WELCOME!

DAMAGE FROM DUCTING OUTSIDE THE BUILDING ENVELOPE IN RESIDENTIAL CONSTRUCTION

Speakers:

John Kane Greg Labbé





ABOUT US



John Kane is a trainer at Southface Energy Institute. He teaches home performance principles and practice to weatherization staff and private contractors. He has worked as a technical advisor in the EarthCraft House high performance building program, a remodeling contractor, and a commercial general contractor.





ABOUT US



Greg Labbé is a partner of BlueGreenGroup, a technical services consulting group that offers building shell upgrading, diagnostics, testing and rating.

Prior to this Greg worked over a dozen years with the venerable non-profit GreenSaver managing and training a slew of energy auditors, insulators, air sealers and was Director of Consulting Services.





ABOUT YOU?

Raters?

Home Inspectors?

Insulators?

Weatherization Professionals?

Trainers?

New to the industry?

- >1 year
- >5 years
- >10 years





AGENDA

Introduction

Building science

Why ductwork should be inside

Messy mixed-climate duct systems

Three Canadian case studies

Best practices





OUR GOALS TODAY:

Explain some basic building science concepts for the home performance industry

Provide field observations (everyday horror stories)

Discuss best practices.

Demonstrate that putting ductwork in unconditioned spaces is at best risky and inefficient, and at worst catastrophic.





INTRODUCTION

Keeping our homes comfortable means conditioning them.

For optimum comfort, we must consider several factors:

- · Air temperature
- Radiant temperature
- Air movement
- Humidity (ideally around 30-50% RH)

Conditioning that space costs money; significantly more money depending on the effectiveness of the building shell and mechanical systems





ASSUMPTIONS WE'LL MAKE...

Attics, garages and ventilated crawl spaces are unconditioned and are cold in winter and hot in summer.

Ductwork is usually leaky and poorly insulated.

Ductwork is rarely inspected for air tightness or insulation quality.





WHAT'S THE PENALTY FOR PUTTING THE DUCT SYSTEM OUTSIDE?

If ducts are in good condition, studies show that around 20% of the output of an air conditioner is lost when the distribution system runs through an unconditioned space.

Let's assume it's about the same or more for heating season.

Jump, Walker & Modera 1996; Hedrick 2003





RESULT

Anyone who's inspected attic duct work knows they are rarely well insulated, rarely have all seams sealed, often have exposed metal walls and can sometimes be open at seams, disconnected entirely or crushed.

Therefore a 20% efficiency penalty is a conservative estimate, especially if the entire system (ducts and air handler are outside the thermal boundary).





WHAT DOES THIS REALLY MEAN?

A 15 SEER A/C with ducts running through the attic will operate like a 12 SEER unit!

(Neal 1998).





ADDING INSULT TO INJURY

Barring the energy losses, there are devastating effects leaky ductwork can have on the health of its occupants and the structure of the house.

They contribute to Indoor Air Quality:

- Mold
- Foul smells
- Dust
- · Humidity loss or gain

In northern climes, they often produce ice damming.





WHY DOES THIS STILL HAPPEN?

Convenience and cost:

- In new construction, builders want to maximize the finished square footage
- In retrofit work, space for mechanical systems may be limited
- Short term, upfront savings benefit the builder; increased lifecycle costs impact the owner for the life of the building

