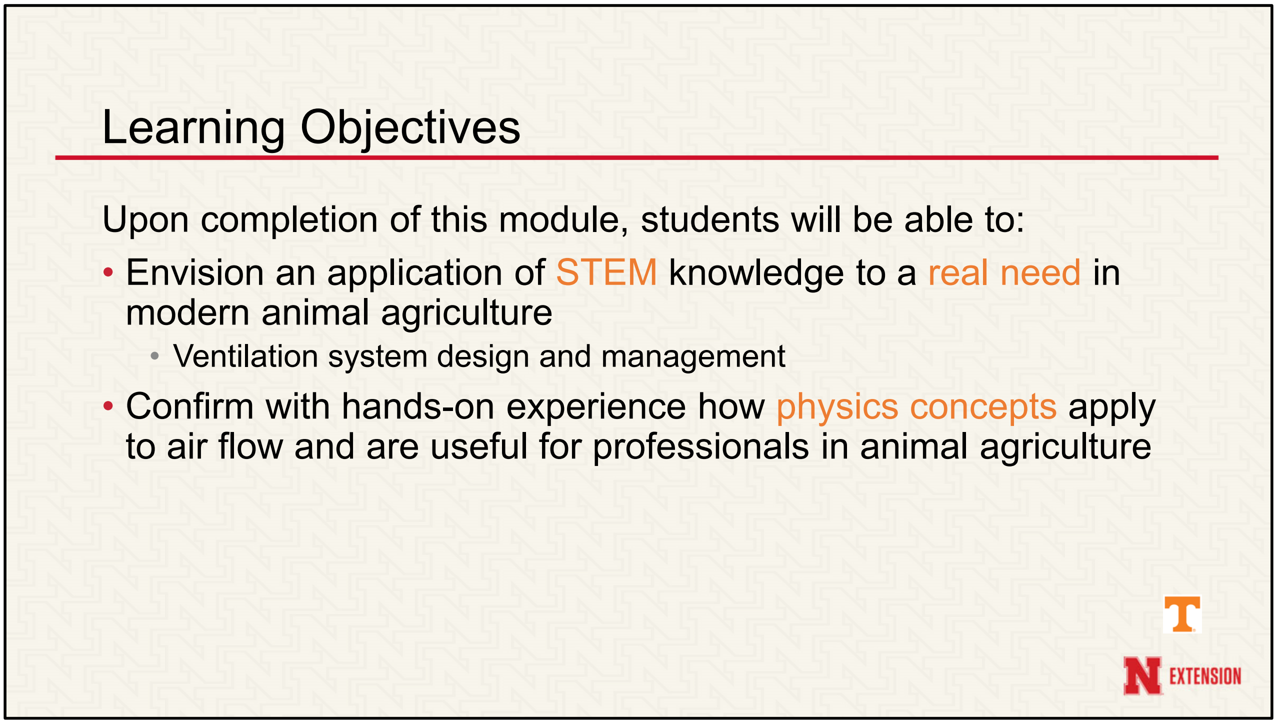


Mechanical ventilation of animal housing, a real-world applications of physics concepts.

