Advanced Building Science

- Ventilation
  - Ventilation Overview
  - Key Concepts
  - Ten Ways to Ventilate
  - Good Design and Installation

- Readings
  - HF: Chapter 16.17 to 16.31
  - RVS Handout: Chapter 1 & 2 (focus on sections 1,2,4)

Ventilation Review

- Air flow requires pressure and hole
  - Outside pressures
    - airflow around buildings
    - temperatures (stack effect)
  - Interior pressures
    - chimneys
    - mechanical systems
- Mechanical ventilation
  - Attempts to augment and/or level out air exchange
  - Must manage or work within these pressures

Ventilation

- **Why Do We Build Tight Houses?**
  - By coincidence
    - Many of our modern building materials and construction methods are inherently air tight.
    - Very simple houses with minimal envelope complexities and few exhaust devices can be very tight.
  - By demand
    - Consumers have continued to push for comfortable, draft-free, and efficient homes and builders have responded to reduce callbacks.
  - By code
    - Our building, fire, and energy codes have continually added new provisions that have, both intentionally and unintentionally, increased overall house tightness.

Ventilation

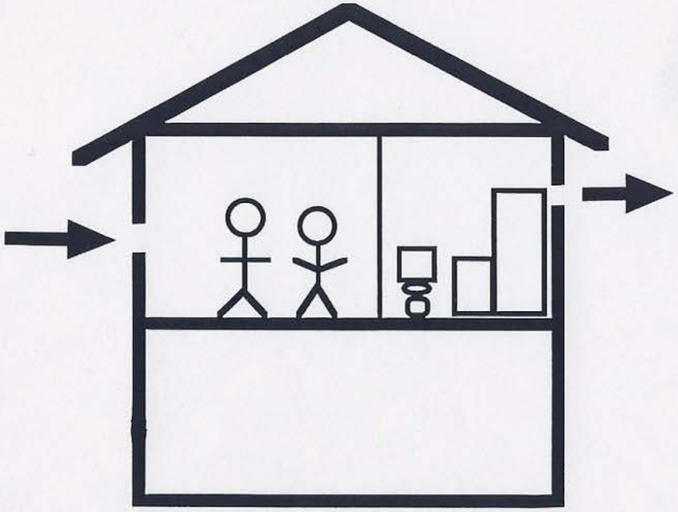
- **Can Leaky Houses Work?**
  - Sometimes, they do just fine!
  - **However**, they:
    - are **frequently** over-ventilated from an energy perspective,
    - are **occasionally** under-ventilated from an air quality perspective,
    - **can** have moderate to severe comfort concerns (ie. drafts),
    - **may** suffer from a lack of make-up air for **large** exhaust devices,
    - **sometimes** have pipe freezing problems, and
    - **might be** prone to structural moisture problems, unless
      - the indoor humidity is kept low or
      - the pressure is controlled (negative in winter; positive in summer).

Ventilation

- **Can Tight Houses Work?**
  - Yes and No!
  - They can provide:
    - a high level of thermal and acoustical comfort,
    - reduced moisture movement into structural cavities,
    - increased energy efficiency, and
    - more consistent and managed air flow.
  - **However**, they require careful attention to:
    - ventilation air,
    - make-up air,
    - combustion air, and
    - circulation air.

Ventilation

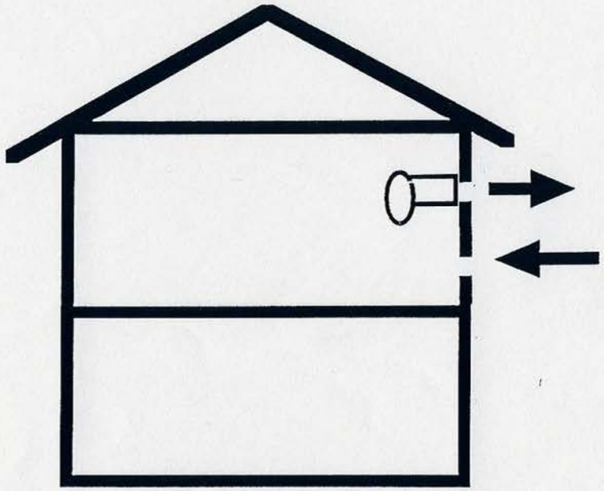
- **Ventilation Air**
  - Replacement, by direct or indirect means, of air in habitable rooms with fresh, outdoor air.



  - Ventilation air is intended to meet metabolic needs, manage indoor air pollutants, and control winter moisture.

Ventilation

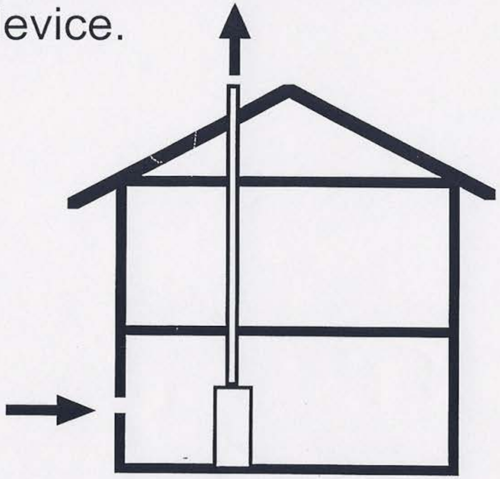
- **Make-Up Air**
  - Outdoor air needed to replace indoor air removed by mechanical exhaust device(s).



  - Makeup air is intended to limit the negative pressure in the home when exhaust devices are in operation.

Ventilation

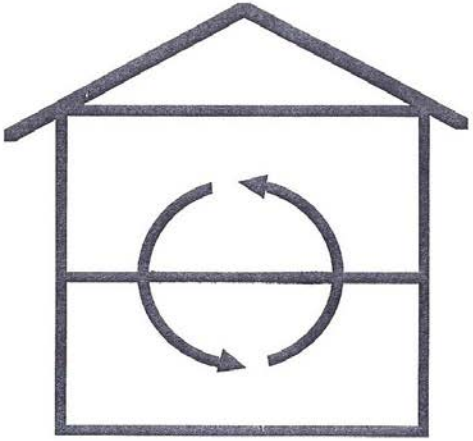
- **Combustion Air**
  - Air from the home (or directly from the outdoors) required to meet the combustion and dilution needs of a vented combustion device.



