Balderston Associates

Green Building Verification | Consulting | Training

2021

AIR SEALING FIELD MANUAL

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Introduction

Houses Leak. Especially old houses. Houses heated in the winter act like chimneys and move warm air out the top while pulling cool air in the bottom. Houses with crawl spaces, partial basements, or attics leak the most.

These are some of the truths I have observed in 30 years of auditing, remodeling, and energy consulting...

Air Sealing can be fun. Its an investment in the quality and energy performance of your home that can save energy and improve health blah blah.....

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Introduction

In the following pages you will find a pictorial, practical guide to air sealing we hope will help you whether you are working on your own home or working on the profession of energy retrofitting. .....

the main content pages show right and wrong images for many air sealing details

G-1

GENERAL | HOME INSPECTION

Inspect for CO

Cabon Monixide is odorless, colorless, and can be deadly. Check ambient house air, first register, and mechanical room with furnace/water heater running.

All Homes with gas appliances should have CO monitors

01

Turn on CO monitor outside, then enter house and check for CO. If at any time you find more that 3 ppm ambient CO, call your utility (PSE hotline at 1-888-225-5773).

02

Turn on furnace and water heater. Check the house, furnace room, and the first register for CO.

03

Check for smell of gas... if you smell gas or detect a gas leak of any size, call your utility! (PSE hotline at 1-888-225-5773). Wait for them to arrive.

G-2

GENERAL | HOME INSPECTION

Check for Moisture Problems

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CHECK

- [ ] the attic, crawl space & ground cover, closets, and bathrooms for signs of moisture problems.
- [ ] the operation of bath exhaust fans.
- [ ] for asbestos, lead pest infestation, and other hazards.

IDENTIFY

- [ ] the source of the problem.
- [ ] Is it current or has it been remedied?
- [ ] Homes with significant moisture problems are not eligible.

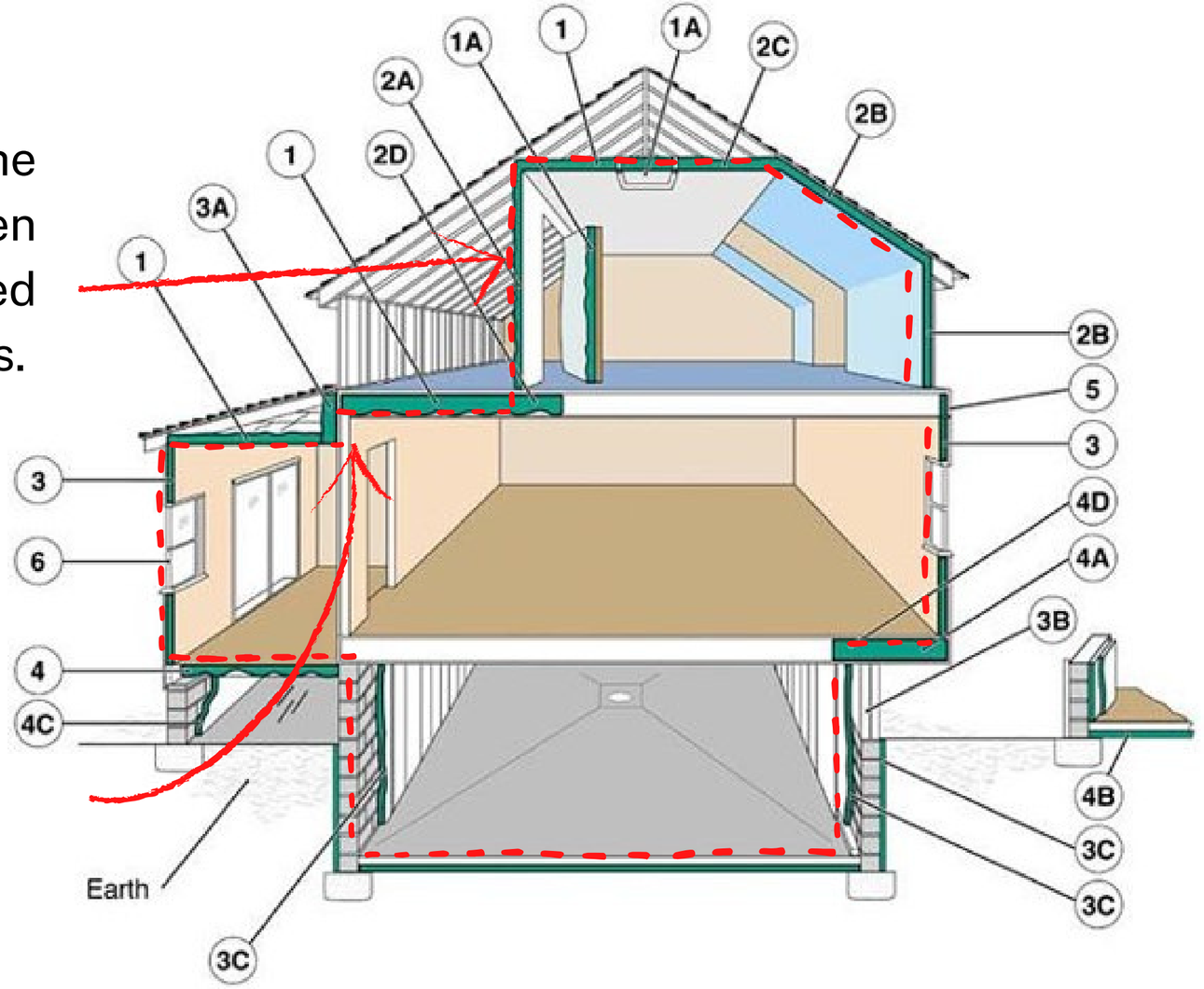
MEASURE RELATIVE HUMIDITY




G-3 GENERAL | HOME INSPECTION

Trace the Thermal Envelope

Learn to see all the boundaries between heated and unheated areas.



Confirm insulation levels in attic (flats, knee walls, & slopes), walls, floors, and basements.

Don't miss small features that may need insulation

AS-1 BLOWER DOOR TEST -IN

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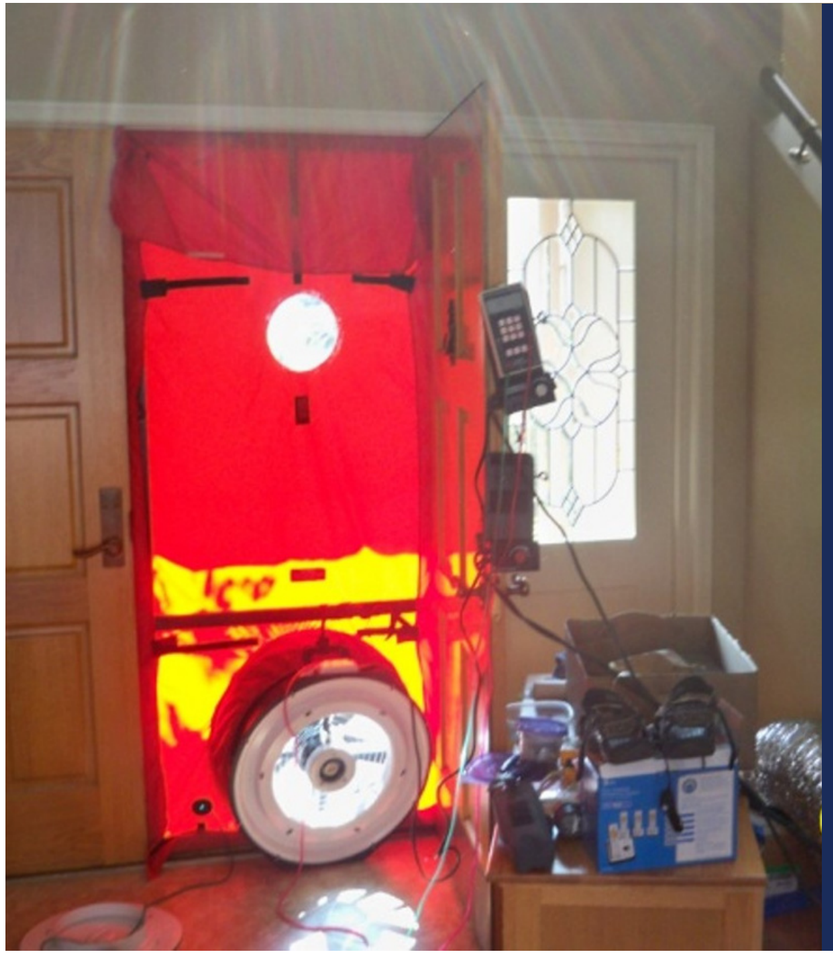
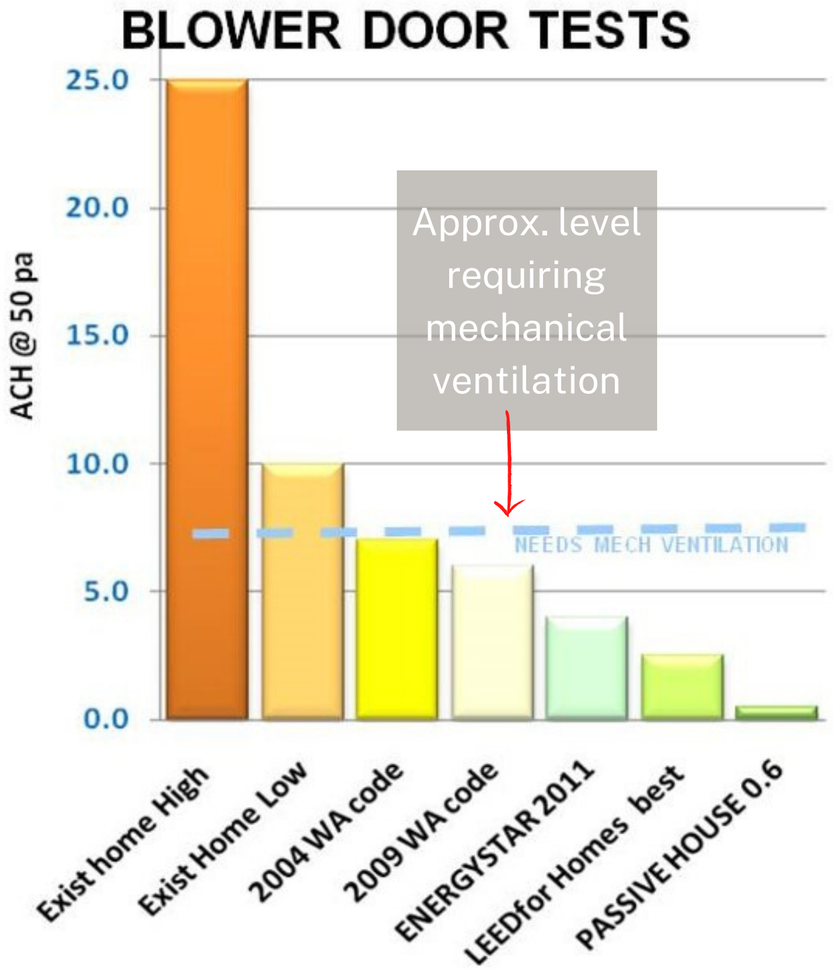
Test – In at Start of Job

For air sealing work, Set up and keep blower door in for the day.
Check your work from several times. Use diagnostics to find leaks



Test done by BPI or HERS certified technician



AS-1.1 BLOWER DOOR - TEST REPORT

WA Energy Code Form

can be fixed to elect. panel

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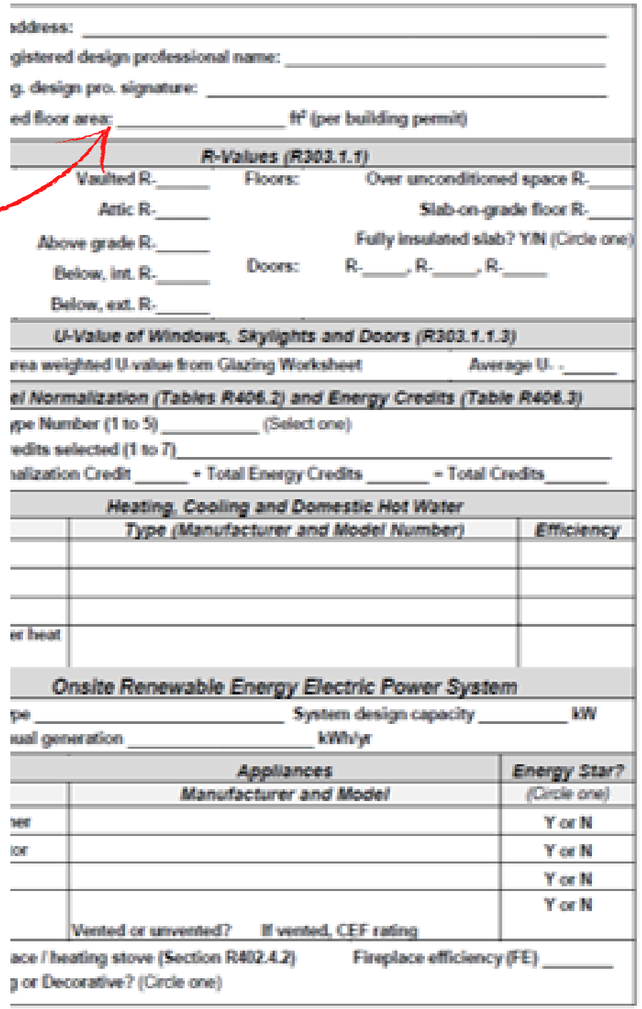
- Enter Floor Area on
- Enter Bedrooms, Occupant's Info
- Estimate Goals



address: _____

gistered design professional name: _____

g. design pro. signature: _____

ed floor area: _____ ft² (per building permit)

R-Values (R303.1.1)

Vaulted R-_____ Floors: Over unconditioned space R-_____

Attic R-_____ Slab-on-grade floor R-_____

Above grade R-_____ Fully insulated slab? Y/N (Circle one)

Below, int. R-_____ Doors: R-____, R-____, R-____

Below, ext. R-_____

U-Value of Windows, Skylights and Doors (R303.1.1.3)

rea weighted U-value from Glazing Worksheet Average U- _____

el Normalization (Tables R406.2) and Energy Credits (Table R406.3)

ype Number (1 to 5) _____ (Select one)

edits selected (1 to 7)_____

ualization Credit _____ + Total Energy Credits _____ = Total Credits _____

Heating, Cooling and Domestic Hot Water

	Type (Manufacturer and Model Number)	Efficiency
er heat		

Onsite Renewable Energy Electric Power System

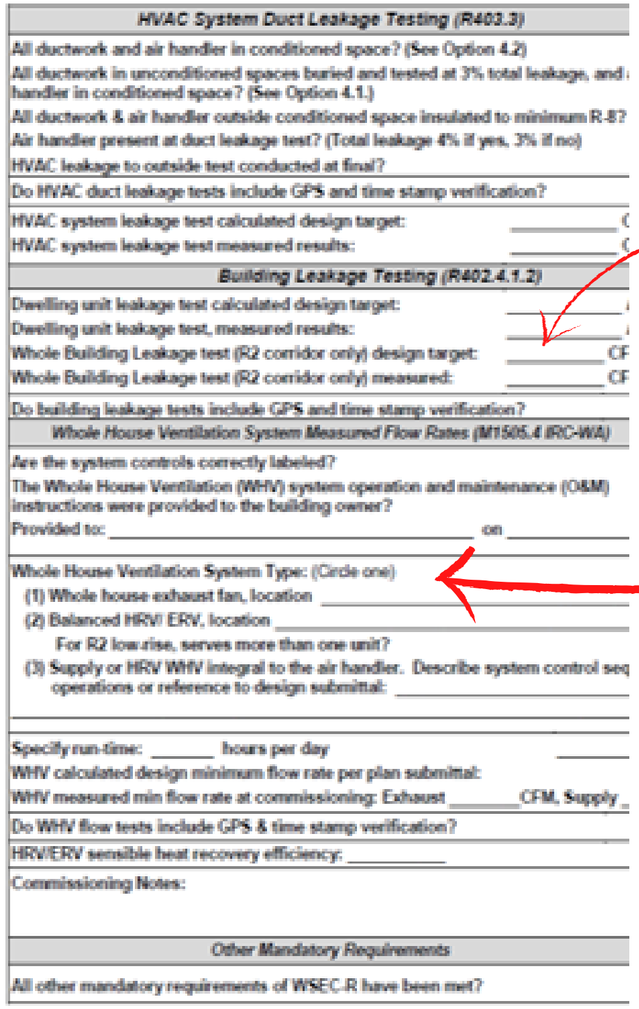
pe _____ System design capacity _____ kW

ual generation _____ kWh/yr

Appliances	Energy Star?
Manufacturer and Model	(Circle one)
ner	Y or N
or	Y or N
	Y or N
Vented or unvented? If vented, CEF rating	Y or N

ace / heating stove (Section R402.4.2) Fireplace efficiency (FE) _____

g or Decorative? (Circle one)



HVAC System Duct Leakage Testing (R403.3)

All ductwork and air handler in conditioned space? (See Option 4.2)

All ductwork in unconditioned spaces buried and tested at 3% total leakage, and handler in conditioned space? (See Option 4.1.)