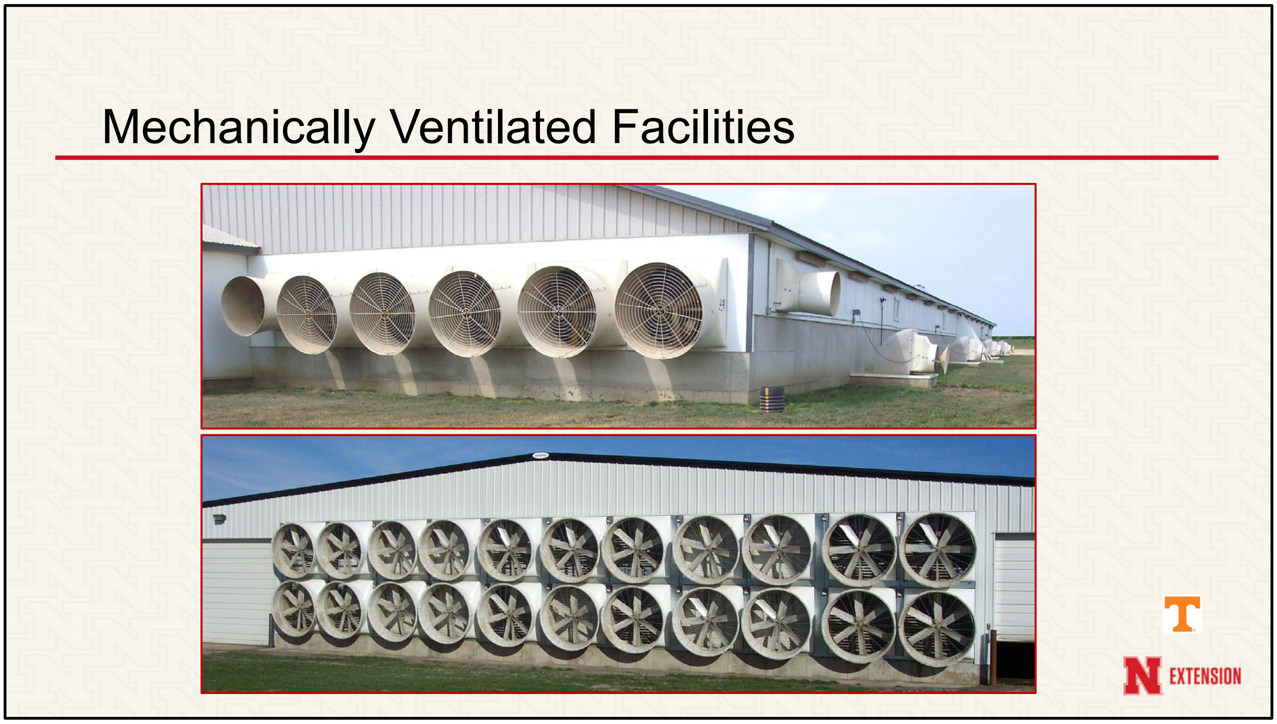
NEXT SLIDE



Upon completion of this module, students will be able to (CLICK) envision an application of STEM knowledge to a real need in modern animal agriculture, and that is the ventilation system design and management.

CLICK – Second, through hands-on experimentation, students will lean how physics concepts apply to air flow and how that is useful for professionals engaged in animal agriculture.

NEXT SLIDE



With mechanically ventilated facilities, which are commonly used with poultry, swine, and dairy production, fans are used to either push or pull air through buildings that house livestock.

NEXT SLIDE

Operating Principles

- Driving force
  - Fans → air movement
- Targeted airflow rates
  - Fan size and operating speed
  - Number of fans
- Airflow distribution
  - Inlet [or outlet] location & size
  - Room size and shape

Some basic operating principles related to this learning activity include …

CLICK – Driving Force. The driving force will be the fans, that function to facilitate air movement.

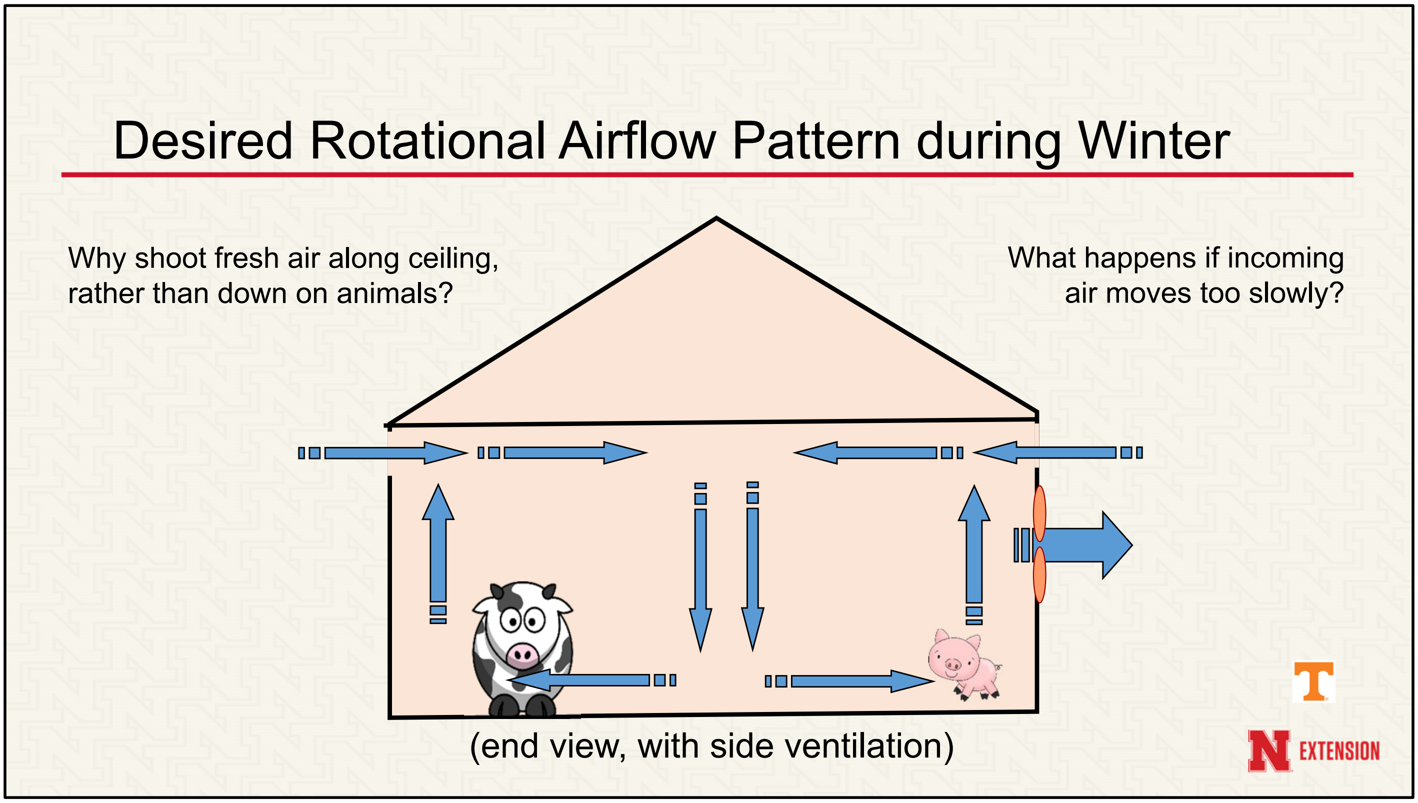
CLICK – Targeted airflow rates will be influenced by fan size and operating speed, as well as the number of fans.