  - Combustion air is intended to ensure proper combustion and venting of combustion by-products.

Ventilation

- **Circulation Air**
  - Air taken from the home and recirculated back to the home using mechanical means.



  - Circulation air is intended to mix the indoor air for improved comfort and to provide more uniform indoor conditions.

Ventilation

- **Much Less Air Exchange Between Indoors and Outdoors Over The Past Several Decades**
  - Some changes have been intentional
    - consumer driven
      - caulking, weatherstripping, window kits
      - reduced window and fan usage
    - industry driven
      - draft stopping to reduce comfort callbacks
      - sealing bypasses to reduce attic moisture and ice dam callbacks
    - more stringent energy codes
  - But many have been unintentional
    - inherently tighter building systems and products
    - high efficiency heating equipment
    - building and fire codes

Ventilation

- **Types of Air Exchange**
  - Air infiltration and exfiltration
    - random leaks
    - driven by natural forces
  - Natural ventilation
    - intentional openings
    - driven by natural forces
  - Chimneys
    - flue or vent
    - thermal or mechanically driven
  - Exhaust devices
    - intentional openings
    - mechanically driven
  - Mechanical ventilation
    - intentional vents or grills
    - fan driven

- **Trends in Air Exchange**
  => significantly reduced by current construction materials & methods

  => reluctance to open windows (comfort, security, privacy, etc.)

  => drastic reductions due to fewer, smaller, or no chimneys

  => more and larger exhaust devices, but infrequent use

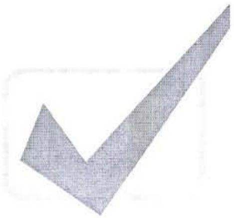
  => until recently, minor changes in ventilation equipment

Ventilation

- **A Proper Context For Ventilation**
  - Ventilation is much more than winter moisture control!
    - ventilation is needed for many other pollutants in the home
    - ventilation is needed in the summer, as well
      - perhaps even more than winter, because other air exchange mechanisms are greatly reduced in the summer
  - Conversely, moisture control is more than ventilation!
    - excessive moisture sources must be eliminated, reduced, or directly managed at the source

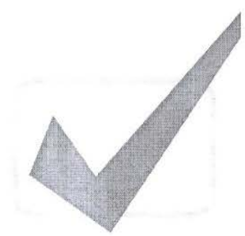
Ventilation

- **A Proper Context For Ventilation**
  - Indoor air quality is much bigger than ventilation!
    - must start by eliminating or removing potential pollutant sources
    - seal or encapsulate high pollutant sources that cannot be removed
    - then, provide source point pollutant removal, where possible
    - and lastly, provide general ventilation for distributed pollutants



Ventilation

- **A Proper Context For Ventilation**
  - The bottom line is simple -- once major moisture and pollutant sources are under control:
    - the ventilation requirements for fresh air, pollutant management, and moisture control are much closer together
    - relatively small amounts of ventilation can provide all three
    - this also minimizes the moisture load concern in the summer



Ventilation

- **Why Should We Ventilate Our Homes?**
  - To provide a healthy indoor environment - one that is dry, clean, and fresh

- **Two Sides Of Ventilation**
  - The introduction of fresh air into the home
    - metabolic requirements
  - The removal of polluted air from the home
    - volatile organic compounds
    - carbon monoxide
    - radon
    - excess moisture

Ventilation

- **Fresh Air For People**
  - Basic oxygen requirements
    - oxygen requirements are about 18 cu. ft. per person per day
    - that is equivalent to an outdoor air rate of 0.2 cfm per person
    - or less than 0.001 air change per hour in a 2000 sq. ft. home
  - Basic carbon dioxide emissions
    - carbon dioxide is product of respiration
    - is a good surrogate for body odors and acceptable thresholds for "stuffiness"
    - generally 15 cfm per person will keep carbon dioxide levels below 1000 ppm and odors at an acceptable level

Ventilation

- **Removal Of Common Indoor Pollutants**
  - Volatile organic compounds
    - primarily a source concern, but VOCs cannot be eliminated
    - may need high levels of ventilation for a short time,
    - continuous ventilation can control on-going low-level emissions
  - Carbon monoxide
    - absolutely a source concern; cannot rely on ventilation to control
    - must ensure proper combustion and venting
    - must restrict carbon monoxide from the garage
  - Radon
    - primarily a source concern
    - reducing radon entry from the soil is first line of defense
    - continuous ventilation can keep low levels in check

Ventilation

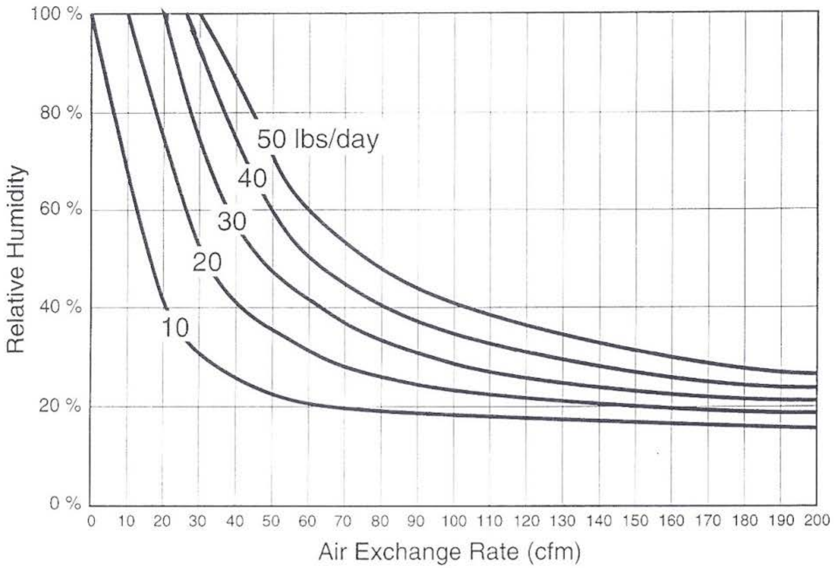
- **Removal Of Indoor Moisture**
  - Moisture is both a source control and ventilation issue.
    - always preferable to reduce moisture sources
    - spot ventilation is important for large moisture sources, like baths, kitchen, or basements in both winter and summer
    - continuous ventilation in winter provides good removal of occupant generated moisture