Inertia: this is the way we've always done it

Lack of education: we don't know any better

Lack of strong energy codes, code enforcement, and incentives



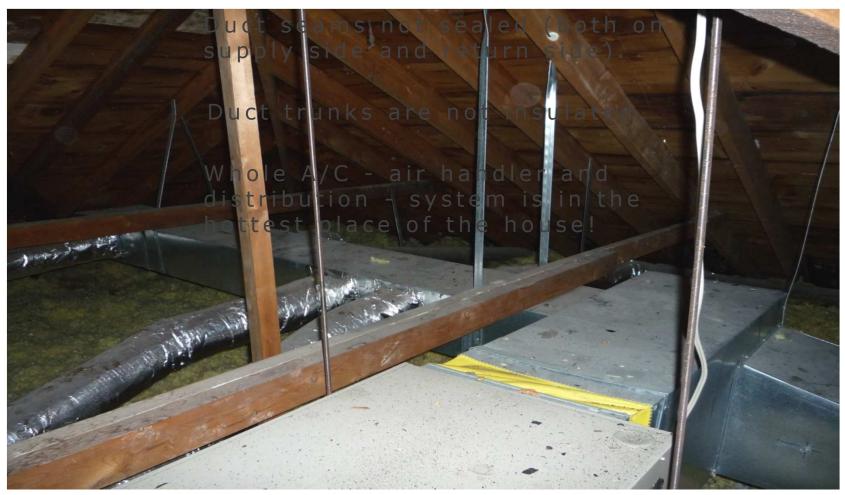








ANSWERS







BUILDING SCIENCE BACKGROUNDER

What makes air move?

How is heat lost/gained?

What's a thermal boundary?





WHAT MAKES AIR MOVE?

A hole or free passage

A pressure or temperature difference

"Do ducts ever provide a hole and a pressure difference?"





IT'S ONLY AIR! RELAX!!

Uncontrolled air movement is always risky.

Air is the vehicle that carries moisture and energy loss.

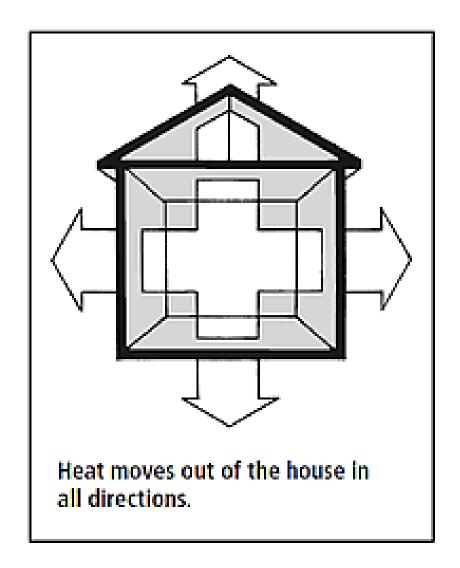
If air moves, moisture moves.

1st Priority: Control air leakage





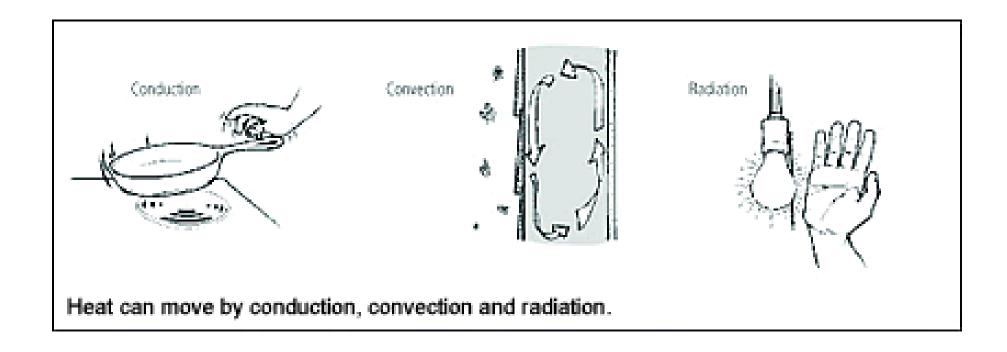
HOW DOES HEAT MOVE?







HOW IS HEAT LOST OR GAINED?