All ductwork & air handler outside conditioned space insulated to minimum R-8?

Air handler present at duct leakage test? (Total leakage 4% if yes, 3% if no)

HVAC leakage to outside test conducted at final?

Do HVAC duct leakage tests include GPS and time stamp verification?

HVAC system leakage test calculated design target: _____ (

HVAC system leakage test measured results: _____ (

Building Leakage Testing (R402.4.1.2)

Dwelling unit leakage test calculated design target: _____

Dwelling unit leakage test, measured results: _____

Whole Building Leakage test (R2 corridor only) design target: _____ CF

Whole Building Leakage test (R2 corridor only) measured: _____ CF

Do building leakage tests include GPS and time stamp verification?

Whole House Ventilation System Measured Flow Rates (M1505.4 IRC-WA)

Are the system controls correctly labeled?

The Whole House Ventilation (WHV) system operation and maintenance (O&M) instructions were provided to the building owner?

Provided to: _____ on _____

Whole House Ventilation System Type: (Circle one)

(1) Whole house exhaust fan, location _____

(2) Balanced HRV/ ERV, location _____

For R2 low rise, serves more than one unit?

(3) Supply or HRV WHV integral to the air handler. Describe system control seq operations or reference to design submittal: _____

Specify run-time: _____ hours per day _____

WHV calculated design minimum flow rate per plan submittal:

WHV measured min flow rate at commissioning: Exhaust _____CFM, Supply _

Do WHV flow tests include GPS & time stamp verification?

HRV/ERV sensible heat recovery efficiency: _____

Commissioning Notes:

Other Mandatory Requirements

All other mandatory requirements of WSEC-R have been met?

- Enter CFM@50, Read ACH@50
- Check if mechanical ventialtion needed.

AS-1.2 BLOWER DOOR DIAGNOSTICS

Find Leaks to Speed the Work

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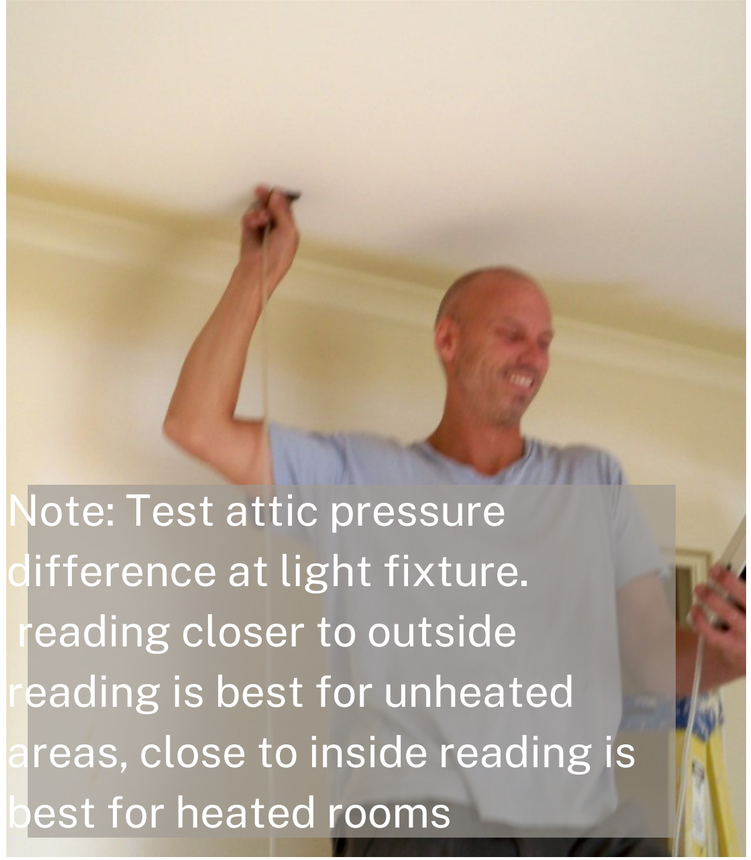
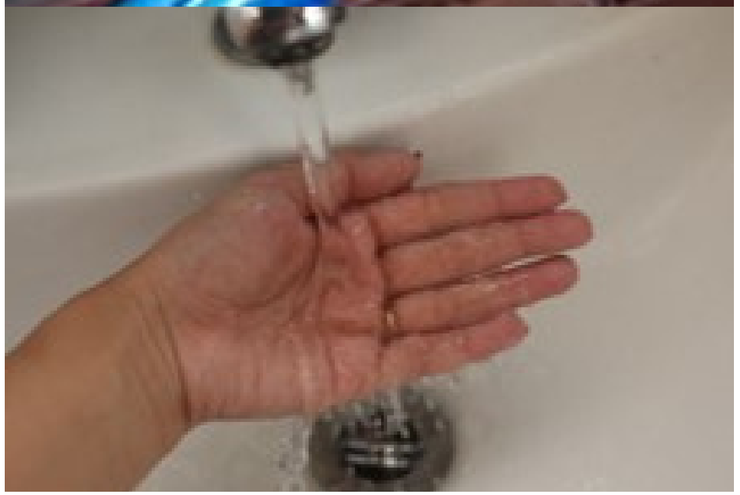
Check pressures to attic, garage, bedrooms, or crawl

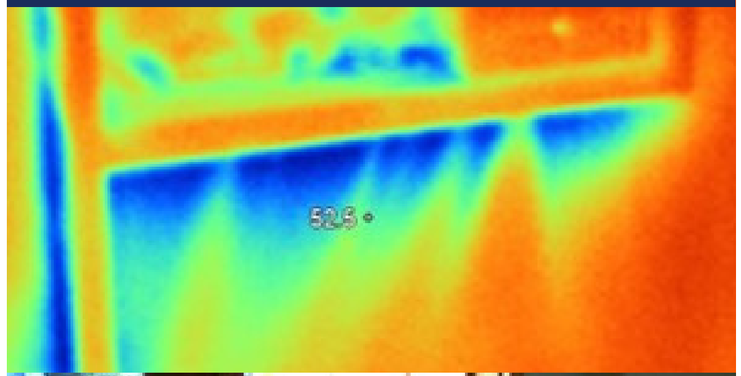


Note: Test attic pressure difference at light fixture. reading closer to outside reading is best for unheated areas, close to inside reading is best for heated rooms

Use damp hands or smoke to find flow



Use infrared to map leaks



Note: Inside must be 15 deg.F warmer or cooler than outside

AS-2 **ATTIC**

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Attic Hatch/Door

Weather-stripping permanently attached to create an effective air seal between the hatch/door and the frame.

Heat loss at hatch with no insulation

Thick, smooth Wstrip for a better seal. Fully insulate hatch

AS-2.1 **ATTIC**

Attic Side Hatch/Door

Weather-stripping permanently attached to create an effective air seal between the hatch/door and the frame

With gasket - face of stop may need repair so it is smooth.

AS-2.2 **ATTIC**

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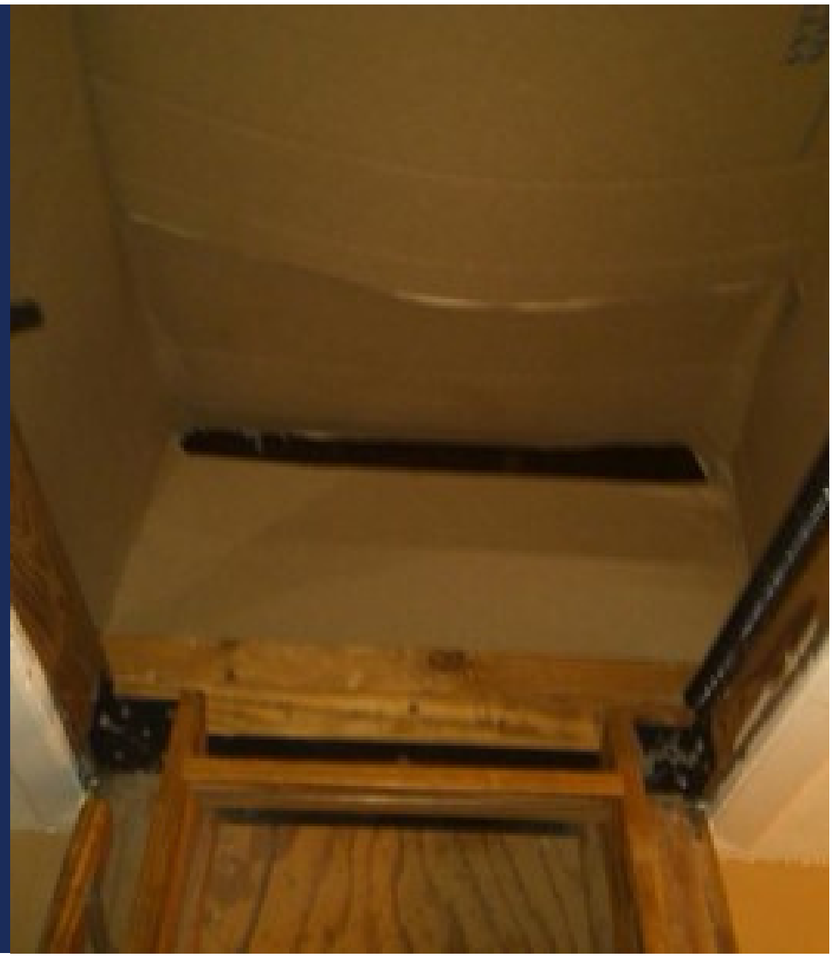
Pull Down Stair Cover

Gasket or weather-stripping permanently attached between frame and door or air-tight cover installed between stairs and attic.



AS-2.3 **ATTIC**

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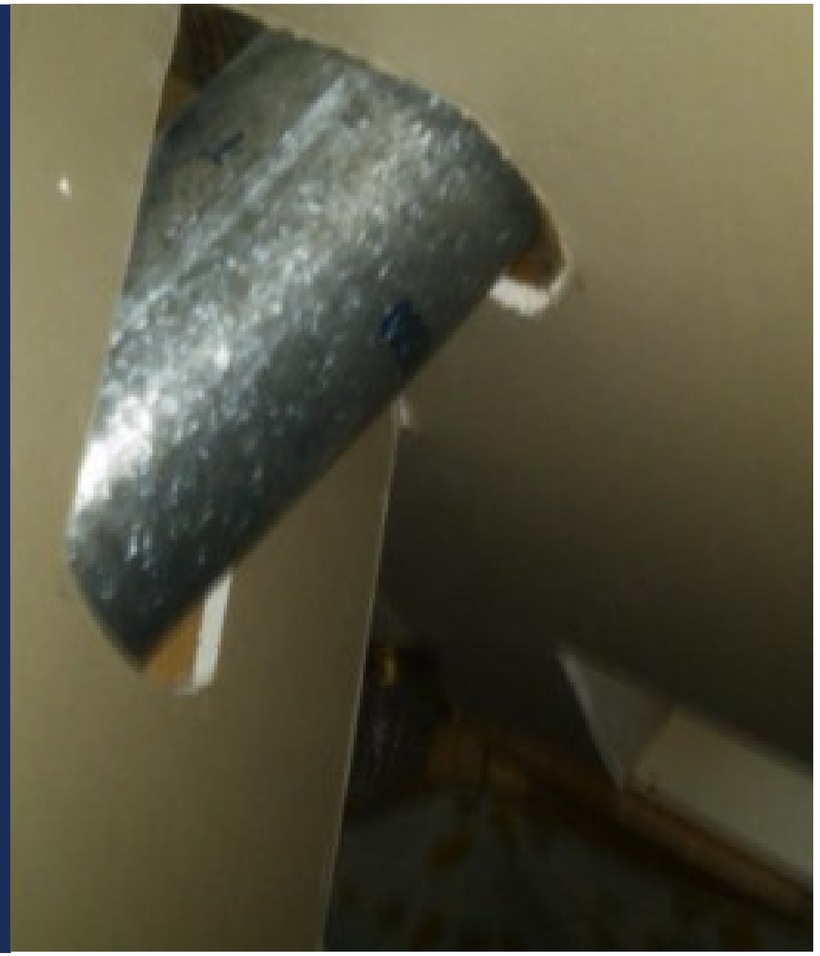
Duct Penetrations

Foam/caulk or other air-tight seal around perimeter of ducts entering the attic.



AS-2.4 **ATTIC**

Chases

Foam/caulk/rigid material sealed to attic floor/wall. Use fire rated materials at chimneys and flues.

Use solid support for large openings

AS-2.5 **ATTIC**

Recessed Cans – Option A

Non IC rated can lights must have baffle to maintain 2” clearance at sides. Air seal required option A, B or C

DO NOT COVER Unless rated “IC”

Check rating on inspection

Top is 6” above fixture. This one is pinched and sealed

AS-2.6 **ATTIC**

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Recessed Cans – Option A

Option for non ICAT cans, install air-tight drywall, sheet metal, or other non-combustible assembly

Each fixture has many leaks

Non-combustible material, not insulated on top, sealed to ceiling

AS-2.7 **ATTIC**

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Recessed Cans – Option B

Foam/caulk ICAT rated air tight fixture at ceiling. Many of these cans are labeled “WA State Approved”

Can lights create large bypass

ICAT “air tight’ fixture, sealed at drywall joint with caulk

AS-2.8 **ATTIC**

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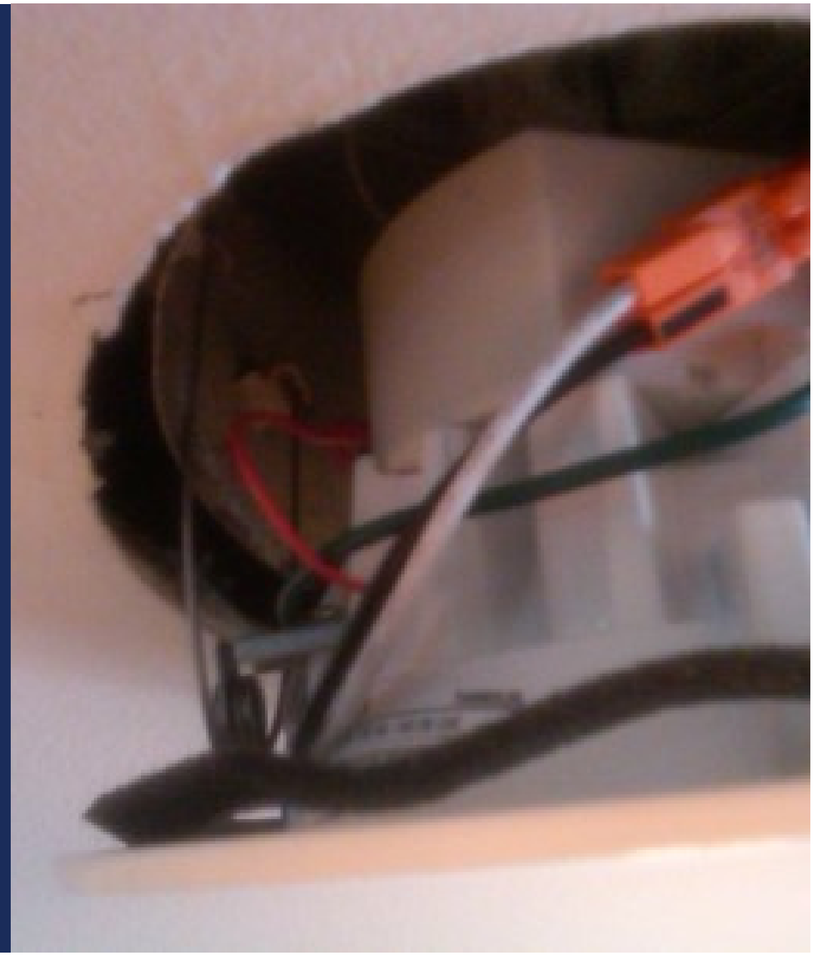
Recessed Cans – Option C