Ventilation

- **Removal Of Indoor Moisture**
  - Moisture is both a source control and ventilation issue.
    - always preferable to reduce moisture sources
    - spot ventilation is important for large moisture sources, like baths, kitchen, or basements in both winter and summer
    - continuous ventilation in winter provides good removal of occupant generated moisture

Ventilation

- **Removal Of Indoor Moisture (Winter Conditions)**
  - Indoor Relative Humidity vs. Ventilation Rate
    - for moisture generation rates from 10 to 50 pounds per day



Ventilation

- **Concern for Outdoor Moisture In Summer**
  - Summer ventilation strategies can bring in outdoor moisture
  - This summer moisture load can be managed by:
    - employing an energy recovery ventilator (with moisture transfer)
    - redesigning the air-conditioning system to handle the latent load
    - using a whole-house dehumidification system

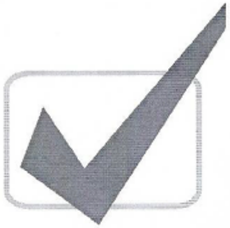
Note: A tight house with managed ventilation may actually bring in less outdoor humidity that a leaky house.

Ventilation

- **A Simplified Approach To Ventilation**
  - Air out
    - location of exhaust (stale, moist) air
    - amount of exhaust air (% mechanical)
  - Air in
    - location of supply (fresh) air
      - leaks (from outdoors?)
      - intentional openings (where?)
    - amount of supply air (% mechanical)
    - should it be conditioned?
      - temperature
      - humidity
      - filtration

Ventilation

- **A Simplified Approach To Ventilation**
  - Resultant house pressure
    - if exhaust and supply are not mechanically balanced
    - if exhaust cannot effectively communicate with supply
  - Internal flow pattern
    - from supply to exhaust
    - does fresh air flow through the occupied zones
  - System controls
    - exhaust and supply air
    - distribution (or circulation)



Ventilation

- **A Quality Ventilation System Should:**
  - Provide a continuous, baseline ventilation
  - Have additional capacity available, when needed
  - Remove exhaust air from areas with highest contaminants
  - Supply outdoor (fresh) air to all habitable rooms
  - Provide the outdoor (fresh) air as clean as possible
  - Not impose serious pressure imbalances on the home
  - Have acceptable thermal and acoustical comfort
  - Be easy to operate and maintain
  - Be cost effective to install and operate

Adapted from the R-2000 Design Guidelines by the Canadian Home Builders Association

Ventilation

- **Ten Ways To Ventilate**
  - Generic ventilation strategies based on:
    - ventilation type
    - exhaust approach
    - heat recovery
    - fresh air distribution

Ventilation

- **Basic Ventilation Types**
  - Exhaust-only: Exhaust air is fan-powered, but the supply air is not.
  - Balanced: Fan-powered exhaust air is matched by fan-powered intake air.
  - Supply-only: Fresh air is fan-powered, but the exhaust air is not.
    - this is not generally recommended for cold climates and is only permitted under the performance option for ventilation systems

Ventilation

- **Basic Exhaust Approaches**
  - Source-point: Ventilation exhaust is taken from key source points, usually bathrooms, kitchen, and laundry room.
    - considered the most effective approach and is highly recommended for both exhaust-only and balanced systems
  - General: Ventilation exhaust is taken from one or more central house locations, such as a hallway or stair landing.
    - marginally effective with careful placement of exhaust points
  - Volume: Ventilation exhaust is taken from the return of a forced-air system.
    - is not very efficient and requires continuous air handler operation

Ventilation

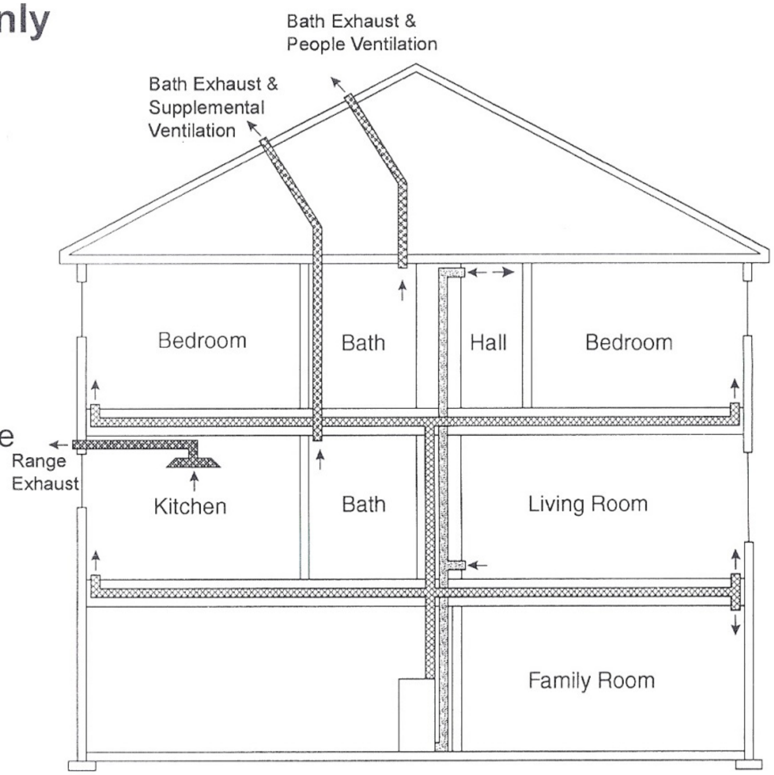
- **Heat Recovery**
  - Without heat recovery: Most exhaust-only systems and a few of the balanced systems do not have incorporate a heat recovery option.
  - With heat recovery: Many balanced systems employ a heat recovery core. There are a few exhaust-only systems that incorporate heat recovery, as well.