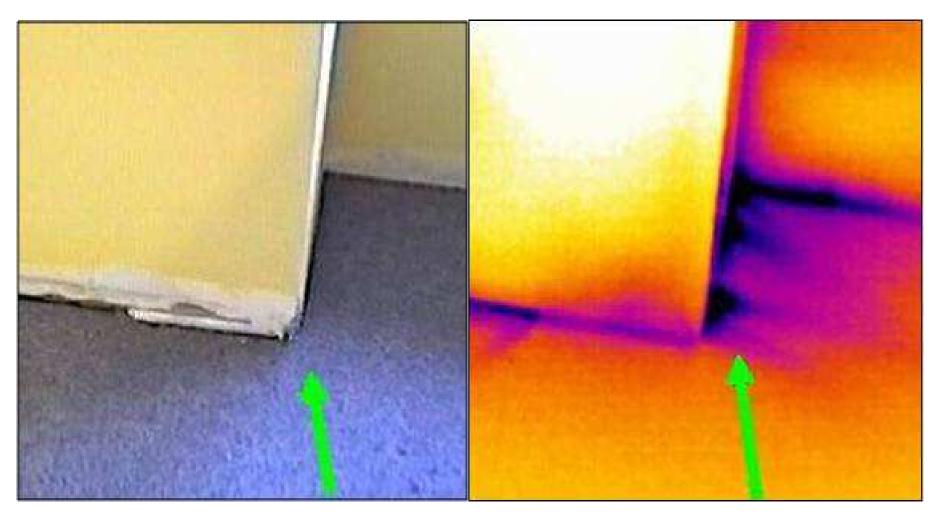
CONDUCTION







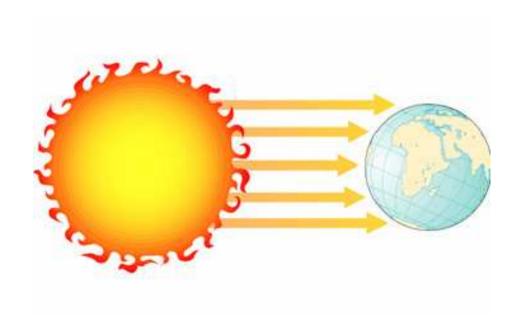
CONVECTION







RADIATION







WHAT AFFECTS THE RATE OF HEAT LOSS?

The rate of heat transfer through a wall or duct is a function of:

- 1. The R value of the wall or duct
- 2. The difference in temperature





RATE OF HEAT LOSS

The greater the temperature difference, the faster the heat transfer.

Logic dictates the greater the temperature difference, the more insulation should be added...

...so let me pose a question. In most of the USA attic insulation is required to be between R-30 and R-48, so what is the requirement for duct insulation in attics?

A:The 2009 IECC requires even lower R-values on ductwork: R-8 on supplies in attics, R-6 on all ducts elsewhere outside the thermal envelope

2nd Priority: More Insulation





ABOUT BUILDINGS AND THEIR THERMAL BOUNDARY

A home's thermal boundary is defined as the insulation & air barrier layer that separates the inside conditioned air from the great outdoors.

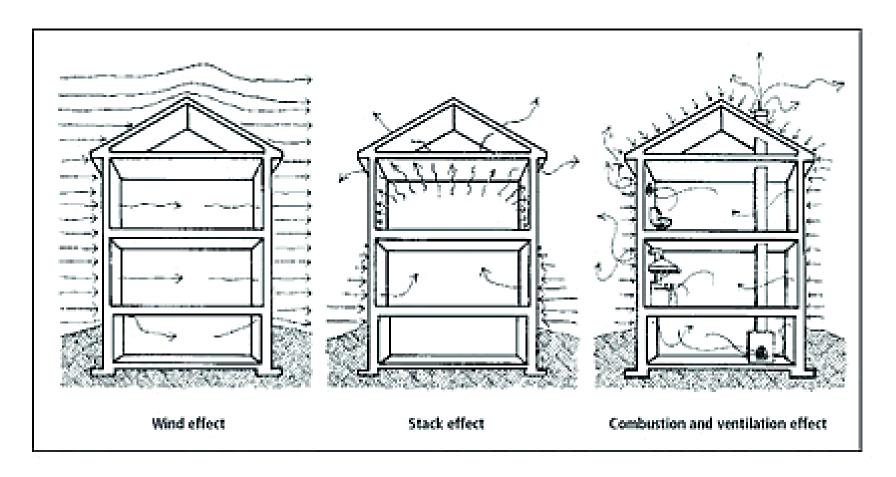
A home's thermal boundary is under constant and variable pressure due to wind, temperature and mechanical effects.

Let's take a look at those forces...