LED or air tight trim kit, gasket seal to smooth ceiling

LED trim kit with gasket



Air tight trim kit

AS-2.9 **ATTIC**

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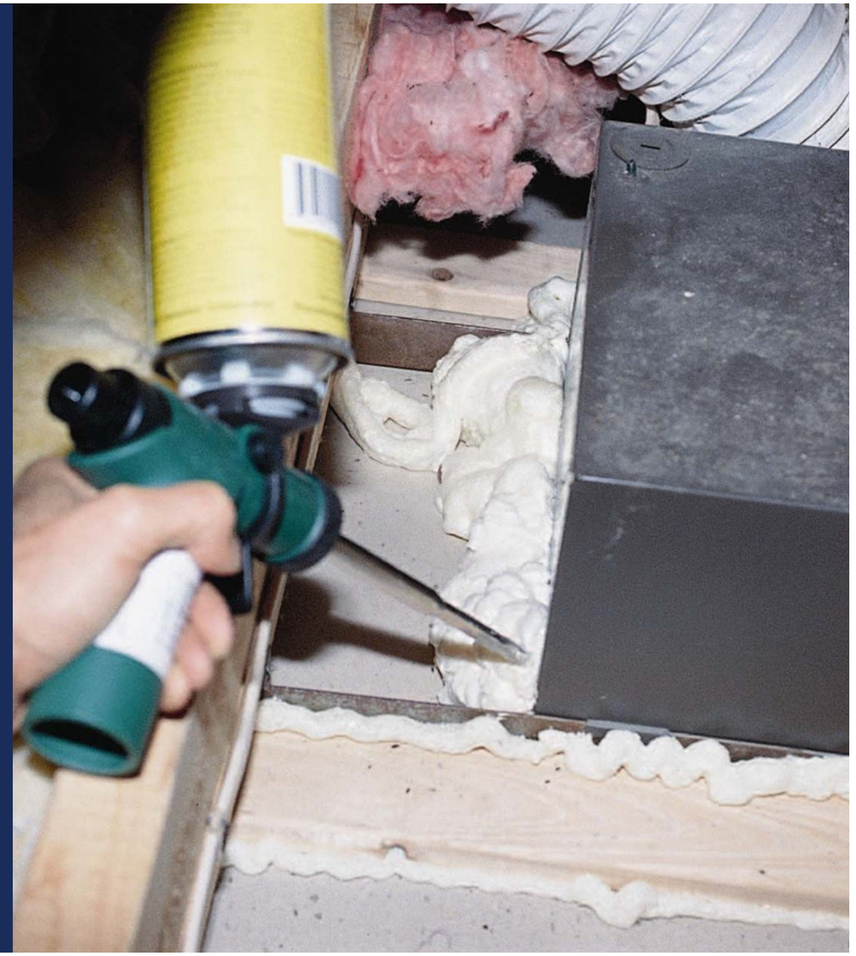
Bath Fans

Foam/caulk or other air-tight seal around fixture perimeter.

Seal thoroughly



AS-2.10

ATTIC

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Electrical Penetrations

Foam, caulk or other air-tight seal around perimeter and all holes in electrical or light box.

Fire rated sealant is best

AS-2.11 **ATTIC**

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Plumbing Penetrations

Penetrations sealed. Rockwool or stuffed fiberglass is a filter, not a sealant.

Seal all the way around

AS-2.12 **ATTIC**

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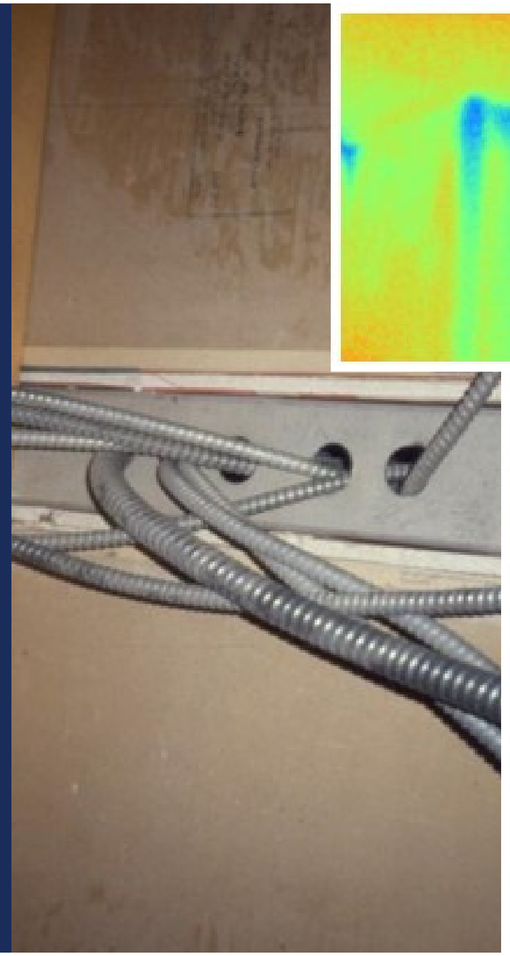
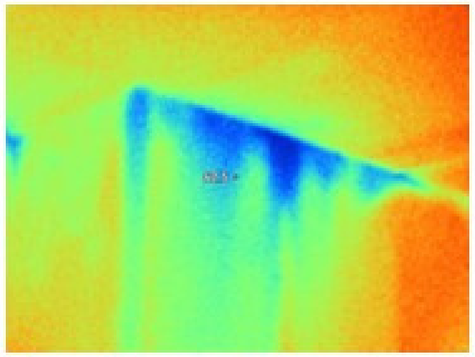
Top Plates

Seal drywall or plaster to top plate at all joints & wood to wood connections. Sweep insulation aside as needed. Outside top plates may be hard to reach!

IR photo shows top plates leak under test





Seal all the joints. OK if outside plates not reached.

AS-2.13

ATTIC

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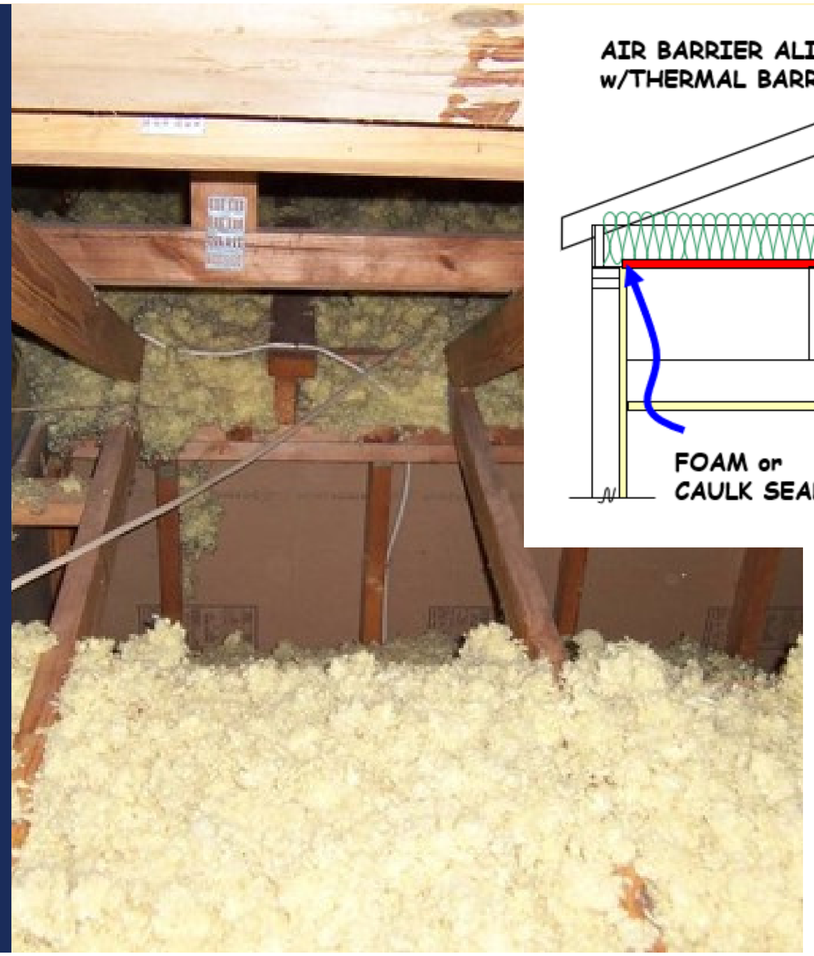
Drop Soffits

Rigid material covering attic floor opening and sealed with foam/caulk.

The best soffit is always built after drywall is installed.



AS-2.14 **ATTIC**

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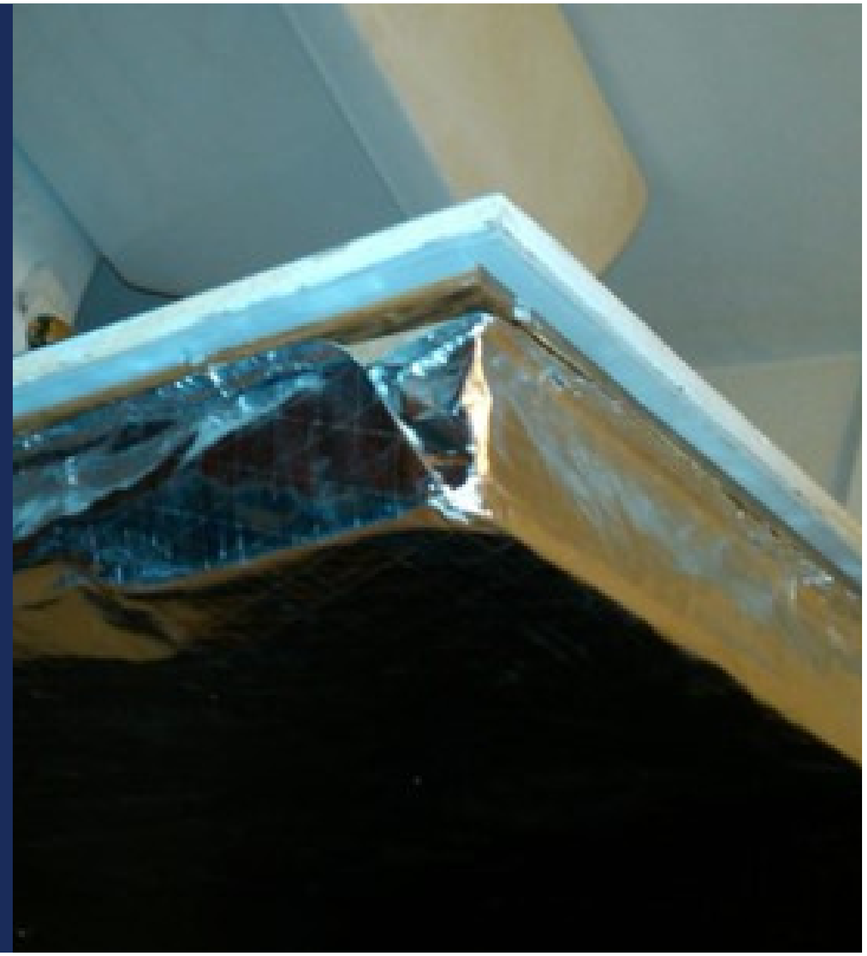
Knee Wall Doors

Weather-stripping permanently attached for an effective air seal between the door and the attic access frame.

No weather-strip, T&G door

Door must have a latch or screws for a tight seal



AS-2.15

ATTIC

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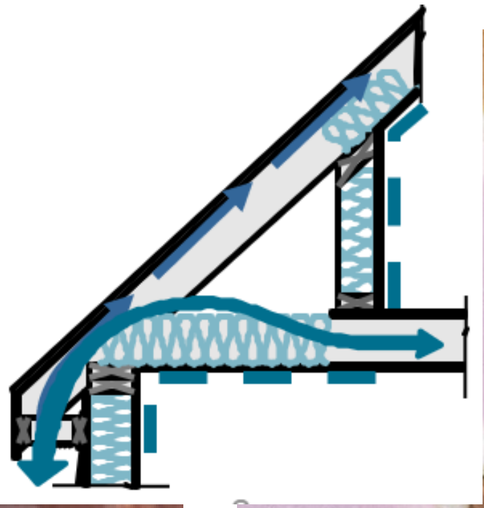
Knee Wall Bypass

Ah…the infamous Knee Wall Bypass. Install Rigid material between joists below knee wall. Foam/caulk perimeter of each.

Joist cavities open to space between heated floors



Fire rated materials should be used

AS-2.16 **ATTIC**

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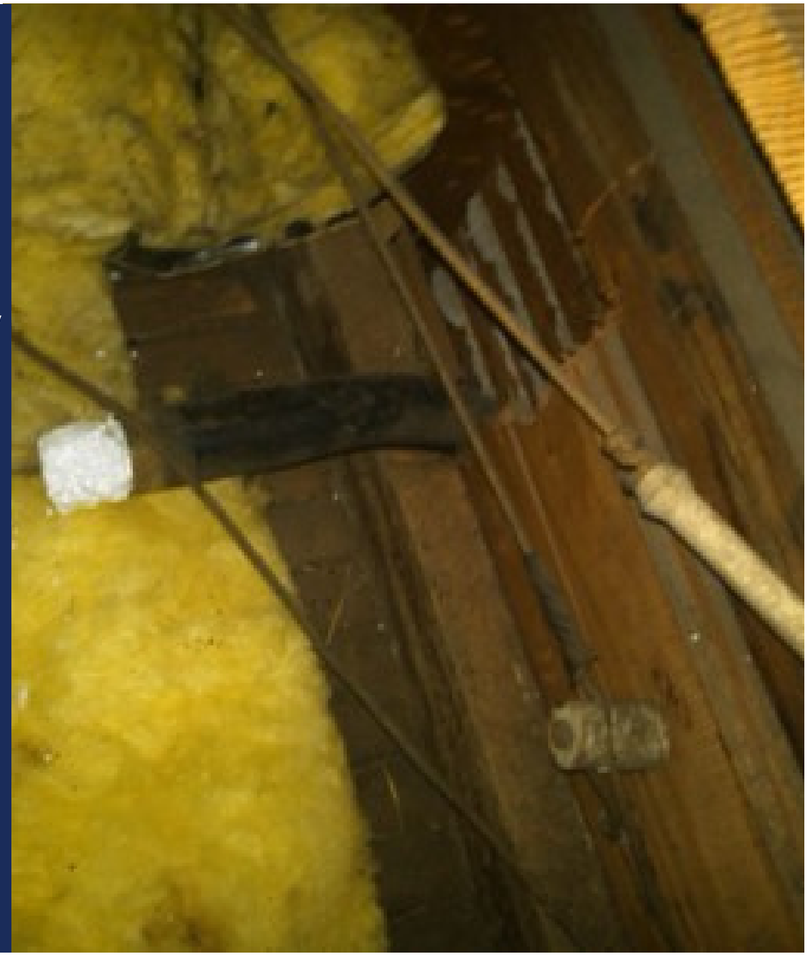
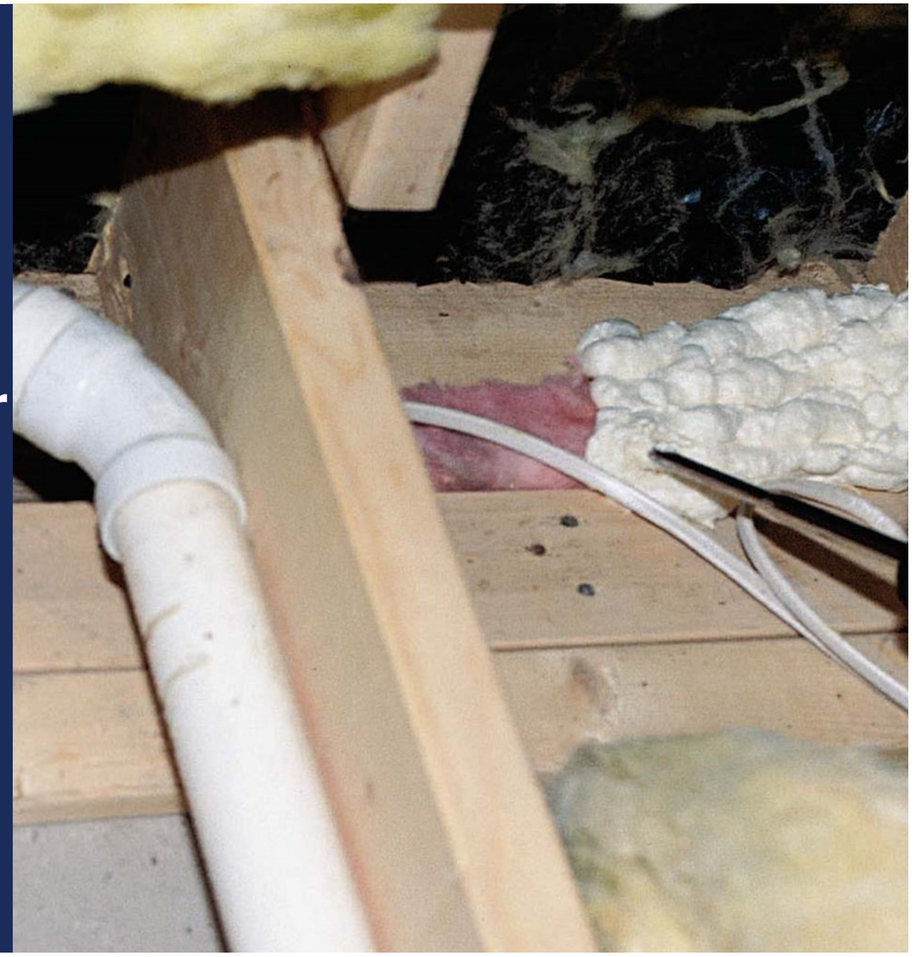
Open Wall Cavities