Ventilation

- **Methods For Fresh Air Distribution**
  - Forced-air: Most ventilation systems rely on the forced-air system to distribute fresh air to the habitable rooms.
  - Dedicated ducts: Homes without a forced-air system, will frequently employ a balanced, heat recovery ventilation system with fresh air ducted to all habitable rooms.
  - Room inlets: Some exhaust-only designs will use small through the wall ports to introduce outside air into each habitable room.

Ventilation

- **1. Decentralized Exhaust-Only**
  - source point approach
  - no heat recovery
  - with forced air

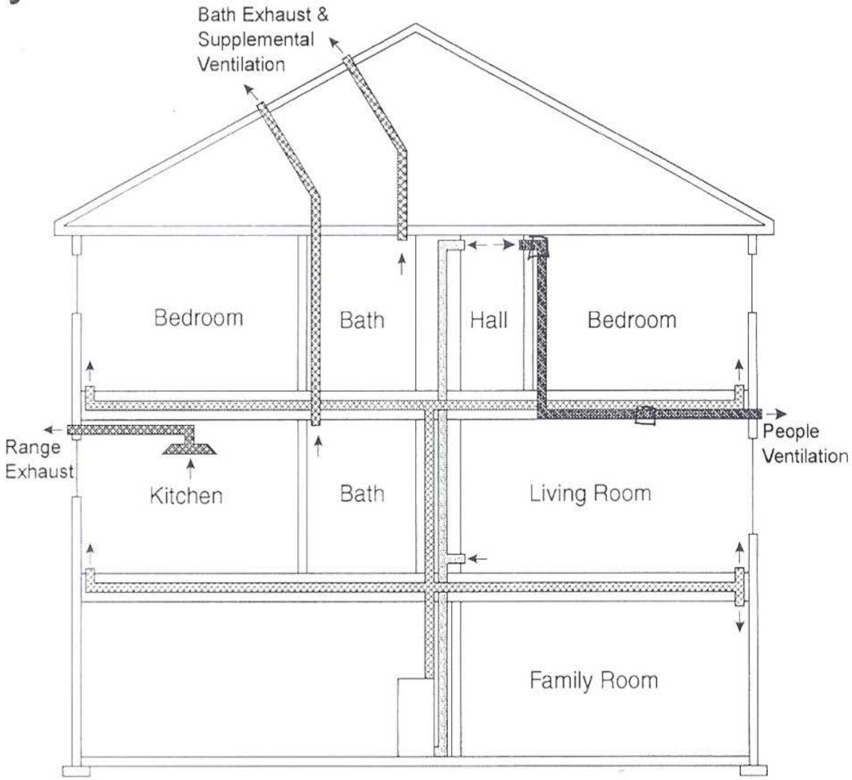


- This option will depressurize the home and may cause undesired infiltration.
- The force-air fan must run intermittently to provide adequate distribution of fresh air.
- All RVS fans must have flow measured and verified.
- Controls for people ventilation must be clearly marked in a central location.
- Continuous venting to the roof may cause ice dams.

Ventilation

- **2. Decentralized Exhaust-Only**
  - general approach
  - no heat recovery
  - with forced air

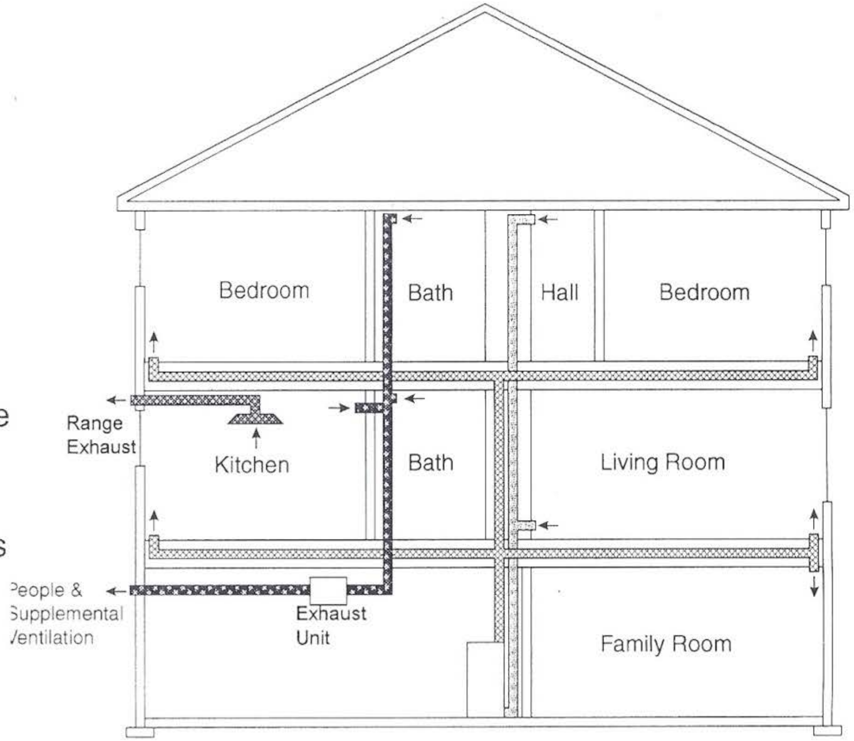
  – This option will depressurize the home and may cause undesired infiltration.
  – The force-air fan must run intermittently to provide adequate distribution of fresh air.
  – All RVS fans must have flow measured and verified.
  – Controls for people ventilation must be clearly marked in a central location.
  – Continuous venting to the roof may cause ice dams.