CLICK – Airflow distribution will be dependent on the inlet or outlet location and size, in addition to the room or building size and shape.

NEXT SLIDE

The PHYSICS challenge related to environmentally controlled housing systems used in livestock production is to (CLICK) provide the proper amount of fresh air to animals with an appropriate speed and distribution pattern. Those who need to know and understand these basic concepts (CLICK) include livestock and poultry producers, veterinarians, equipment company representatives, builders, and engineers. Why is this important? (CLICK), it's integral to keeping animals healthy and productive.

NEXT SLIDE



This diagram illustrates a desired rotational airflow pattern during the winter. With this set-up, the fan is pulling air out through the side of the building. Meanwhile, fresh air is being drawn in through side openings just below the roof. Ideally, this fresh air reaches to approximately the mid-point of the building before coming down on the animals. Once it hits the floor, that air is forced to the side and back up the walls.

Couple of questions to contemplate, First (CLICK), why shoot the fresh air along the ceiling rather than down on the animals? (PAUSE) Because the outside air will be cold, and the cold draft will chill the animals. It needs a chance to mix with indoor air and to significantly slow down before reaching the animals.

Also (CLICK), what happens if incoming air moves too slowly? (PAUSE) Since the outside air is colder than the room air, will also be denser and will want to immediately drop down into the animal zone. Shooting the “air jet” above the animals leads to more uniform distribution of fresh air and less risk of chilling the animals.

NEXT SLIDE

Wording for Key Properties

Airflow rate (Q)

- Volume of air moved per unit of time
  - Cubic feet per minute (ft^3/min or cfm)

Air velocity (v) or speed

- Distance air moves per unit of time
  - Miles per hour (mi/hr or mph)
  - Feet per minute (ft/min)

T

N EXTENSION

For this activity, we need to understand some basic terms including Airflow rate, designated as Q. Airflow rate is the volume of air moved per unit of time, and it is measured as cubic feet per minute.

(CLICK), The air velocity or speed designated with a small “v” is the distance air moves per unit of time. This could be measured as miles per hour, or feet per minute.

NEXT SLIDE

Wording for Key Properties

Air pressure (P)

- Force of air per unit of surface area
  - Pounds per square inch (lb/in^2 or psi)
  - Equivalent water depth (in. H_2O)

Energy

- Work that is being or could be done
  - = P x Q, or Air pressure x Airflow rate

Air pressure, designated with a capital P, is the force of air per unit of surface area. It is often measured as pounds per square inch or psi. It can also be measured as inches of water. In the early 20th century, physicists developed a water manometer to measure pressure. Pressure, being defined as a force per unit of area. A column of liquid of known weight is placed in a U-shaped tube with the simplest design, and when pressure or weight is placed on one side, you measure the distance moved on the other side. So, since water was in the tube, it was designated as inches of water! Why inches of water, because the system is very effective for measuring low pressures. You see, one PSI equals 27.71 inches of water. The water measurement is more accurate at very low pressures.

And (CLICK), energy represents the work that is being or could be done, calculated as P x Q or Air pressure times Airflow rate.

NEXT SLIDE

Hands-on Experience

1) Provide materials to teams
2) Teams construct 'ventilated rooms'
3) Ventilation activities
    - Assess effects of fan speed
    - Assess effects of open area provided
    - Consider effect of fan direction
4) Student teams compare findings and share what they learned

See *Instructions* (separate document) for detailed information

EXTENSION

For this activity, the instructor will provide teams with various construction materials to build a ventilated room. These construction materials include a cardboard box, scissors, and packing tape.

Once constructed, teams will assess (CLICK) the effects of fan speed, the effects of open air provided, and the effect of fan direction on air flow and speed through the facility.

Once done (CLICK), student teams will compare findings and share what they have learned.

NEXT SLIDE

Uniform Air Pressure

- How does air speed & pressure compare when measured at different openings?
- For each scenario, air speed and pressure should be similar regardless of what opening is used for measurement.
  - The pressure of a confined gas is uniform across the airspace
  - Measurement of indoor air speed & pressure through inlets/outlets at a few locations should represent the whole airspace or room.

OK, hopefully, everyone has constructed their ventilated barns, collected some data, and answered the associated questions. Let's now review and discuss those questions.