Foam or rigid material sealed to framing. All joints from opening to drywall sealed.

Open cavity at ceiling height change



Foam applied over stuffed in batt



AS-2.17 **ATTIC**

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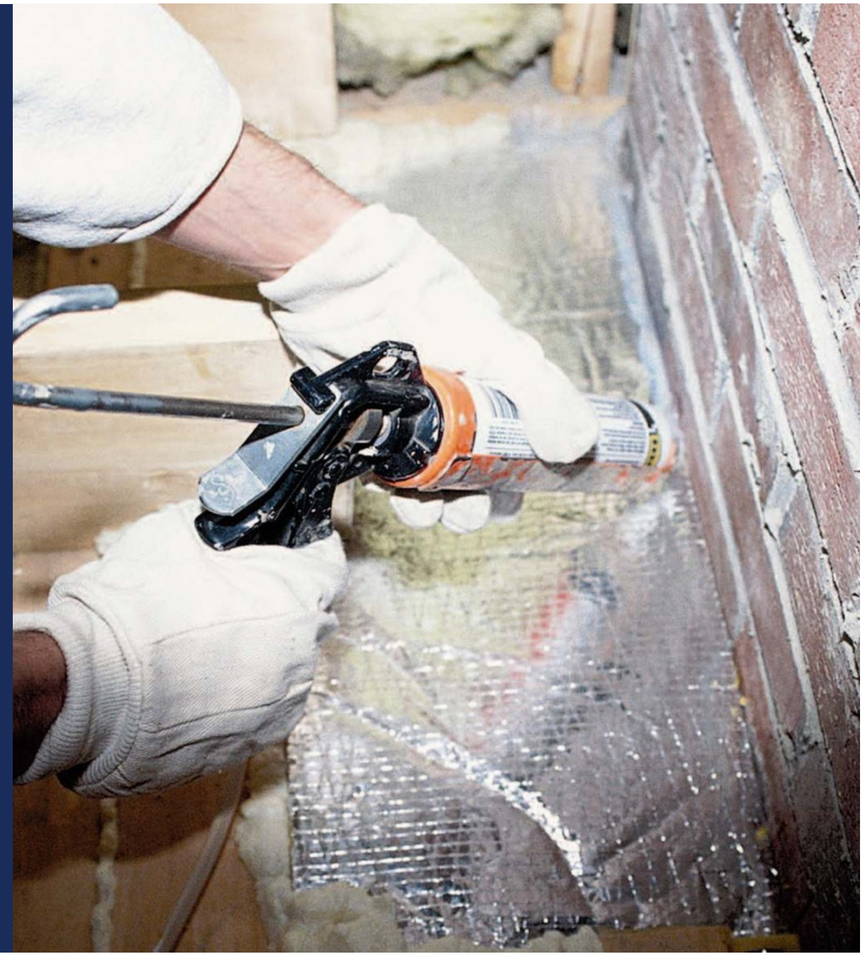
Masonry Chimney

Sheet metal, fiber cement, or other fire rated material attached to seal gap at framing: Use fire rated caulk.



AS-2.18 **ATTIC**

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Masonry Chimney

Sheet metal, or fire rated material sealed to flue with fire rated caulk. Insulation baffle required for 1” clearance

Combust-ibles contacting flue. RISK OF FIRE!

Fire rated caulk and metal baffle

AS-2.19

ATTIC

Balloon Framed Wall Cavities, Double Walls

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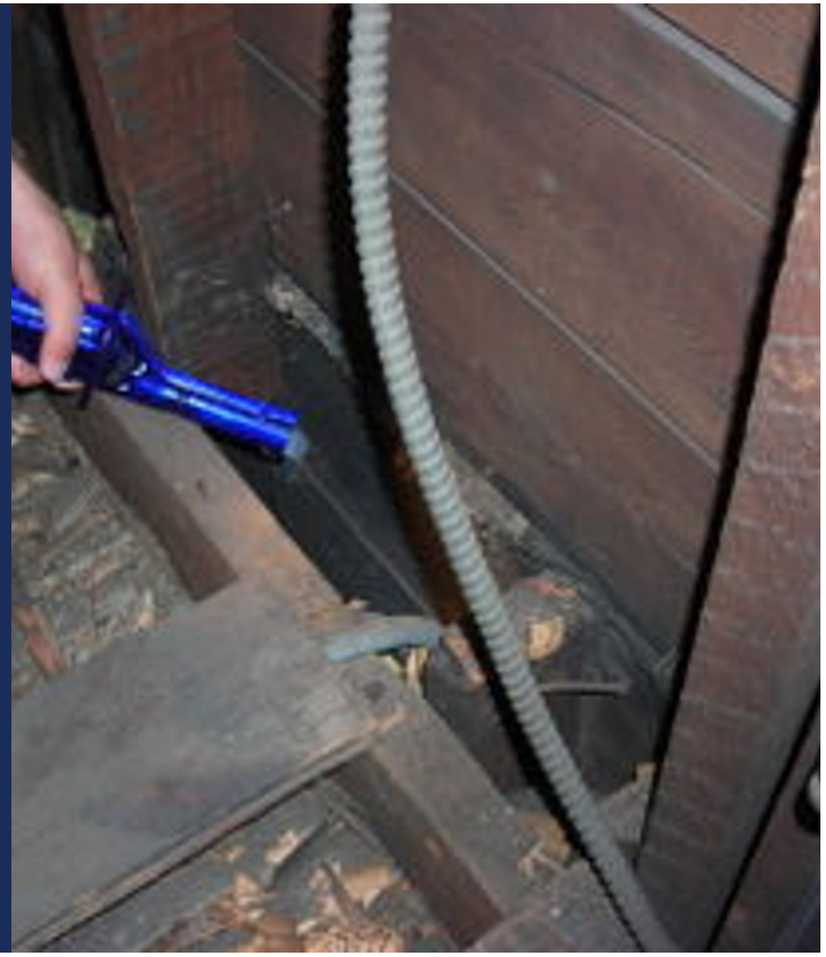
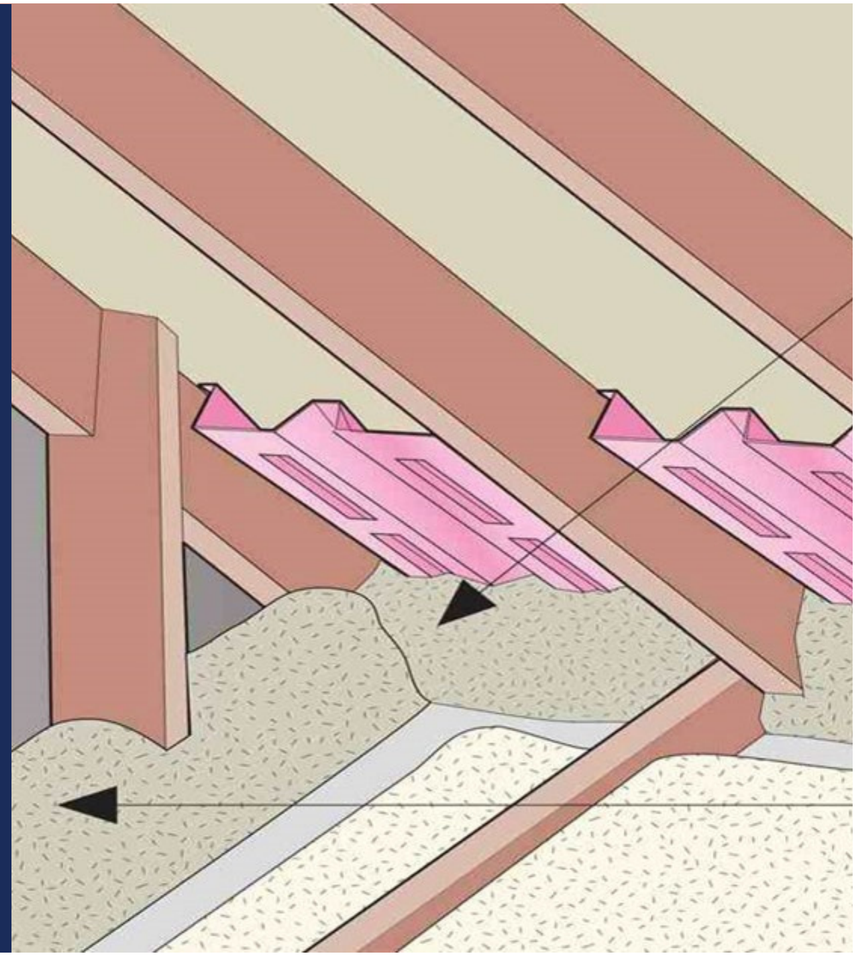
Sealed at Attic and crawl space with 2x lumber, 5/8" drywall, or other 1hr rated material.

Cavity may be open to basement - also a fire safety problem.



Fire block and seal at ceiling.



AS-2.20

ATTIC

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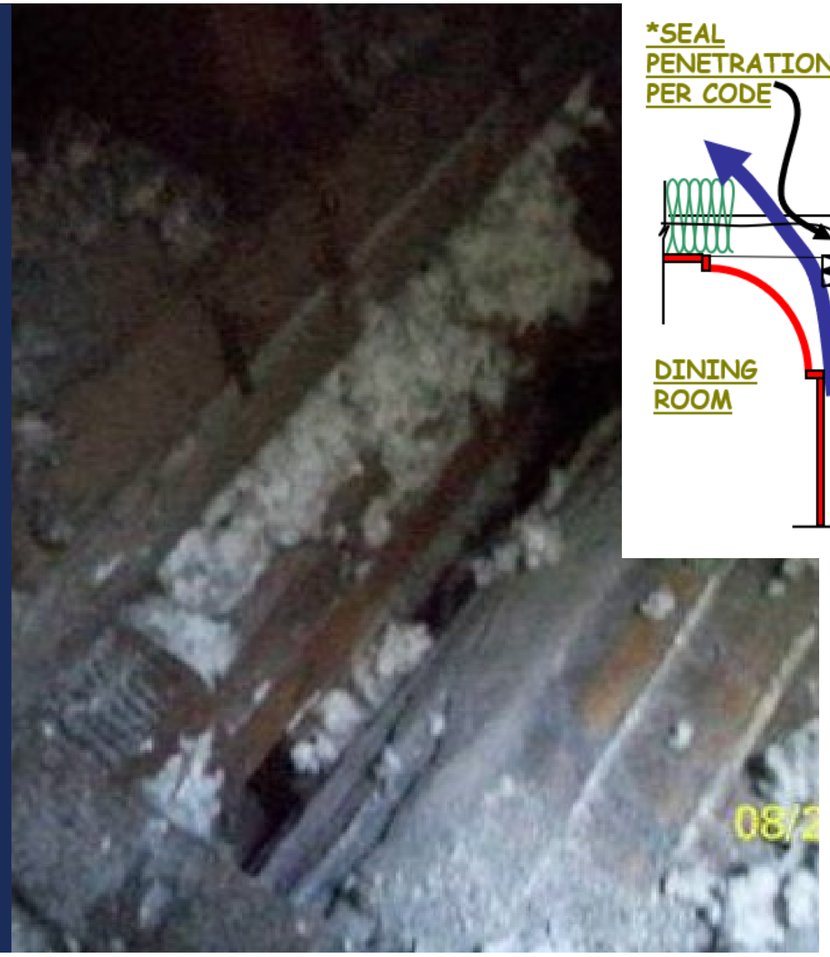
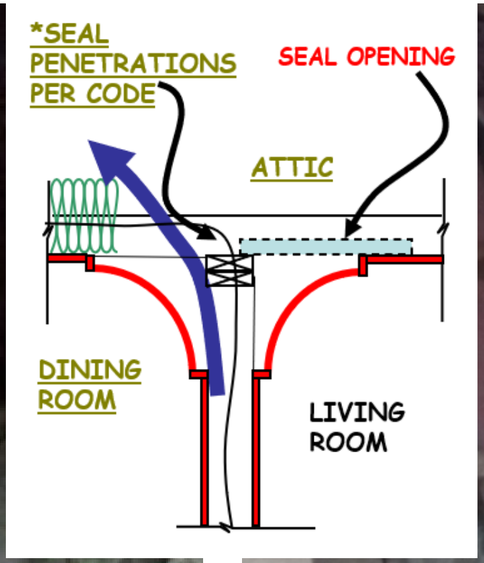
Cove Ceiling Openings

Seal opening to wall cavity with 2x lumber, 5/8" drywall, or other 1hr rated material.

Plaster cove creates and opening from wall to attic





Fire rated foam sealed in place

AS-2.21

ATTIC

Wall To Ceiling Transitions – Dropped/Raised Ceiling

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Seal top plates or all joints in framing at wall/ceiling joint.