Ventilation

- **3. Centralized Exhaust-Only**
  - source point approach
  - no heat recovery
  - with forced-air

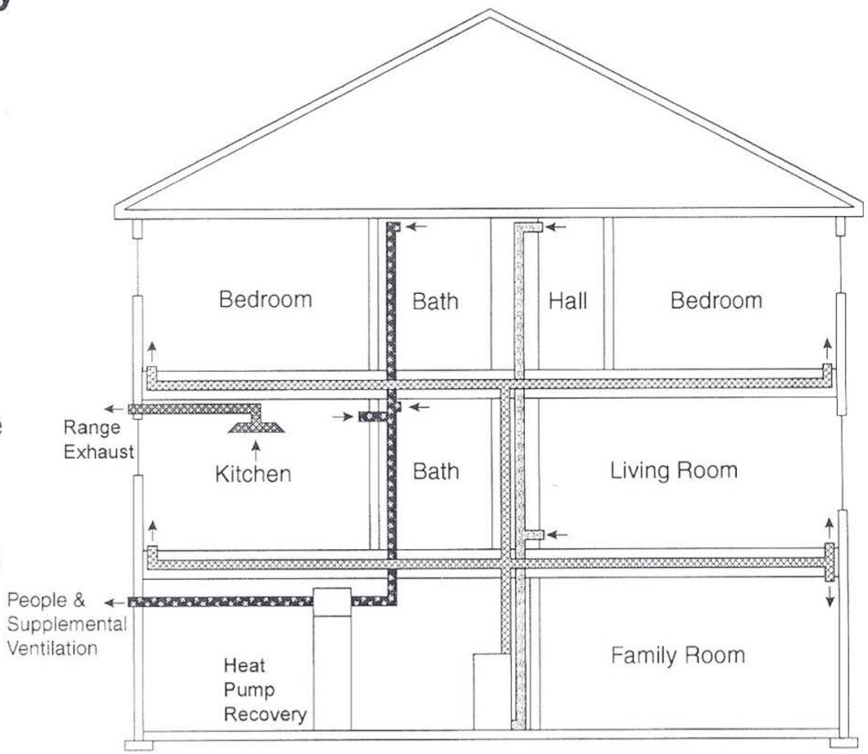
- This option will depressurize the home and may cause undesired infiltration.
- The force-air fan must run intermittently to provide adequate distribution of fresh air.
- This fan must meet both people and total ventilation requirements
- All RVS fans must have flow measured and verified.
- Controls for people ventilation must be clearly marked in a central location.



Ventilation

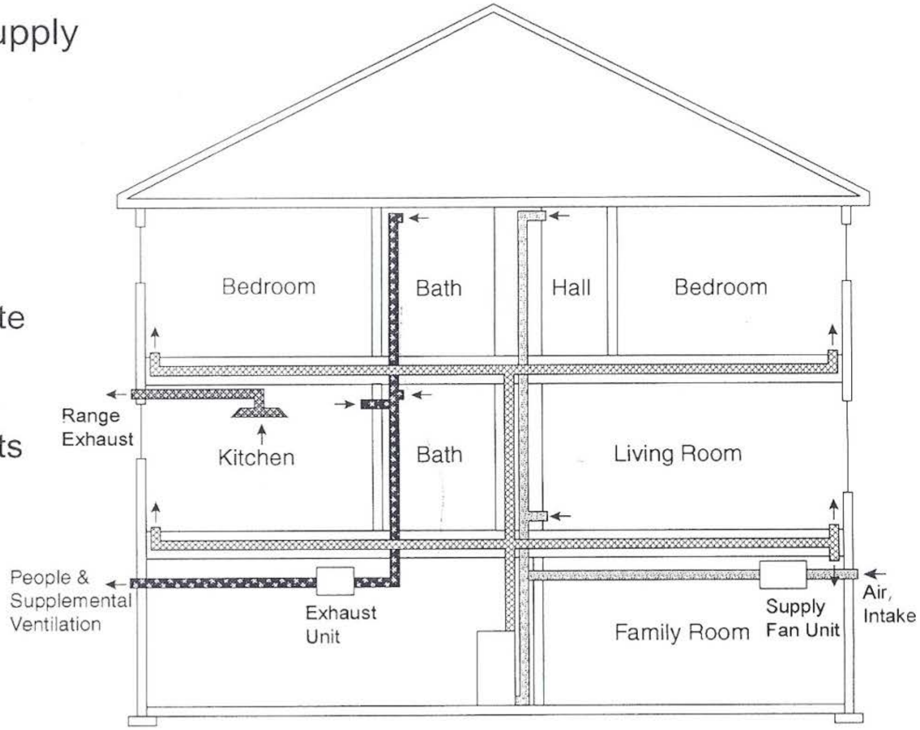
- **3a. Centralized Exhaust-Only**
  - source point approach
  - with heat recovery
  - with forced-air

– This option will depressurize the home and may cause undesired infiltration.
– The force-air fan must run intermittently to provide adequate distribution of fresh air.
– This fan must meet both people and total ventilation requirements
– All RVS fans must have flow measured and verified.
– Controls for people ventilation must be clearly marked in a central location.



Ventilation

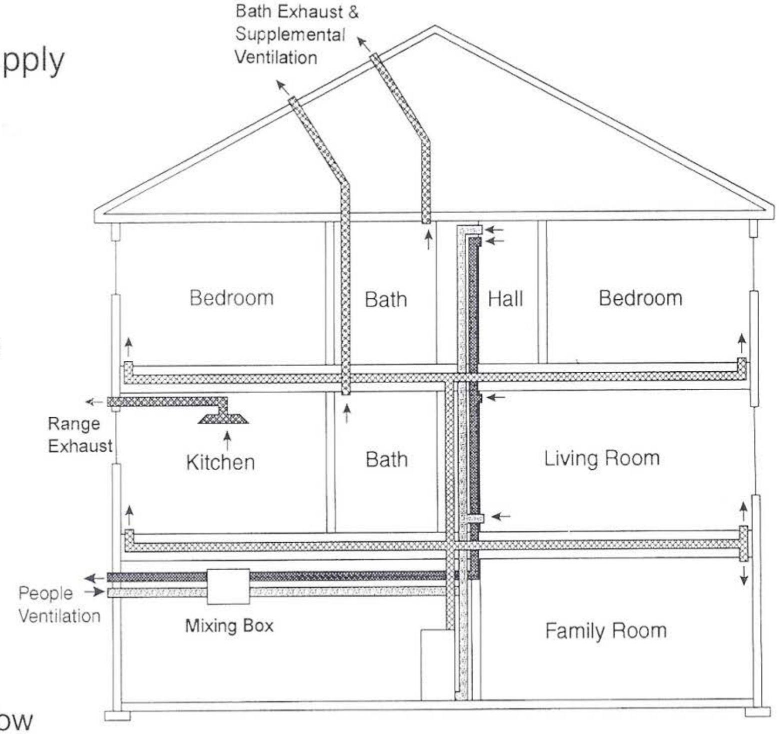
- **4. Balanced**
  - separate exhaust and supply
  - source point approach
  - without heat recovery
  - with forced-air



- The force-air fan must run intermittently to provide adequate distribution of fresh air.
- This fan must meet both people and total ventilation requirements
- All RVS fans must have flow measured and verified.
- Controls for people ventilation must be clearly marked in a central location.
- Supply air may need to be tempered by preheat or blending.