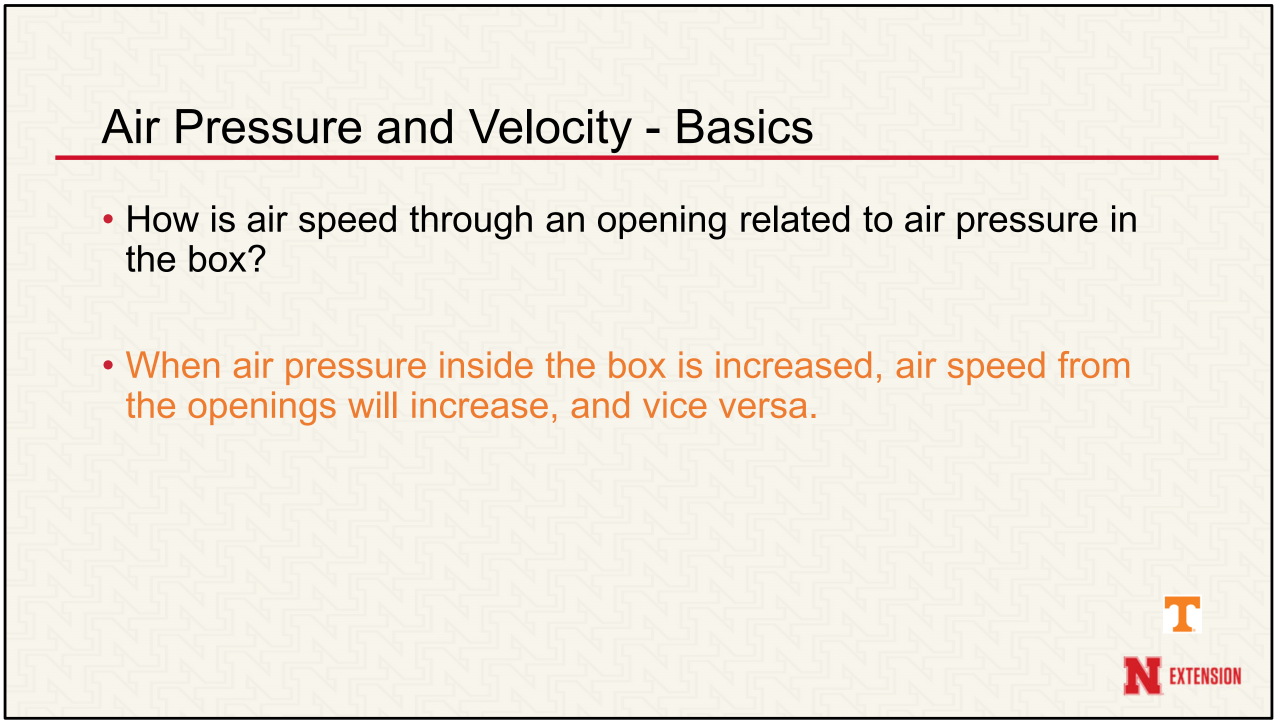
How does air speed and pressure compare when measured at different openings?

CLICK – For each scenario tested, air speed and pressure should have been similar regardless of what opening was used to collect measurements.

CLICK – This is because the pressure of a confined gas, like air in the box, is uniform across the airspace.

CLICK – Thus, measurement of indoor air speed & pressure through inlets or outlets of air at a few locations should represent the whole airspace within the room.

NEXT SLIDE



How is air speed through an opening related to air pressure in the box?

CLICK – When air pressure inside the box is increased, air speed from the openings will increase, and vice-versa.

NEXT SLIDE

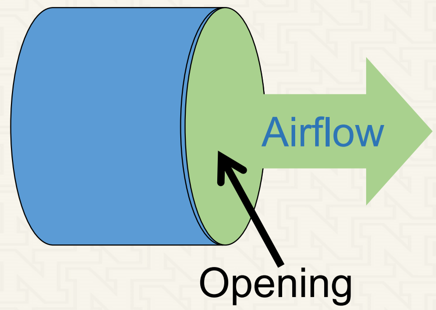
Airflow Rate, Q

Q = A x v, where

Q = Flow rate (cfm)

A = Open area (sq. ft.)

v = Average air velocity (ft/min)



<u>Applicable conversion factors:</u>

1 sq. ft. = 144 sq. in.