Plaster cove creates and opening from wall to attic

Fire rated foam sealed in place

AS-2.22 **ATTIC**

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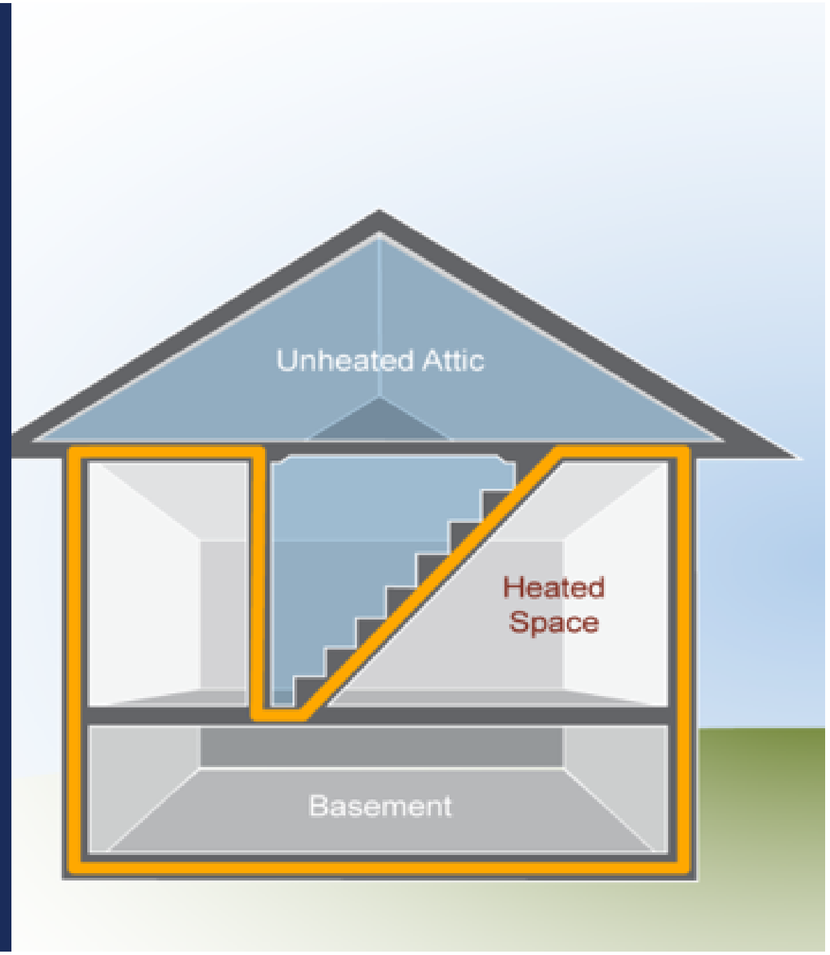
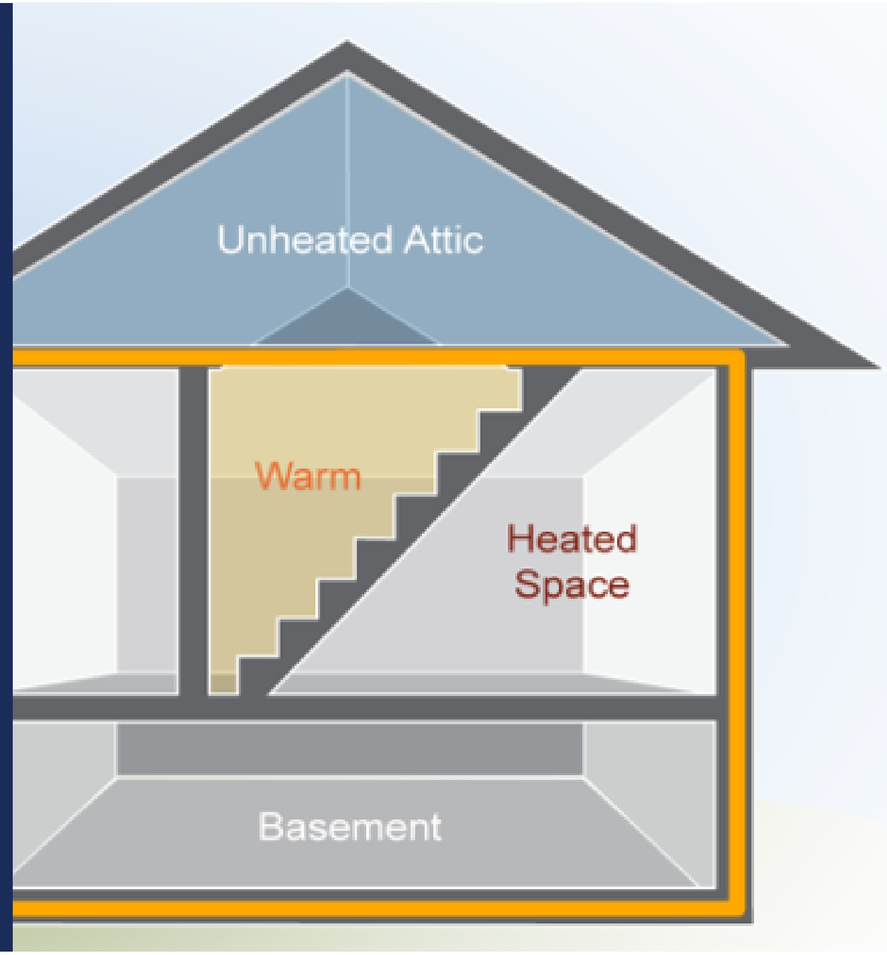
Interior Stairwells To Attic

Air-tight cover between stairs and attic or sealed at stair stringers and all joints between stair and vertical walls

No stair cover makes much more surface area



Stair cover makes seal at ceiling plane



AS-2.22

ATTIC

Tongue And Groove Ceilings/Walls

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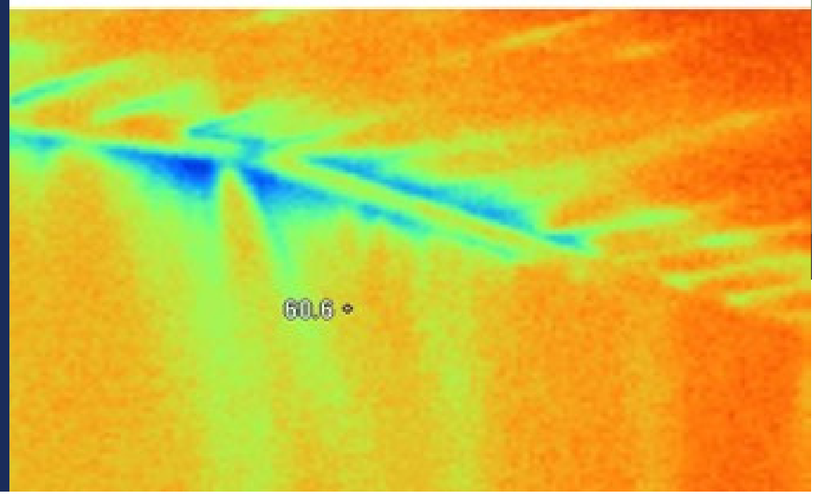
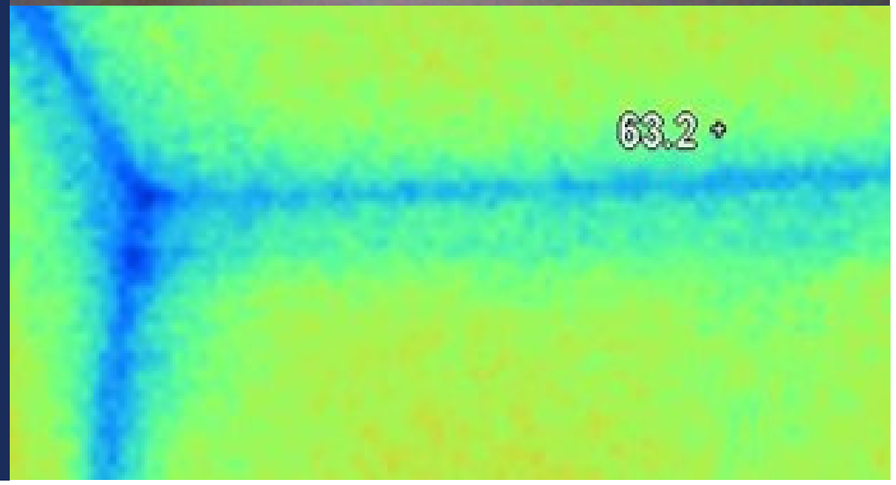
Remove molding and seal all corners and joints. Seal all joints over 1/16" wide. Clear latex caulk recommended. T&G ceilings should never be installed without drywall behind them. Without air sealing, Wwter could condense on roof sheating in cold weather.

Many Leaks at joints with no backing



All joints caulked, wiped out with damp cloth



AS-3.0

CRAWLSPACE / UNCOND. BASEMENT

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Hatch/Door

Weather-stripping permanently attached for effective air seal between the crawl access frame and hatch/door.

Dust marks show constant air flow

AS-3.1

CRAWLSPACE / UNCOND. BASEMENT

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Chases

Seal chases to wall or ceiling with moisture resistant material. Use fire rated materials at chimneys.

Opening to soffits in finished partial basemen

Seal chase at thermal boundary with metal or rigid foam

AS-3.2

CRAWLSPACE / UNCOND. BASEMENT

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Duct Penetrations

Foam/caulk or other air-tight seal around perimeter of duct boots between the boot and the subfloor.

AS-3.3

CRAWLSPACE / UNCOND. BASEMENT

Plumbing Penetrations

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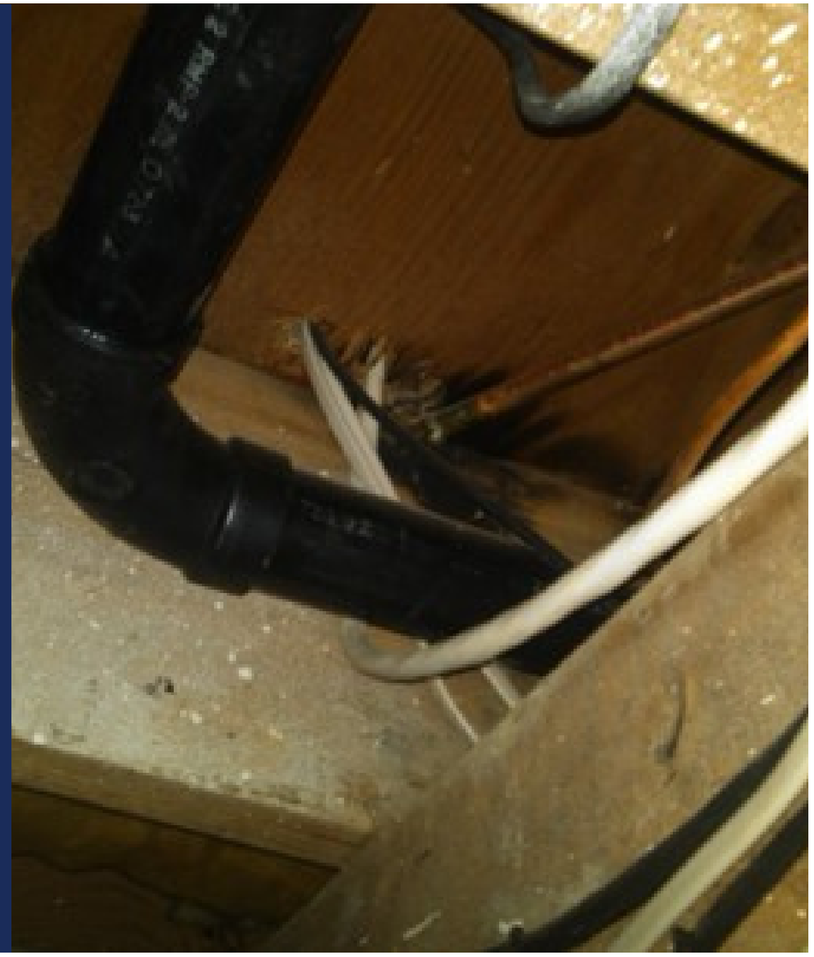
Penetrations sealed. Rigid moisture resistant material sealed to the floor if opening is larger than 1”.

AS-3.4

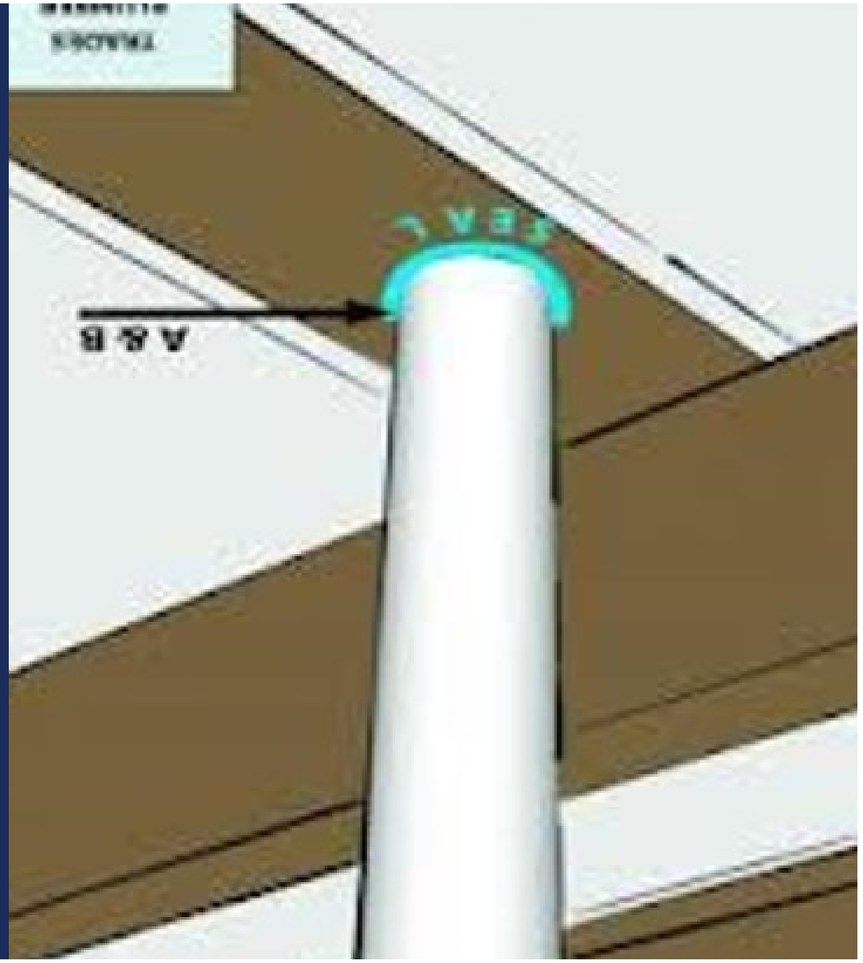
CRAWLSPACE / UNCOND. BASEMENT

Electrical Penetrations

Foam, caulking, sealed to crawl space/basement ceiling. If opening larger than 1” use rigid material .



Seal at floor plane



AS-3.5

CRAWLSPACE / UNCOND. BASEMENT

Wall at Partial Crawl Space

Drywall or other rigid material installed and sealed. Seal all penetrations, as well as joints to concrete.

Sealing between boards

Seal at drywall and framing

AS-3.6

CRAWLSPACE / UNCOND. BASEMENT

Joists Over Common Garage Wall

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Rigid material fit between joists and sealed at all 4 sides and plumbing/electrical penetrations.

Also check canti-levered floor areas

Blocks create seal at thermal / air boundary

AS-3.7

CRAWLSPACE / UNCOND. BASEMENT

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Bathtub Cutout

Use rigid material and foam/caulk to seal large opening at bathtub.
Best practice - insulate tub from below first.