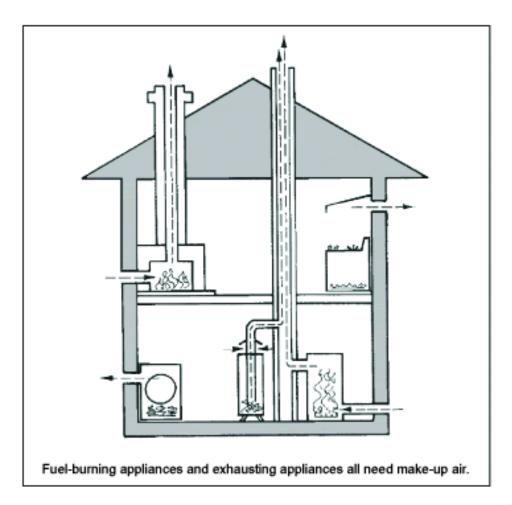
THE FORCES ON THE THERMAL BOUNDARY





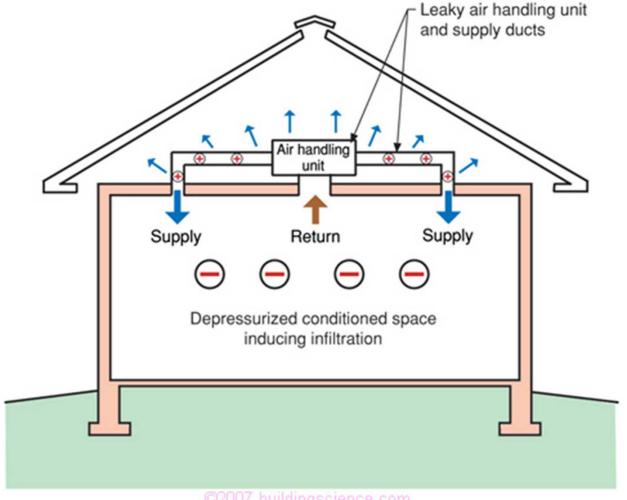


THE MECHANICAL FORCES ON THE THERMAL BOUNDARY









More exposed supply side leakage means hot humid attic, depressed living space constantly washed with fresh outside dry air.

Note: Colored shading depicts the building's thermal barrier and pressure boundary. The thermal barrier and pressure boundary enclose the conditioned space.



www.buildingscience. com BSD-102: **Understanding Attic** Ventilation



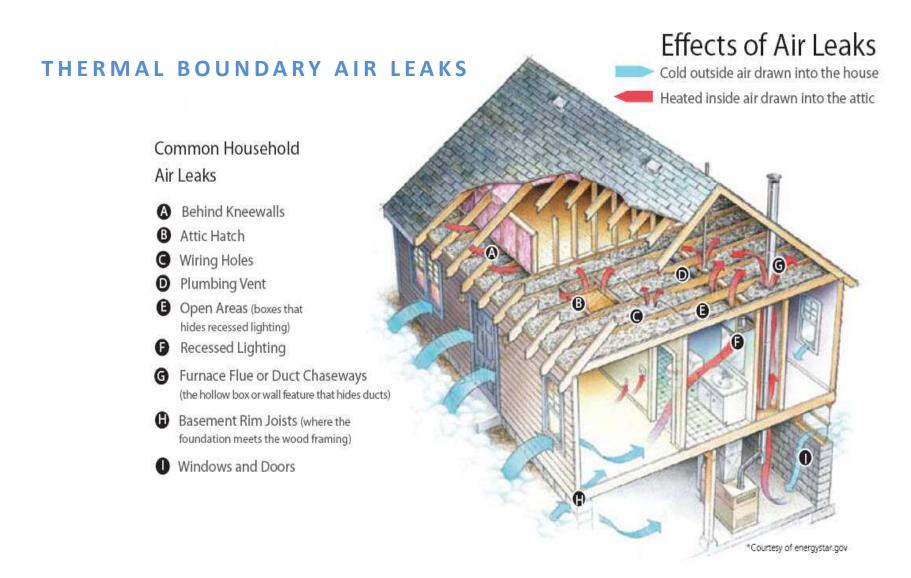
EXERCISE

In the following 3 slides

- 1- draw the thermal boundary and
- 2- identify potential weaknesses.