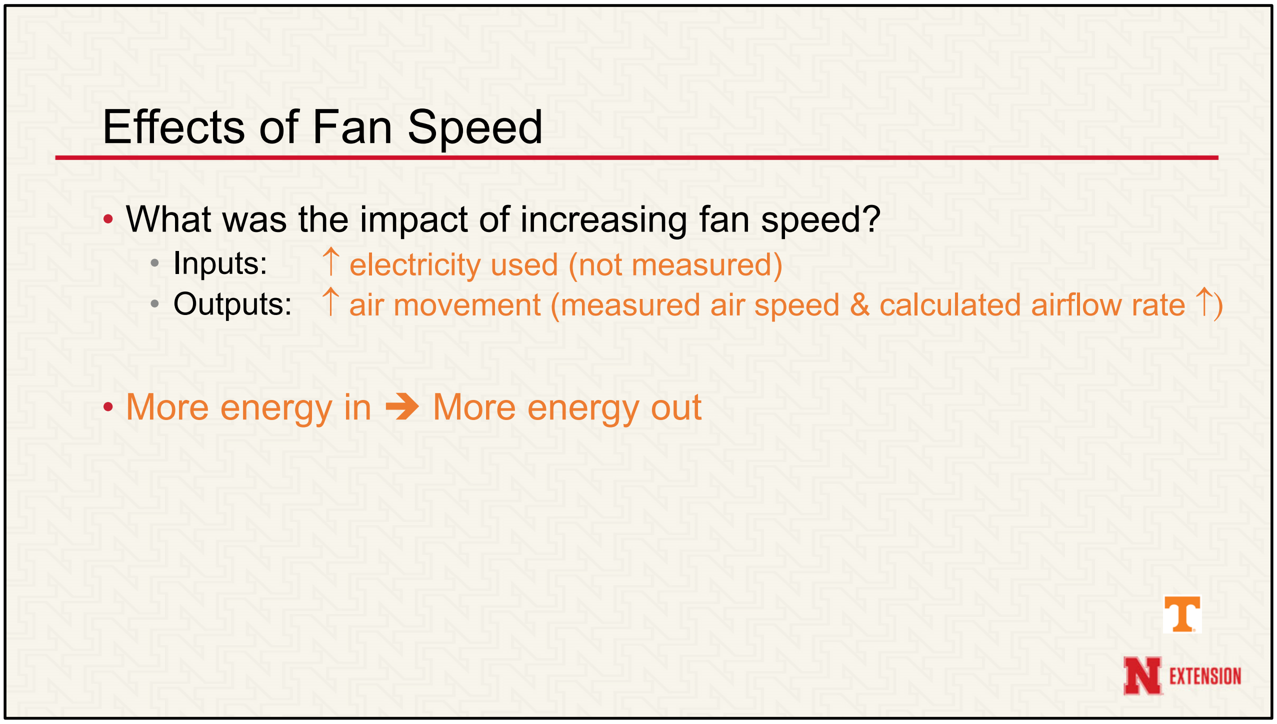
1 mph = 88 ft/min

Students will calculate airflow rates several times based upon measurements of opening sizes and air speeds from openings.

You will use the equation Q = A times V, where Q represents the flow rate measured in units of cubic feet per minute, A is the open area through which air can flow, measured in square feet, and v is the average air velocity, measured in feet/minute.

Application conversion factors: 1 square foot = 144 square inches, and 1 mph = 88 feet per second.

NEXT SLIDE



What was the impact of increasing fan speed on Inputs and Outputs?

CLICK – While not measured, increased fan speed would have required greater electricity usage.

CLICK – In response, there should be an increase in air movement measured as either air speed or as calculated airflow rate.

CLICK – Bottomline, if more energy is put in, more energy comes out.

NEXT SLIDE

Effect of Air Openings

- For a set fan speed, what was effect of changing air openings?
  - If air openings were reduced
    - Air speed and pressure ↑, but total airflow ↓
  - If air openings were increased
    - Air speed and pressure ↓, but total airflow ↑

WHY?

- As air openings are ↓, pressure & air velocity ↑.
  - However, velocity does not ↑ enough to offset ↓ air openings
- As air openings are ↑, pressure & air velocity ↓.
  - Despite ↓ velocity, total airflow ↑ through larger air openings.

EXTENSION

For a set fan speed, what was the effect of changing air openings?

CLICK – If air openings were reduced, air speed and pressure should have increased, but total airflow decreased.

CLICK – If air openings were increased, just the opposite should have occurred. Air speed and pressure should have decreased, but total airflow increased.

CLICK – Why, to some extent, this seems contradictory, but can you explain?

CLICK – As air openings are reduced, pressure and air velocity are increased, but velocity does not increase enough to offset the loss in air openings.

CLICK – And as air openings are increased, pressure and air velocity will decrease through each of those openings, but despite decreased velocity, total airflow should increase through larger air openings.

NEXT SLIDE

Restricted Openings

- As air openings were reduced,
  - Which was more noticeable, ↑ in pressure or ↓ in flow rate?
  - How did the "productive work" of the fan change? (↑, ↓, stay the same)
    - Remember, work done by fan (air pump is based up P x Q)
  - Was fan working more, less, or about the same (based on observations)?
    - Explain what happened to any lost energy
- Flow rate should ↓ as much or more than pressure & velocity ↑ so fan had to work harder to move a similar amount of air.
  - Faster air speeds lead to greater friction loss & more energy use.