Open cavities drawing in cold air

Sealed at thermal boundary

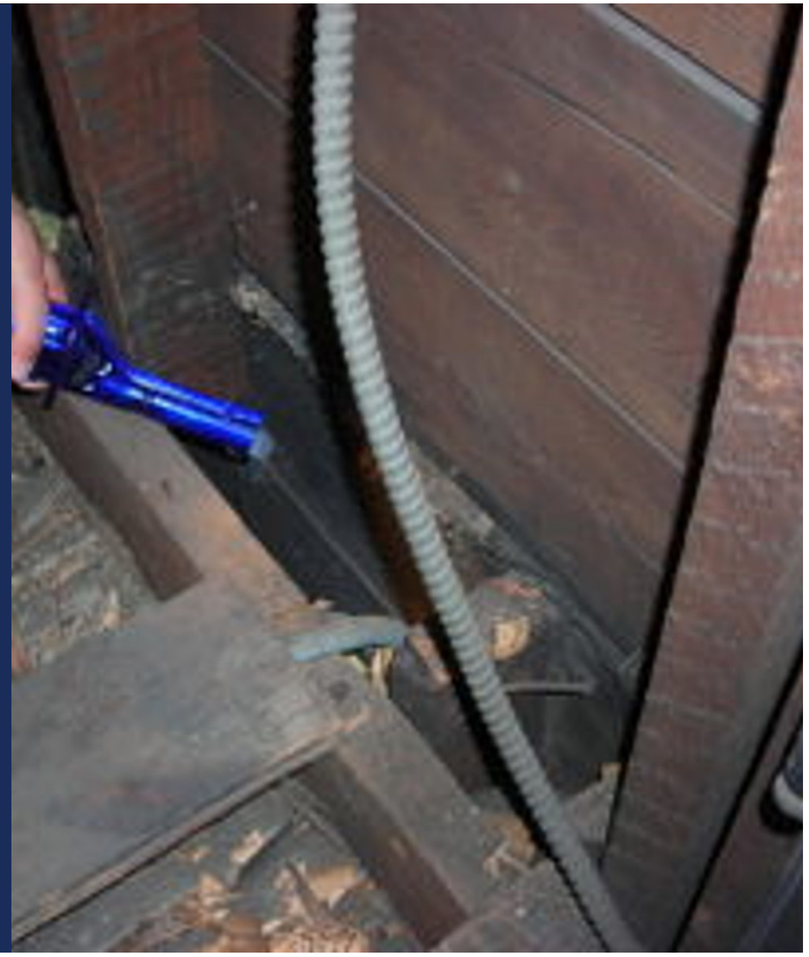
AS-3.8

CRAWLSPACE / UNCOND. BASEMENT

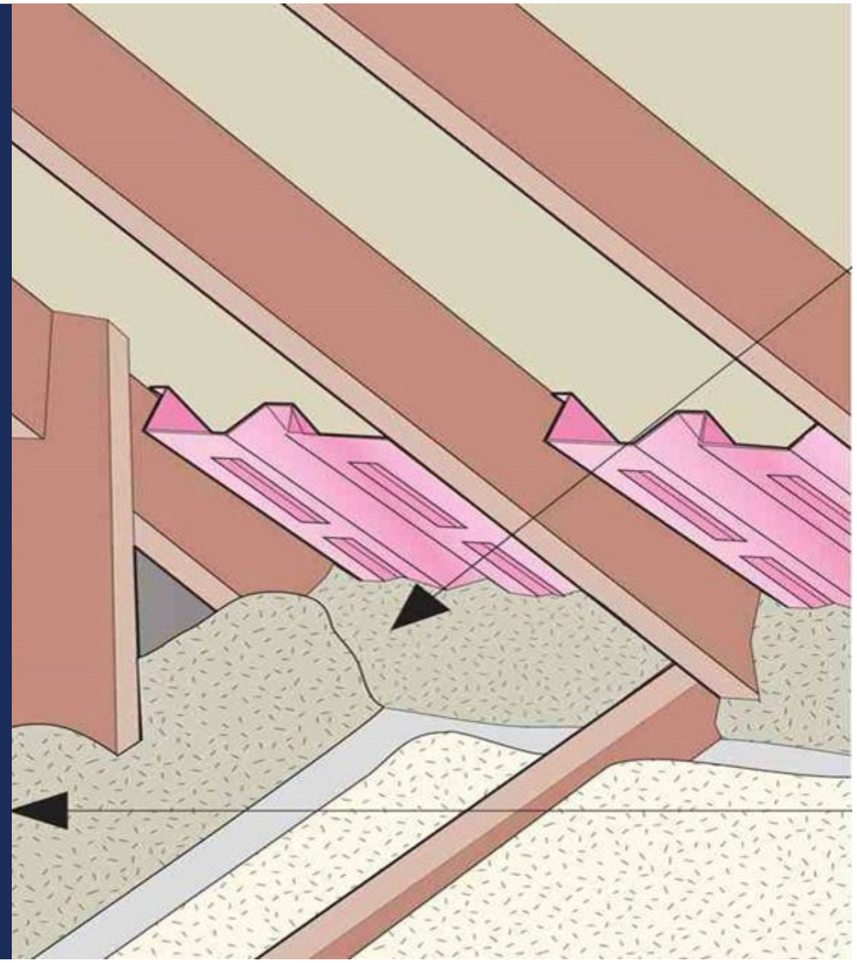
Balloon Framed Wall Cavities

Sealed at attic and crawl space with 2x lumber, 5/8” drywall, or other 1-hr rated material

Cavity may be open to basement - also a fire safety problem.



Fire block and seal at ceiling.



AS-3.9

CRAWLSPACE / UNCOND. BASEMENT

Sill Plate to Stem Wall Connection

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Sealed with foam/caulk between wood sill plate and concrete or masonry wall.

Leakage at sill

Use concrete compatible caulk or foam

AS-3.10

CRAWLSPACE / UNCOND. BASEMENT

Rim Joists

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Rigid material between joists. Seal perimeter of each rim joist.
Alternate is to seal all joints with spray foam.

No seal at rim joist or cantileve red floor

Insulate w/foam blocks and seal perimeter

AS-3.11

CRAWLSPACE / UNCOND. BASEMENT

Electrical and Pipe Penetrations that Lead to Attic

Foam, caulking. Rigid material sealed to crawl space/basement ceiling if opening larger than 1”.

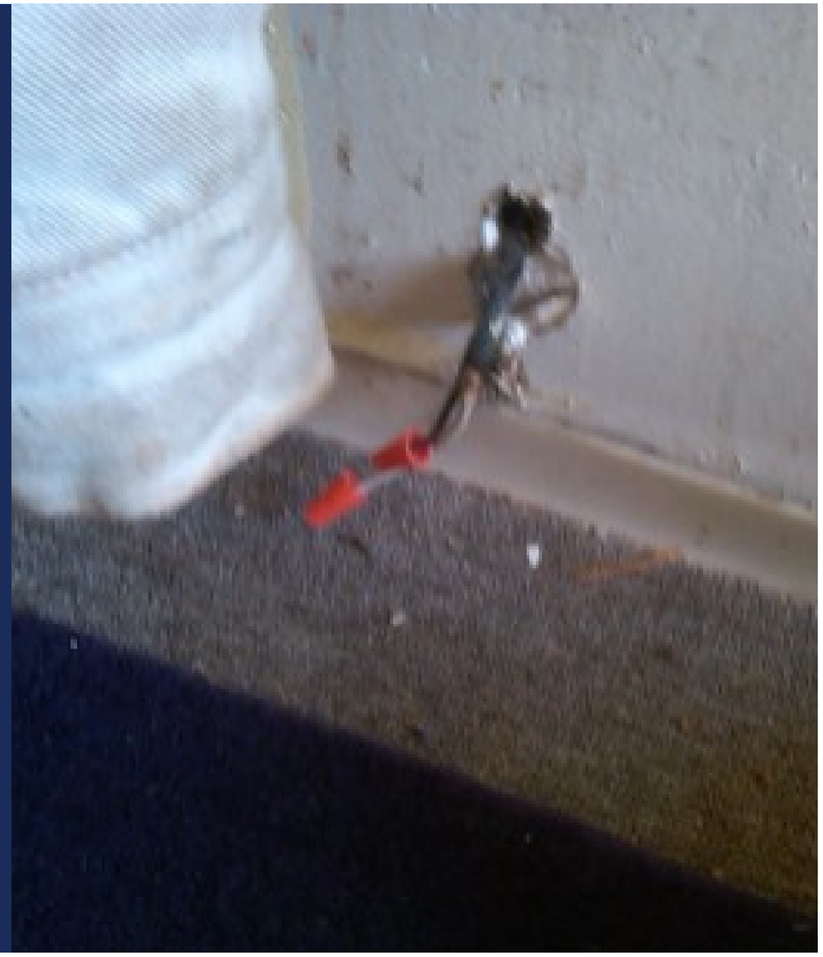
AS-4.0 EXTERIOR WALLS

Plumbing and Electrical Penetrations

Balderston Associates

Foam /caulk/rigid moisture resistant material if opening larger than 1”.

Also check under sinks



AS-4.1 EXTERIOR WALLS

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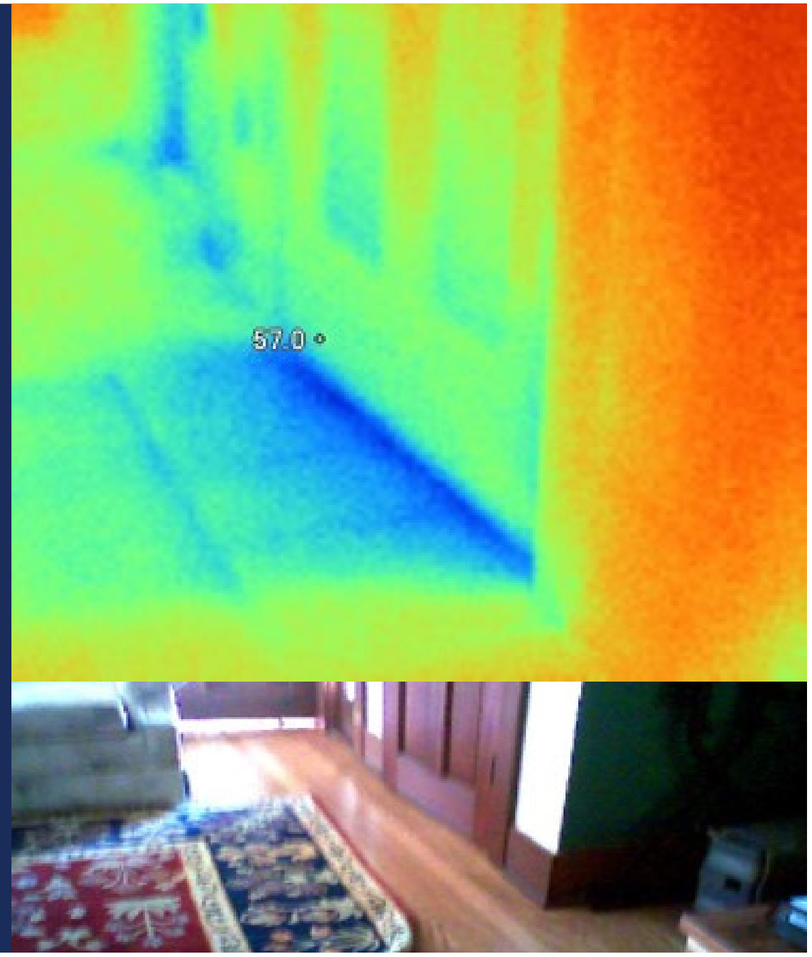
Doors and Windows

Weather stripping and door sweep adjusted to fit. Seal below threshold. Seal around trim at joints to wall.



Adjust or add door bottom so it grips a piece of paper

AS-4.2 EXTERIOR WALLS

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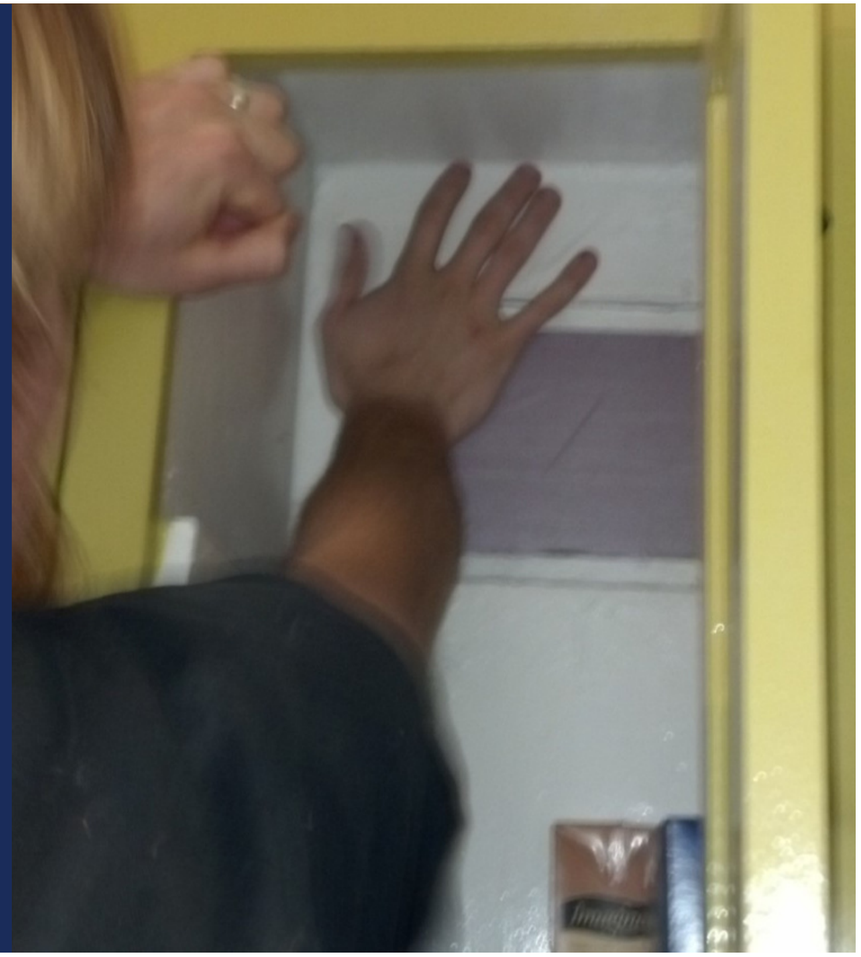
Other Openings

Seal with appropriate caulk, foam, or weather strip to create and effective air barrier

"Cooler cabinet"

Foam block can be removed in summer, or cabinet rebuilt with insulation and sealed door



AS-4.3 EXTERIOR WALLS

TURN OFF POWER FIRST

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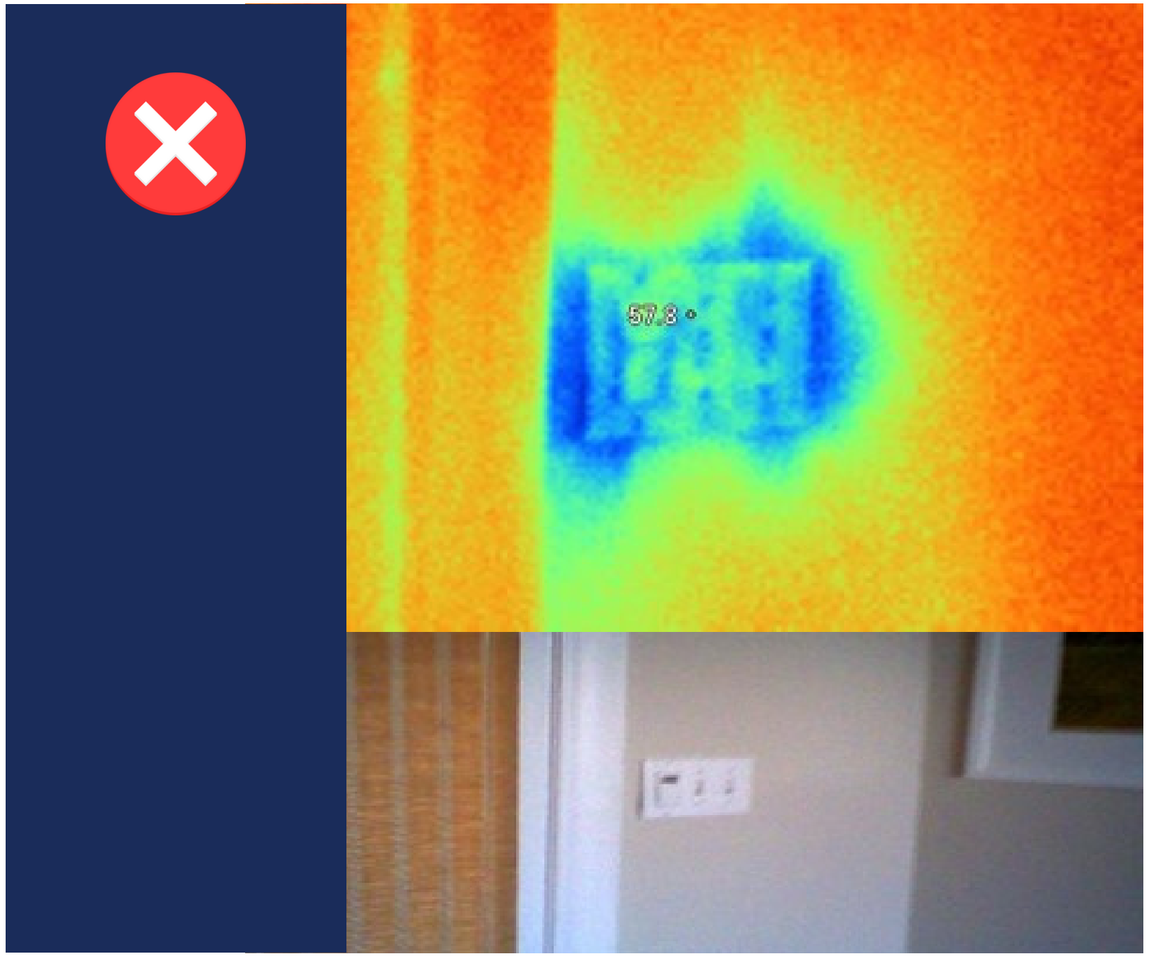
Electrical Boxes

Seal box to drywall. Do not put sealant or foam inside box. Wire openings may be sealed w/fire rated foam.