Ventilation

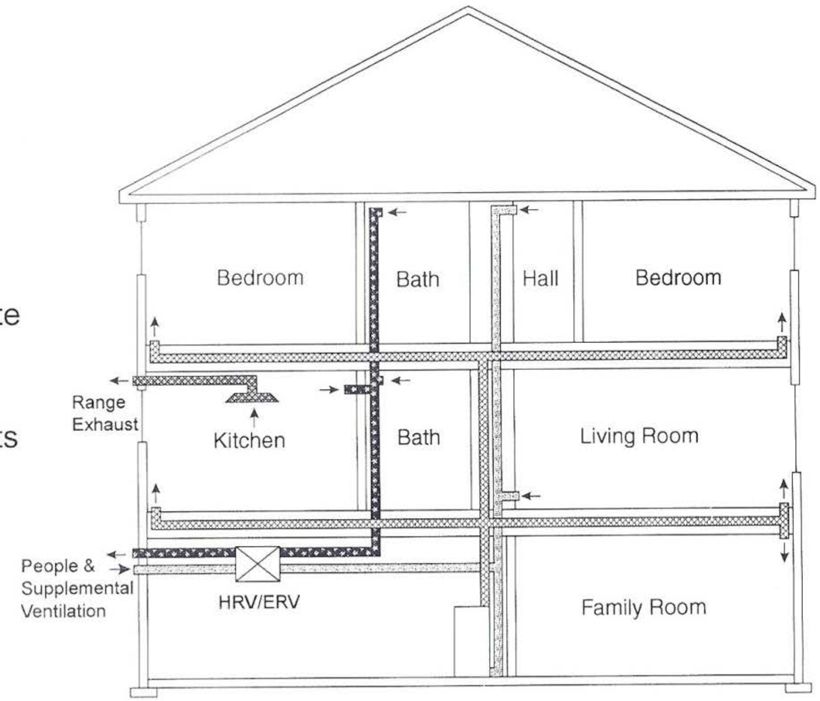
- **5. Balanced**
  - integrated exhaust and supply
  - volume approach
  - without heat recovery
  - with forced-air



- The force-air fan must run intermittently to provide adequate distribution of fresh air.
- This fan must meet the people ventilation requirements
- All RVS fans must have flow measured and verified.
- Controls for people ventilation must be clearly marked in a central location.
- Supply is usually tempered, but flow must be adjusted for mixing losses.

Ventilation

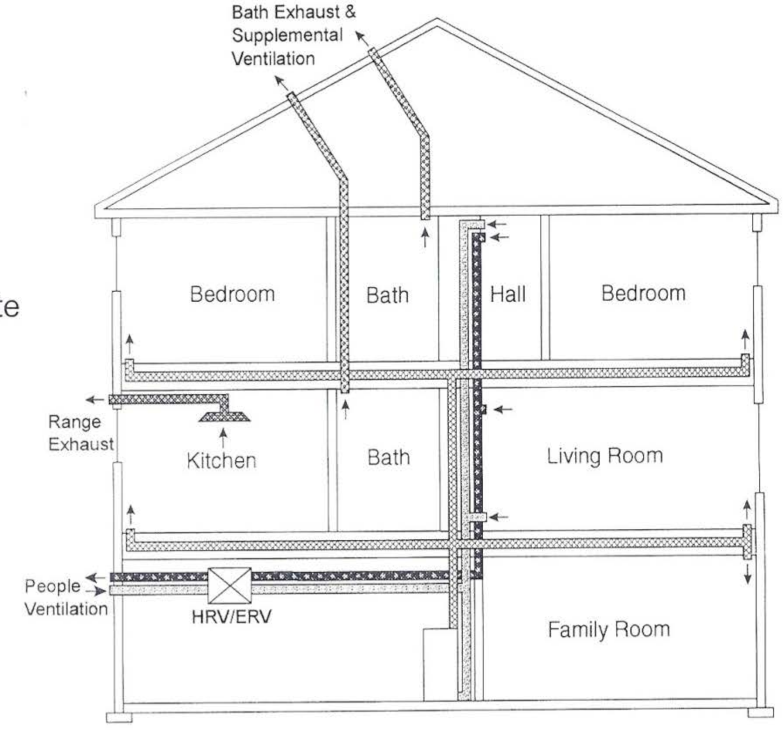
- **6. Balanced**
  - source point approach
  - with heat recovery
  - with forced-air



- The force-air fan must run intermittently to provide adequate distribution of fresh air.
- This fan must meet both people and total ventilation requirements
- All RVS fans must have flow measured and verified.
- Controls for people ventilation must be clearly marked in a central location.
- Airflow must be adjusted for defrost & low temp. reduction.

Ventilation

- 7. **Balanced**
  - general approach
  - with heat recovery
  - with forced-air



- The force-air fan must run intermittently to provide adequate distribution of fresh air.
- This fan might meet the people ventilation requirements only
- All RVS fans must have flow measured and verified.
- Controls for people ventilation must be clearly marked in a central location.
- Airflow must be adjusted for defrost & low temp. reduction.