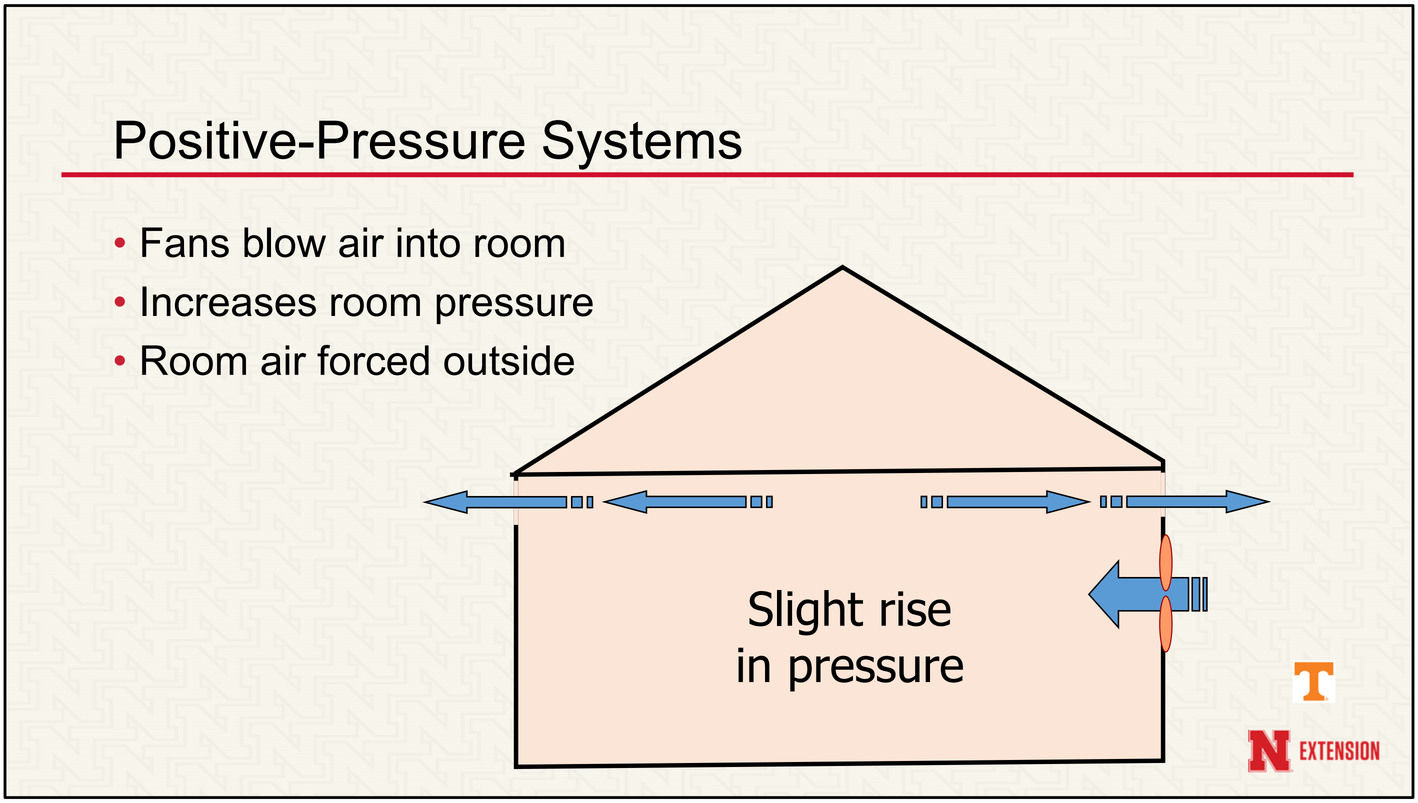
As air openings were reduced, which was more noticeable, increased pressure or decreased flow rate? How did the "productive work" of the fan change? Did it increase, decrease, or stay the same? Remember, work done by the fan or air pump is based upon P x Q or Pressure times Air flow rate. Finally, was the fan working more, less, or about the same (based on observations), and what happened to any lost energy?

CLICK – The flow rate should decrease as much or more than pressure and velocity increase, so the fan works harder to move a similar amount of air. Faster air speeds lead to greater friction loss and more energy usage. This is a big reason why it's important to havhas to e air ducts as well as water pipes, oil lines, etc. be large enough in size – so large volumes can flow at lower speeds.

From Dr. Stowell

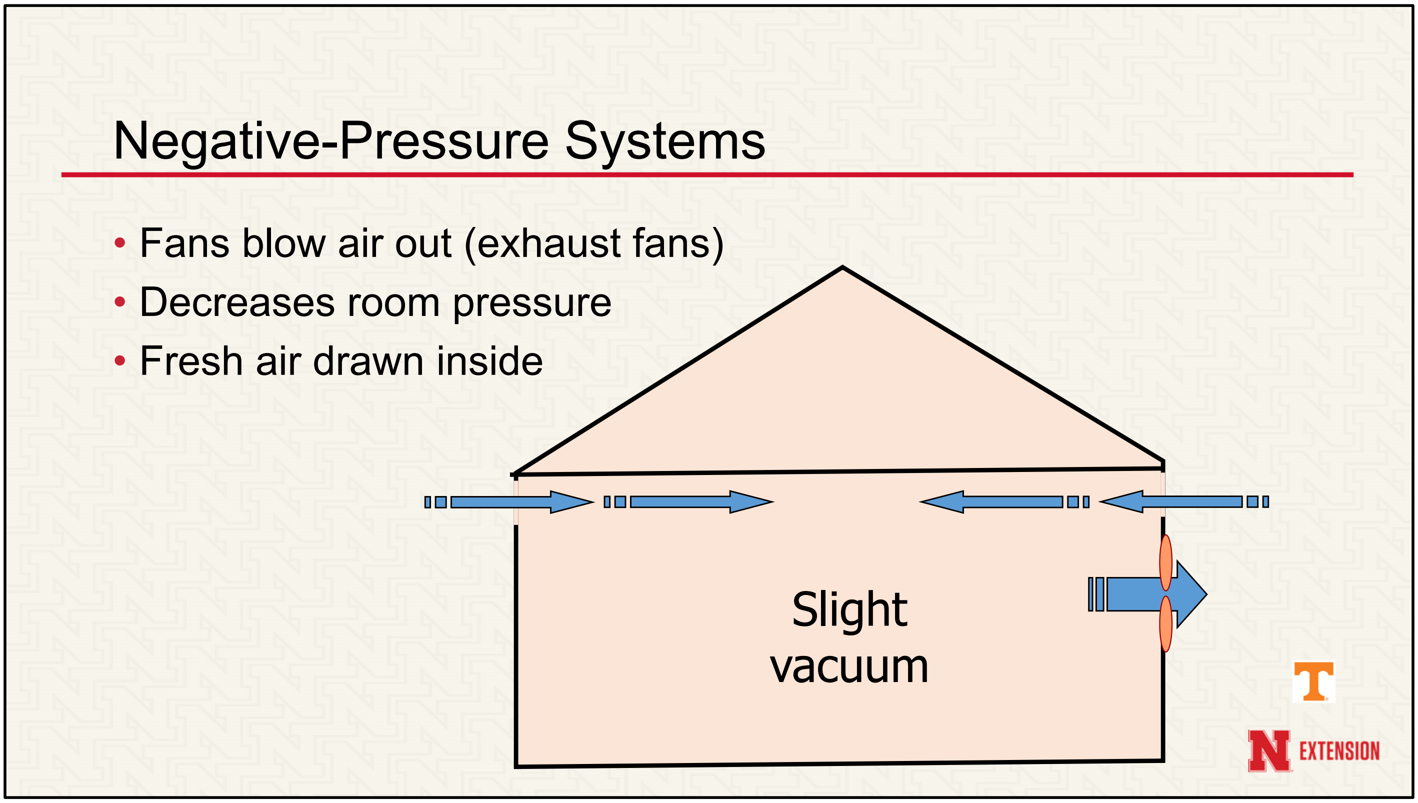
Additional discussion [optional/advanced]