Seal with foam gasket and/or air tight cover plate

AS-4.4 EXTERIOR WALLS

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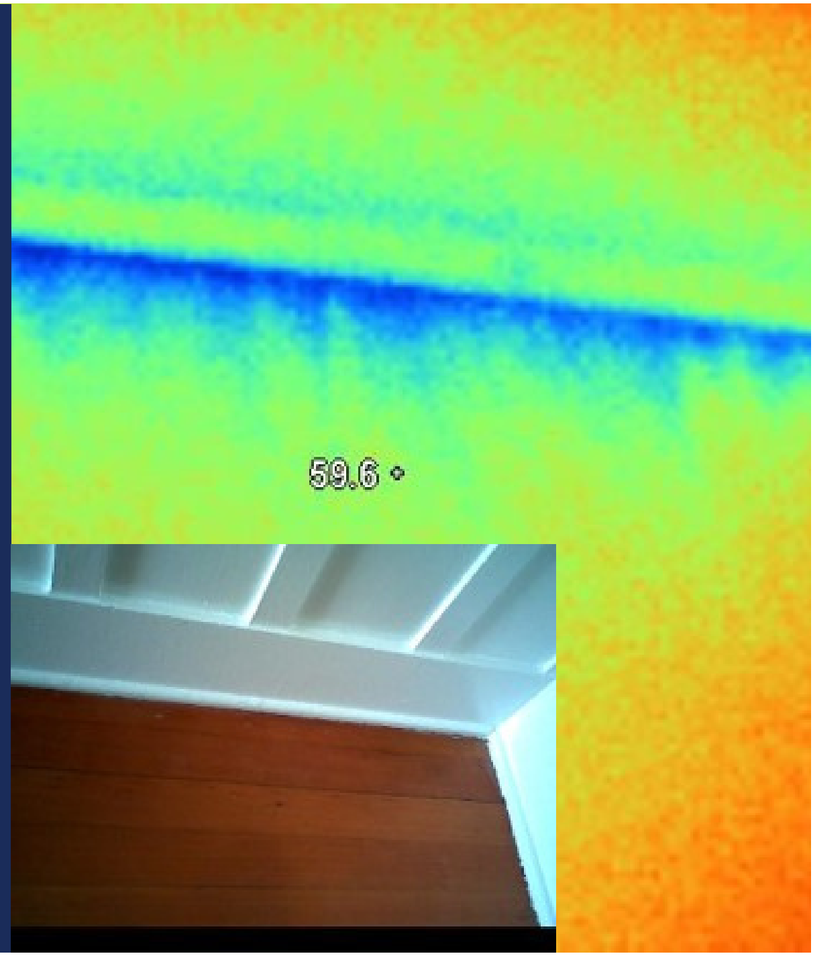
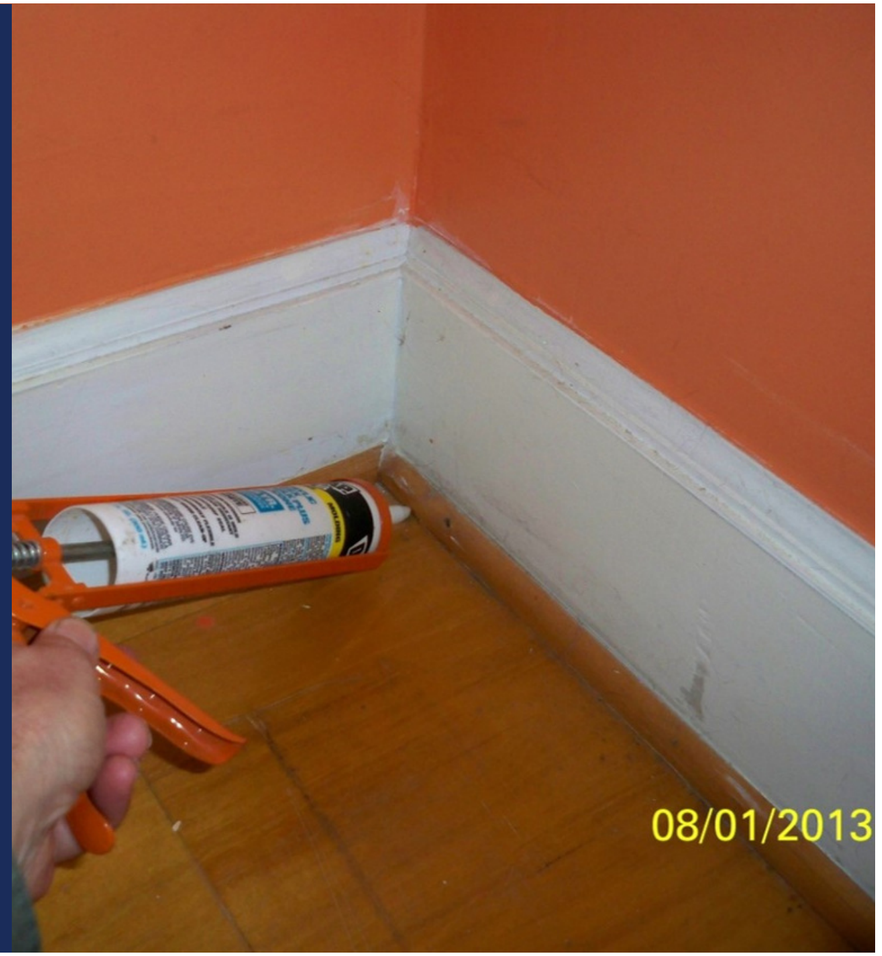
Baseboards

Seal joint to floor with water based caulk after vacuuming. Use clear on finished wood floors and wipe out with damp cloth

Blue streaks show air leaks on IR scan





AS-4.5 EXTERIOR WALLS

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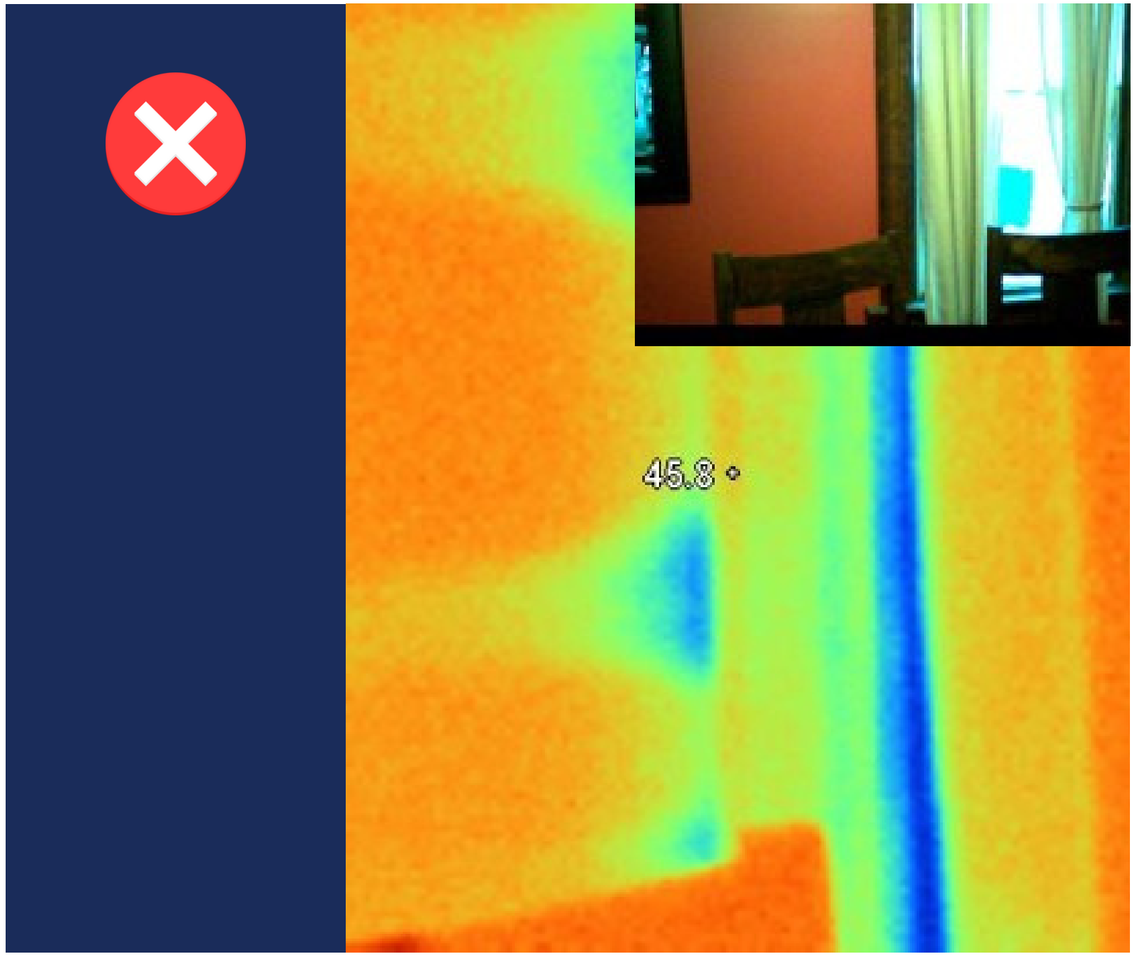
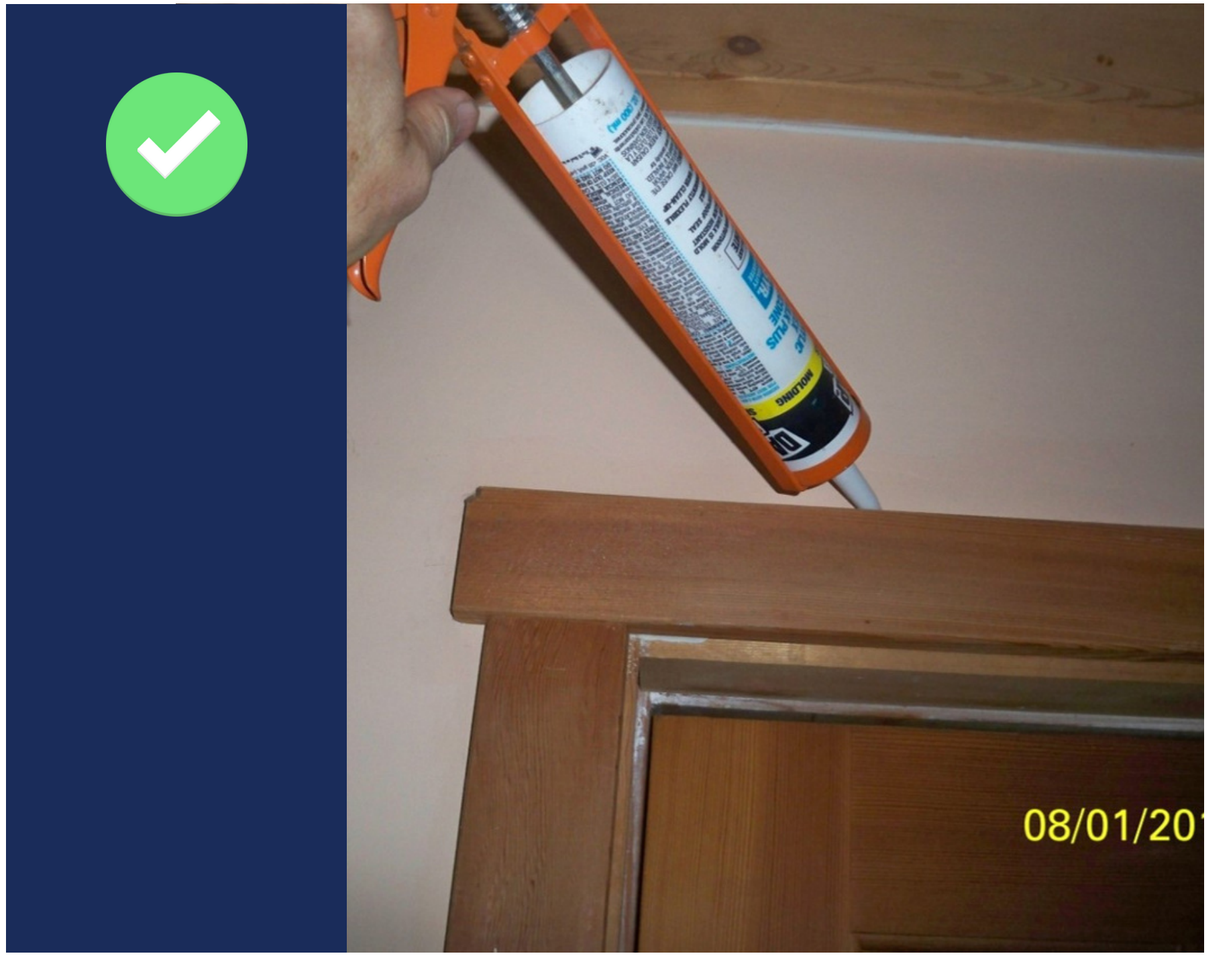
Door and Window Trim

Caulk joints and trim to wall on all sides, including top of head trim and bottom of lower trim





AS-4.6 EXTERIOR WALLS

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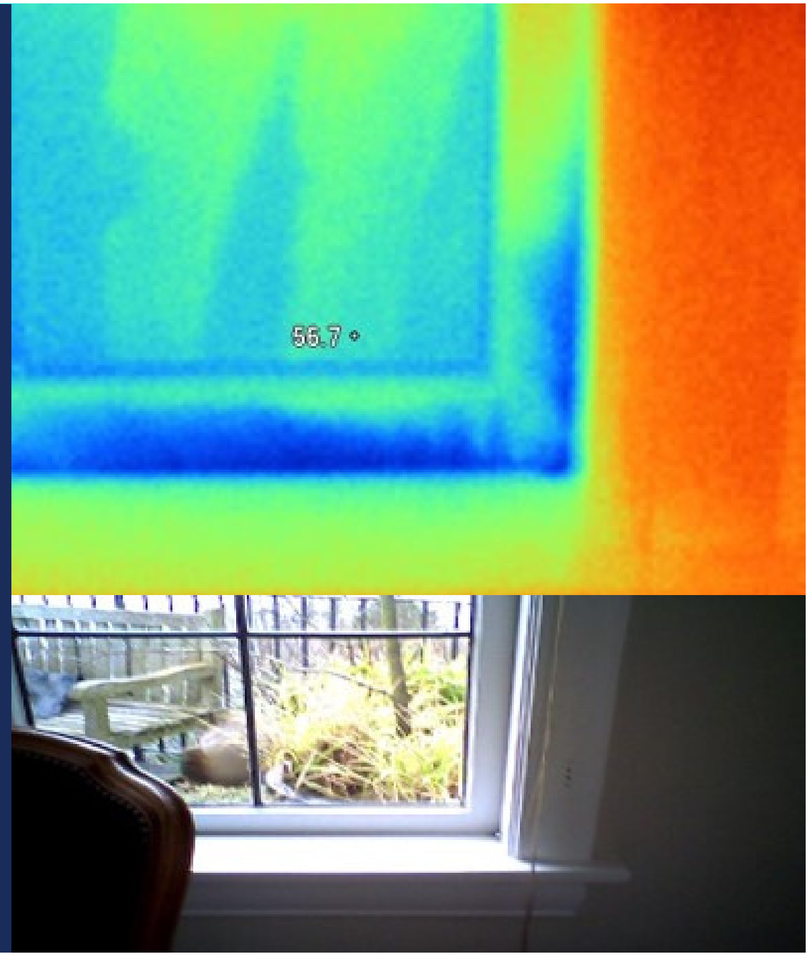
Window Weather-stripping

Weather stripping can be repaired or installed on double hung wood windows

Dark blue spray pattern shows poor weather-stripping



V-seal and pulley seals installed

AS-5.0

VENTILATION - FAN SIZING

Balderston Associates

TABLE 403.8.1
Ventilation Rates For All Group R
Private Dwellings, Single and Multiple
(Continuously Operating Systems)

Floor Area	Bedrooms				
(ft^2)	0-1	2,3	4,5	6,7	>7
<500	30	40	45	55	60
500 - 1000	45	55	60	70	75
1001 - 1500	60	70	75	85	90
1501 - 2000	75	85	90	100	105
2001 - 2500	90	100	105	115	120
2501 - 3000	105	115	120	130	135
3001 - 3500	120	130	135	145	150
>3500	135	145	150	160	165

a. Ventilation rates in table are minimum outdoor airflow rates measured in cfm.