Ventilation

- 8. **Balanced**
  - volume approach
  - with heat recovery
  - with forced-air

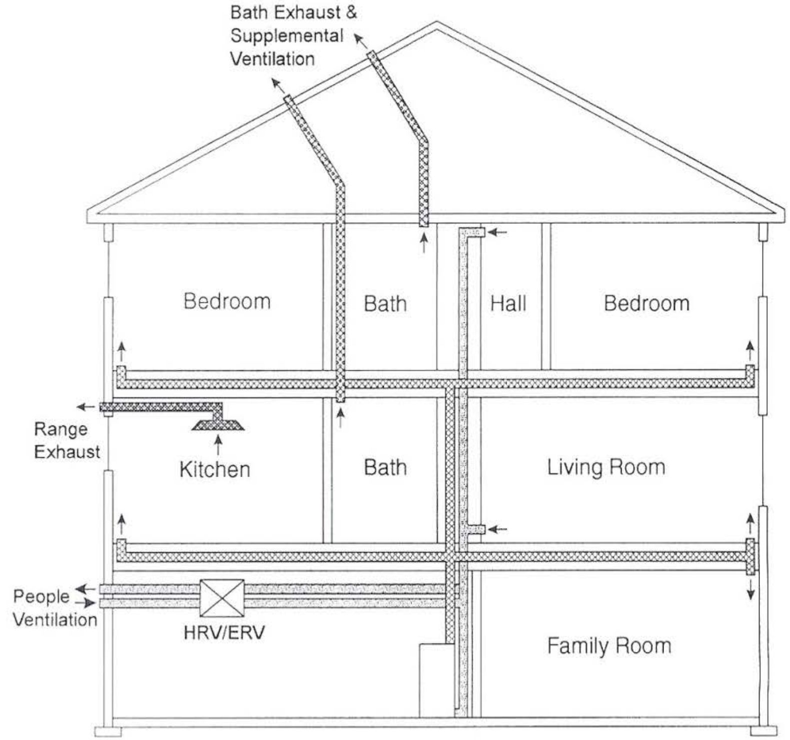
– The force-air fan must run continuously to meet ventilation requirements and provide adequate distribution of fresh air.

– This fan might meet the people ventilation requirements only

– All RVS fans must have flow measured and verified.

– Controls for people ventilation must be clearly marked in a central location.

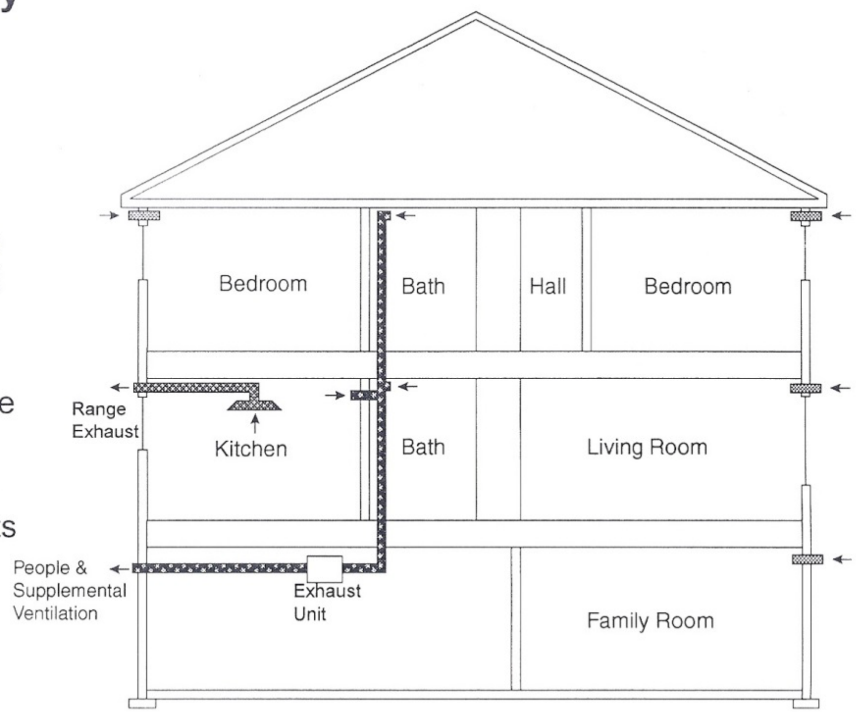
– Airflow must be adjusted for defrost & low temp. reduction.



Ventilation

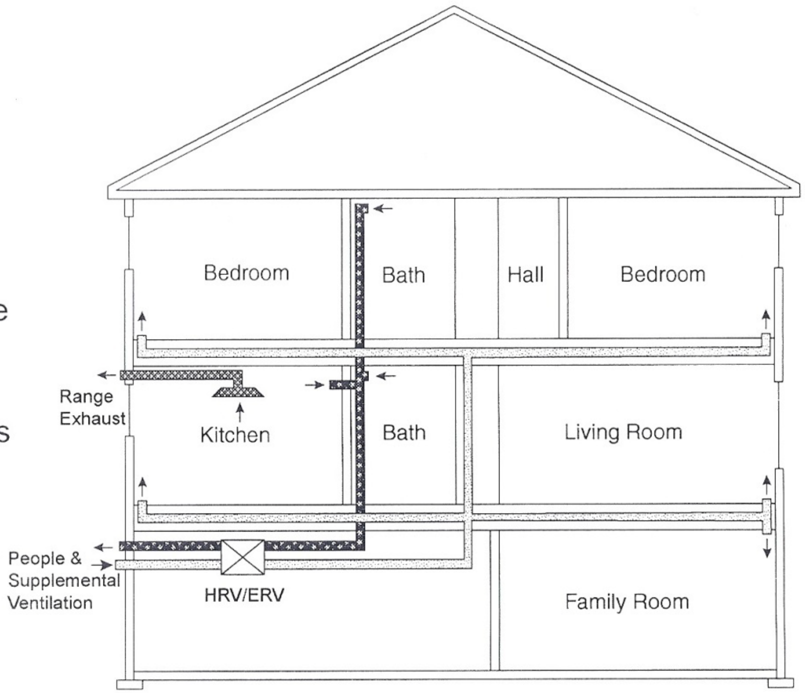
- **9. Centralized Exhaust-Only**
  - source point approach
  - no heat recovery
  - without forced-air

- This option will depressurize the home and may cause undesired infiltration.
- The ventilation fan must run continuously to provide adequate distribution of fresh air.
- This fan must meet both people and total ventilation requirements
- All RVS fans must have flow measured and verified.
- Controls for people ventilation must be clearly marked in a central location.