Flow rate should go down as much or more than the Pressure [and Velocity] goes up, so productive work likely went down and/or the fan had to work harder to move a similar amount of air. In any case, energy is wasted or 'lost' to friction. Faster air speed leads to greater friction loss and more energy use. This is a big reason why it's important to have air ducts (water pipes, oil lines, etc.) be large enough in size – so large volumes can flow at lower speeds.



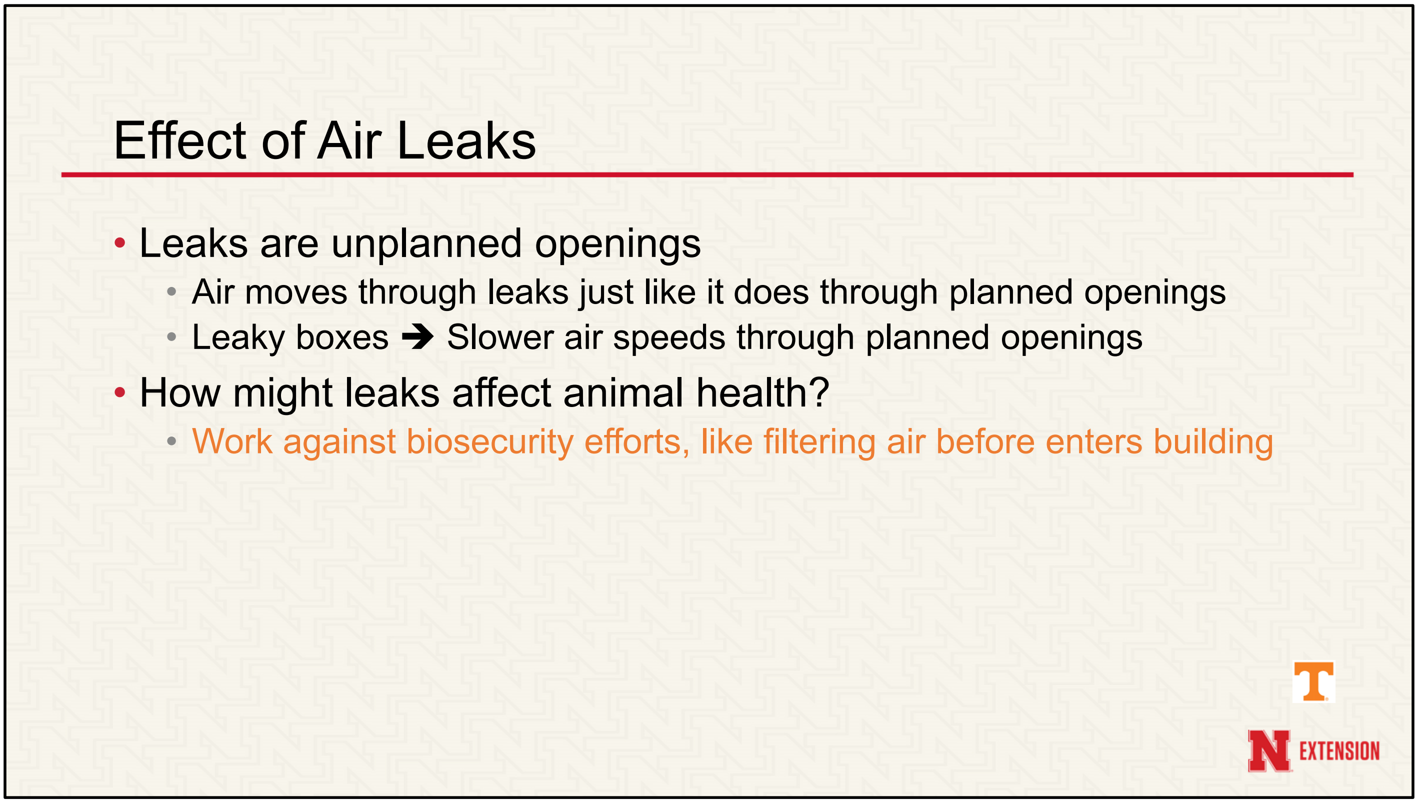
Initially, teams were to set their fans to blow air into the box (CLICK) – to make it easier to measure air speed as it moves through the holes. This mimics a 'positive-pressure ventilation system that that results in a slight rise in room pressure (CLICK) and forces room air outside (CLICK). This type of ventilation system is not very common in animal facilities.