TO CALCULATE REQUIRED WHOLE HOUSE FAN RATE:

- **Use Conditioned Area**
- **Use # Bedrooms**
- **Read Prescriptive Rate in Chart for 24 hr operation**

AS-5.1

VENTILATION - FAN SIZING

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Exhaust Vents and Ducts

Proper size/insulation for bath/laundry exhaust ducts. Use the table from Mechanical Code (MV 107.120) in Specifications

Flex duct over 6 ft and not insulated

Exhaust fans ducts are insulated and smooth walled metal pipe. Use flex for short connections

AS-5.2

VENTILATION - FAN SIZING

Balderston Associates

Exhaust Vents and Ducts

Proper size/insulation for bath/laundry exhaust ducts

Use table MV 107.120 in Specifications

Note: 4” duct is limited for 100 cfm fans

Note:4” Flex duct is very limited for 80 cfm fans

Note:Add 15 ft for each elbow

Duct Type	HVAC Flex Duct				Smooth Hard Duct			
Fan Rating in CFM	50	80	100	125	50	80	100	125
Duct Diameter	Maximum Duct Length in Feet							
3”	not allowed	not allowed	not allowed	not allowed	5	not allowed	not allowed	not allowed
4”	56	4	not allowed	not allowed	114	31	10	not allowed
5”	unlimited	81	42	16	unlimited	152	91	51
6”	unlimited	unlimited	158	91	unlimited	unlimited	unlimited	168
7”	unlimited	unlimited	unlimited	unlimited	unlimited	unlimited	unlimited	unlimited
Table assumes no elbows. Deduct 15 ft of allowable duct length for each elbow.								

AS-5.3 **VENTILATION - FAN SIZING**

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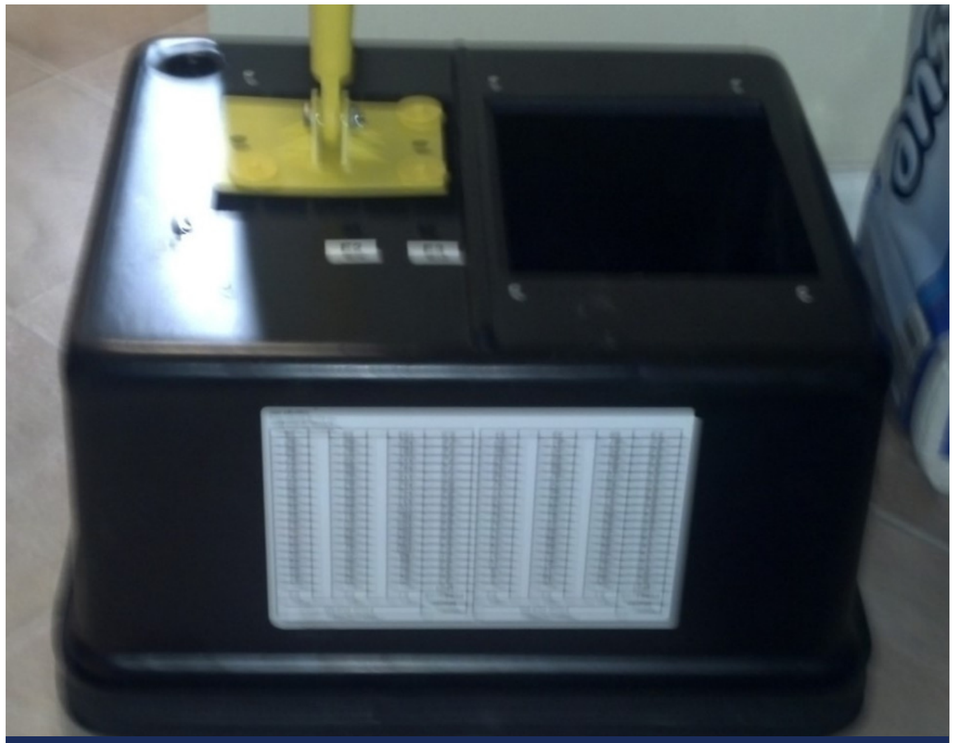
Testing Fan Flow

If fan is working and ducted correctly, assume 25 cfm per bath and 50cfm for kitchen. Testing fan gives whole house ventilation credit

See RESNET chapter 8 for simple bag or box testing methods



Flow box works with manometer. Both methods are easy and fast!

AS-6.0 **COMBUSTION SAFETY**

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Required at Audit

- Ambient CO test
- CO test at first register with furnace on
- CO test in mechanical room with furnace and water heater on

Required at Install

- Install PSE CO monitor
- TEST- IN and TEST- OUT per BPI Building Analyst standard for:
- Worst case CAZ depressurization
- No spillage after 5 minutes
- Warm up 10 minutes, then test CO in flue. Apply BPI action levels or call PSE if over 75 ppm
- Warm up and test draft pressure if test hole is present.

Refer to chart on next page for PSE actions →

AS-6.1 **COMBUSTION SAFETY**

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Action Levels for call to UTILITY Gas First Response

Test Result	and/or	Test Result	Test Result
0 – 25 ppm CO in undiluted flue gas	and	Fails Spillage/Draft at worst case or natural at 60 seconds and re-test at 5 minutes	Contact PSE GFR and wait for technician to arrive; Provide Customer with Health and Safety Advisement
>75 ppm CO in undiluted flue gas	and	Passes Spillage/Draft at worst case or natural	
Ambient CO > 3ppm	and	Any condition	
Gas leaks detected by smell or Detector	and	Any condition	
CAZ test > 3Pa negative	and	Any condition	Inform Customer; Provide Customer with Health and Safety Advisement

Call PSE at 1-888-225-5773 or call 911, but don't use your landline phone, which may cause a spark

AS-6.2 **COMBUSTION SAFETY**

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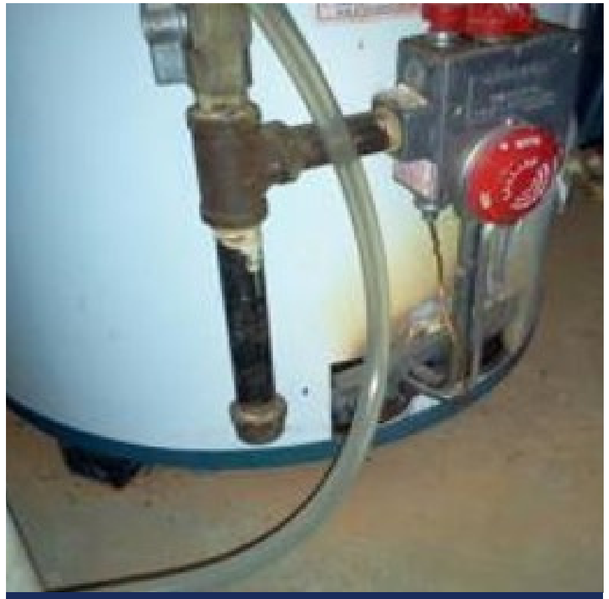
Visual Inspection

Vent damaged, sloped down, or rusted out



Flame rollout or burn marks at bottom access panel

Poor design, too many elbows, long horizontal runs

Corrosion marks at draft diverter indicate spillage

CAZ Issues

NEGATIVE PRESSURE CAUSED BY FANS CAN BACKDRAFT GAS APPLIANCES

Consider:

+Two bath fans: @ 50 cfm each

+Kitchen fan: @ 250 cfm

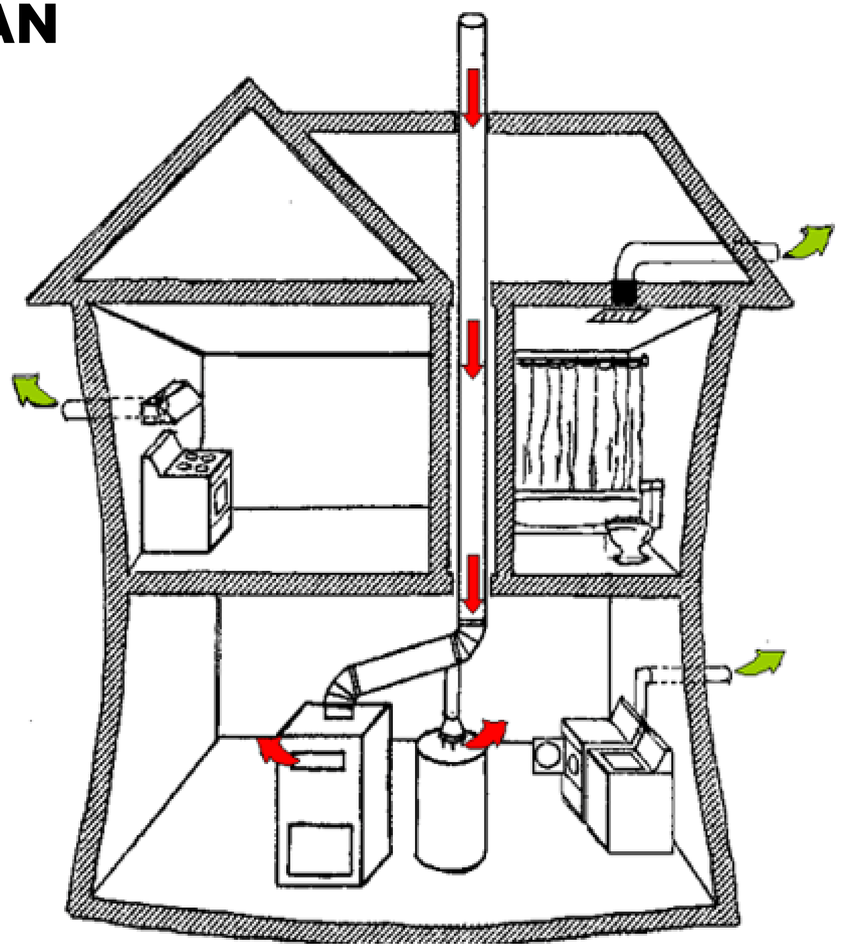
+Dryer: @ 300 cfm

= 600 cfm exhausted from house

+Add in stack effect and wind

= not enough combustion air

THEN think what happens when we make the home more air tight?



AS-6.4 **COMBUSTION SAFETY**

CAZ (Combustion Appliance Zone) Test

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- Locate the CAZ.
- Set the house in winter condition.
- Set up manometer correctly with hose to outside. Read the baseline pressure in CAZ.
- Turn on air handler and set bedroom doors – record AH effect.
- Turn on all fans – kitchen, bath, clothes dryer. Record worst case.
- Change of negative 3 Pa is the limit.
- Inform the customer – Provide and Explain

AS-6.5 COMBUSTION SAFETY

Spillage

BPI - 60 sec
RESNET ch 8 - 5 min

PSE – 5 min

AS-6.6 COMBUSTION SAFETY

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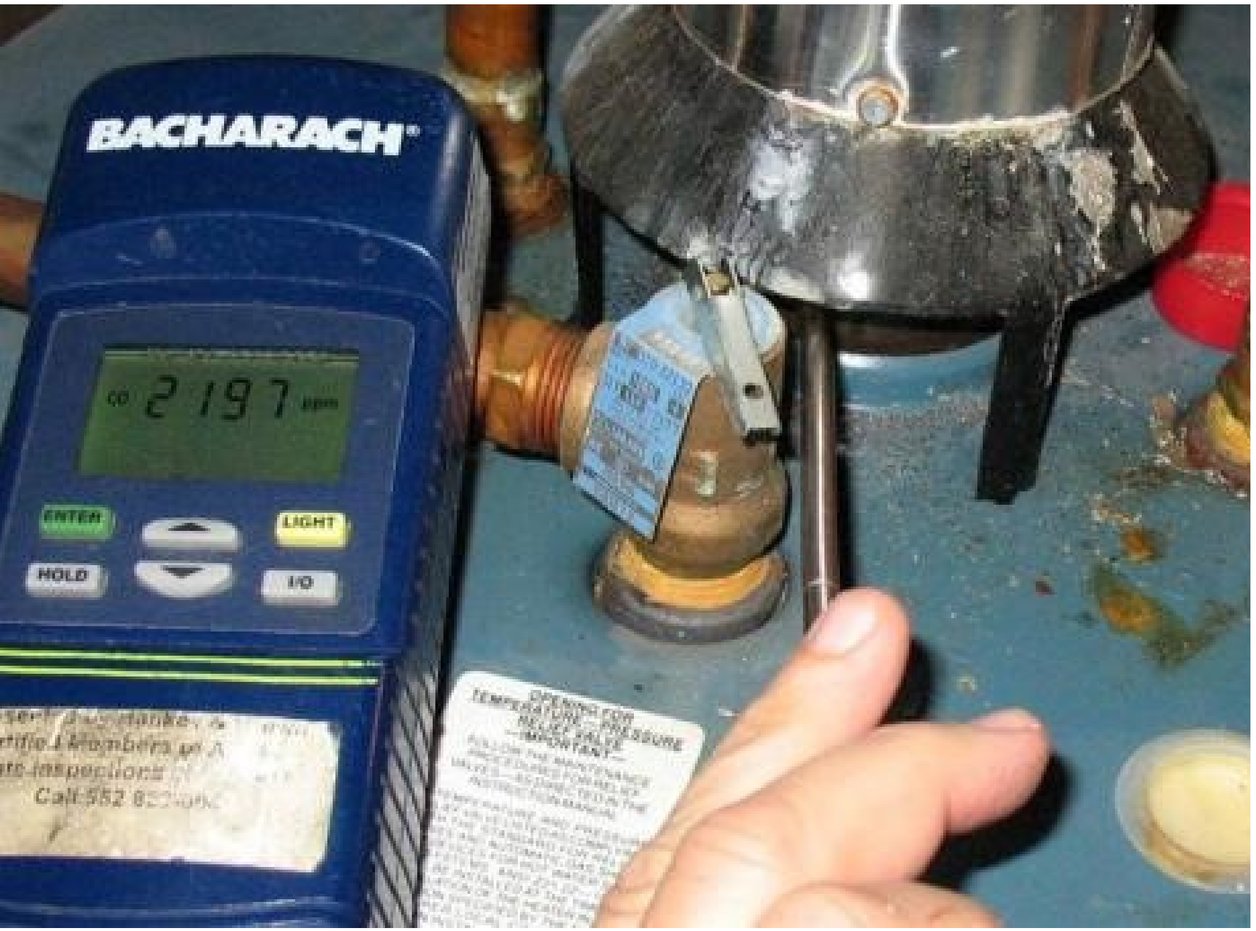
CO in Flue Gas



Test draft if test hole exists – 12” above first elbow

- Warm up 10 minutes
- Zero the meter outside
- Test ppm CO in the throat of flue - to test un-diluted reading

Report your test results on the WEC sticker

Remember...

the whole house is a system!

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