Ventilation

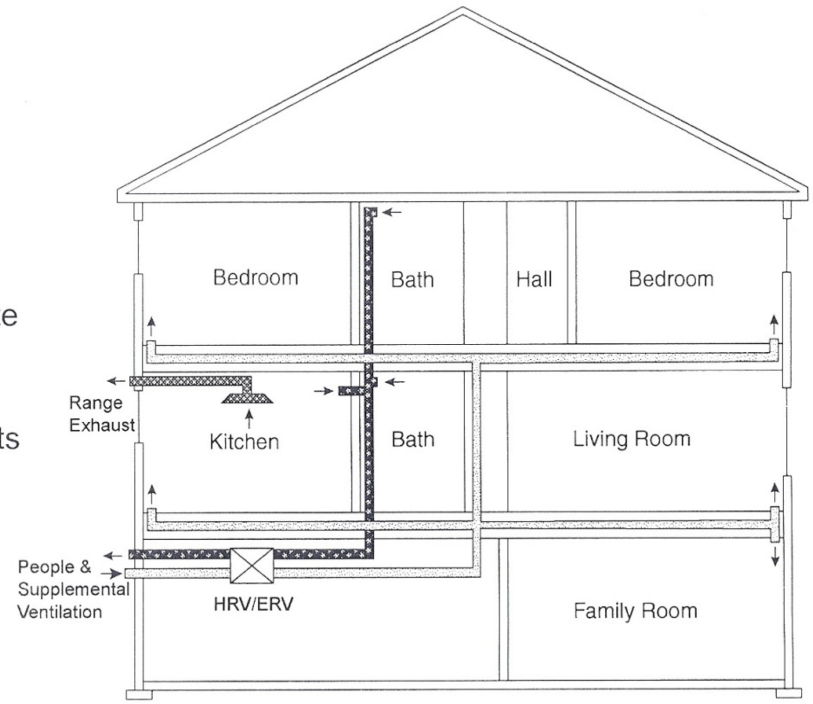
- **10. Balanced**
  - source point approach
  - with heat recovery
  - without forced-air



- The ventilation fan must run continuously to provide adequate distribution of fresh air
- This fan must meet both people and total ventilation requirements
- All RVS fans must have flow measured and verified.
- Controls for people ventilation must be clearly marked in a central location.
- Airflow must be adjusted for defrost & low temp. reduction.

Ventilation

- 10. **Balanced**
  - source point approach
  - with heat recovery
  - without forced-air



- The ventilation fan must run continuously to provide adequate distribution of fresh air
- This fan must meet both people and total ventilation requirements
- All RVS fans must have flow measured and verified.
- Controls for people ventilation must be clearly marked in a central location.
- Airflow must be adjusted for defrost & low temp. reduction.

Heat Recovery Units

- Performance ratings
  - transfer effectiveness (sensible, latent, or total)
  - recovery efficiency
- Basic types
  - fixed plate (many sensible-only with some both)
  - rotary (some sensible-only, but most with both)
  - coil loops (mostly commercial; generally sensible only)
  - heat pipe (sensible only)
- Economics
  - but don't forget tempering advantages
    - comfort, condensation, freeze control

Heat Recovery Units

Table 17-2 Comparison of Air-to-Air Energy Recovery Devices

	Fixed Plate	Rotary Wheel	Heat Pipe	Runaround Coil Loop	Thermosiphon	Twin Towers
Airflow arrangements	Counterflow Crossflow Parallel flow	Counterflow Parallel flow	Counterflow Parallel flow	Counterflow Parallel flow	Counterflow Parallel flow	
Equipment size range, cfm	50 and up	50 to 70,000	100 and up	100 and up	100 and up	
Type of heat transfer (typical effectiveness)	Sensible (50 to 80%)	Sensible (50 to 80%) Total (55 to 85%)	Sensible (45 to 65%)	Sensible (55 to 65%)	Sensible (40 to 60%)	Sensible (40 to 60%)
Face velocity, fpm (most common design velocity)	100 to 1000 (200 to 1000)	500 to 1000	400 to 800 (450 to 550)	300 to 600	400 to 800 (450 to 550)	300 to 450
Pressure drop, in. of water (most likely pressure)	0.02 to 1.8 (0.1 to 1.5)	(0.4 to 0.7)	(0.4 to 2.0)	(0.4 to 2.0)	(0.4 to 2.0)	0.7 to 1.2
Temperature range	–70 to 1500°F	–70 to 1500°F	–40 to 95°F	–50 to 900°F	–40 to 104°F	–40 to 115°F
Typical mode of purchase	Exchanger only Exchanger in case Exchanger and blowers Complete system	Exchanger only Exchanger in case Exchanger and blowers Complete system	Exchanger only Exchanger in case	Coil only Complete system	Exchanger only Exchanger in case	Complete system
Unique advantages	No moving parts Low pressure drop Easily cleaned	Latent transfer Compact large sizes Low pressure drop	No moving parts except tilt Fan location not critical Allowable pressure differential up to 60 in. of water	Exhaust airstream can be separated from supply air Fan location not critical	No moving parts Exhaust airstream can be separated from supply air Fan location not critical	Latent transfer from remote airstreams Multiple units in a single system Efficient microbiological cleaning of both supply and exhaust airstreams
Limitations	Latent available in hygroscopic units only	Cold climates may increase service Cross-air contamination possible	Effectiveness limited by pressure drop and cost Few suppliers	High effectiveness requires accurate simulation model	Effectiveness may be limited by pressure drop and cost Few suppliers	Few suppliers
Cross-leakage	0 to 5%	1 to 10%	0%	0%	0%	0.025%
Heat rate control (HRC) schemes	Bypass dampers and ducting	Wheel speed control over full range	Tilt angle down to 10% of maximum heat rate	Bypass valve or pump speed control over full range	Control valve over full range	Control valve or pump speed control over full range

Source: Howell, Sauer, & Coad, Principles of Heating, Ventilating, and Air Conditioning 1997, Chapter 17.18

In Summary

Questions and Discussion

Next Class

- Ventilation
  - Ventilation Overview
  - Key Concepts
  - Ten Ways to Ventilate
  - Good Design and Installation

- Readings
  - HF: Chapter 16.17 to 16.31
  - RVS Handout: Chapter 1 & 2