NEXT SLIDE



At the end of the hands-on experience, teams were to set fans to draw air out of the boxes (CLICK). This mimics a 'negative-pressure' or exhaust ventilation system that creates a slight vacuum in the building decreasing air pressure (CLICK), and fresh air is drawn inside (CLICK). This is the most common type of mechanical ventilation system used in animal facilities.

NEXT SLIDE

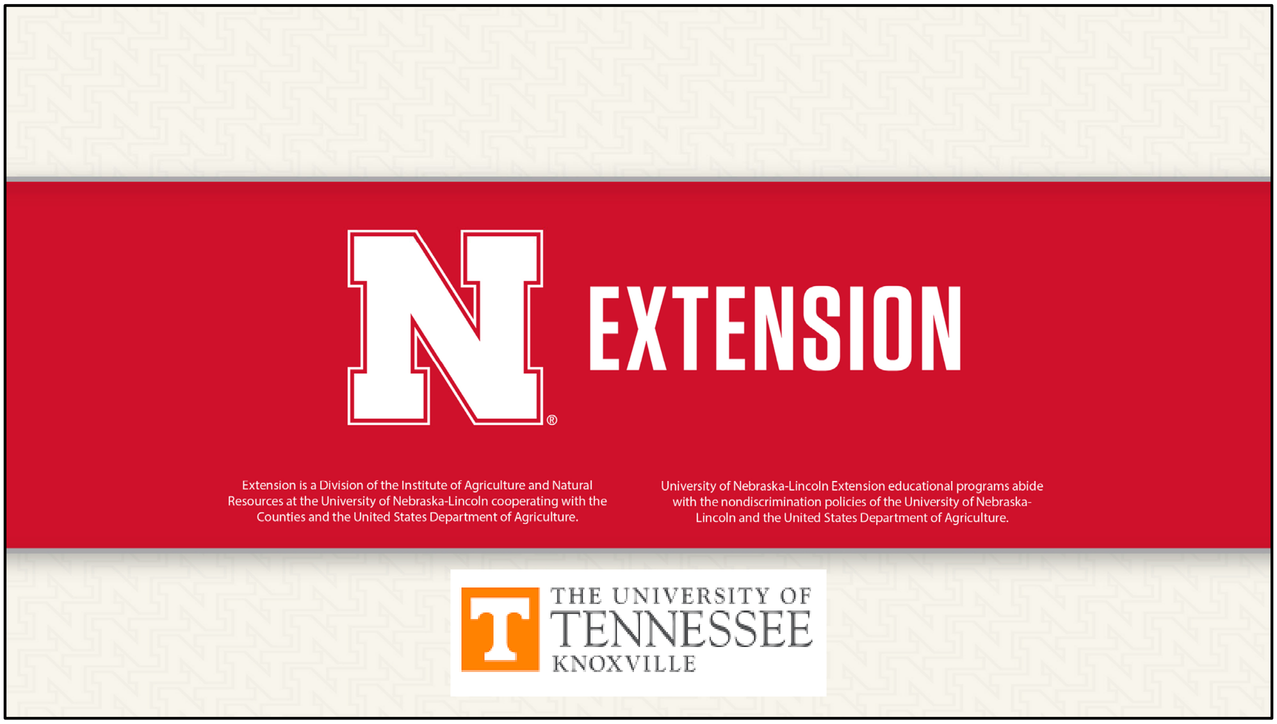


Hopefully, your team constructed the box, so air entered and exited where it was supposed to and not from gaps around the fan or unsealed cracks or holes. You see (CLICK), air moves through leaks just like it does through planned openings, and leaky boxes will have lower air speeds through planned openings. In real buildings, some leakage always exists, but it can be quite high in poorly constructed and/or poorly maintained facilities, leading to airflow in undesired places and/or patterns.

CLICK – How might leaks affect animal health?

CLICK – Leaks work against biosecurity efforts to keep viruses and other pathogenic organisms out. If an air filtering system is installed, it'll do little good if there are leaks that allow air to effectively bypass the filtering system.

NEXT SLIDE



Hopefully, this module and learning activity illustrated the importance of physics to practical applications and implications in animal food production systems.