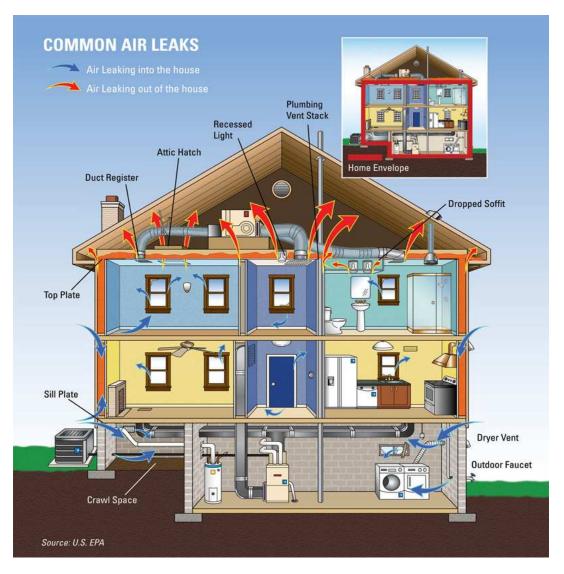










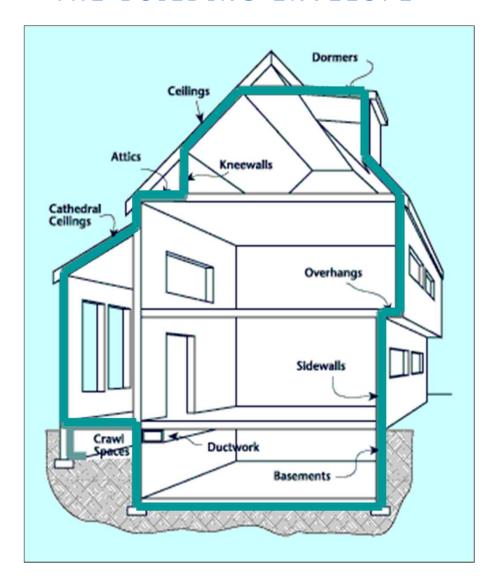




Note the red arrows where stack effect is forcing out conditioned air **Southface**



THE BUILDING ENVELOPE







EXAMPLES OF DUCTWORK OUTSIDE THE BUILDING ENVELOPE

Let's discuss the potential energy, comfort, and indoor air quality (IAQ) issues presented by the following cases:

























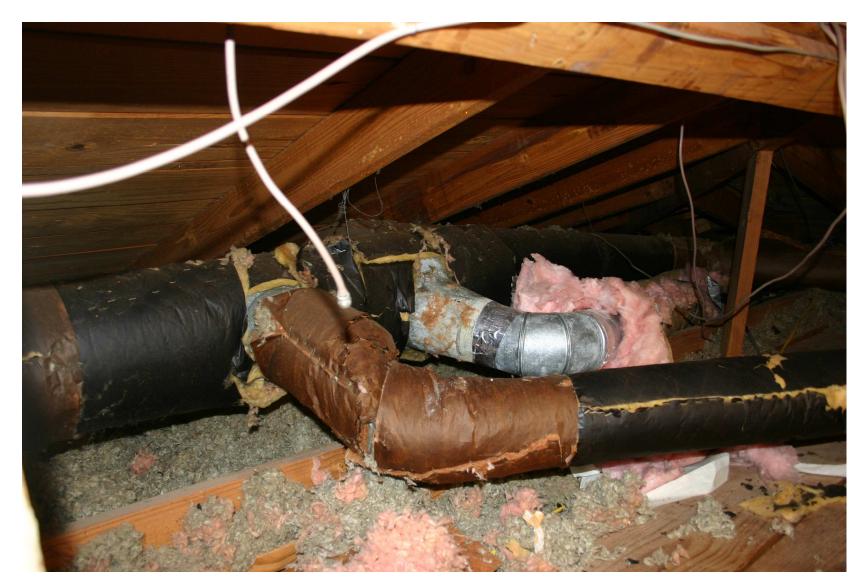




























PUT YOUR COAT & TUQUE ON; WE'RE HEADING NORTH EH!

Homes in a Southern climate suffer from bad design just like the North.

But what ever the South suffers, the North suffers MORE!





OTHER CONSEQUENCES IN THE NORTH?

If a home's thermal boundary is severely breached or has a distribution system that's actively pumping air (therefore warmth and moisture) into an attic, what's the worst that can happen in a northerly climate?















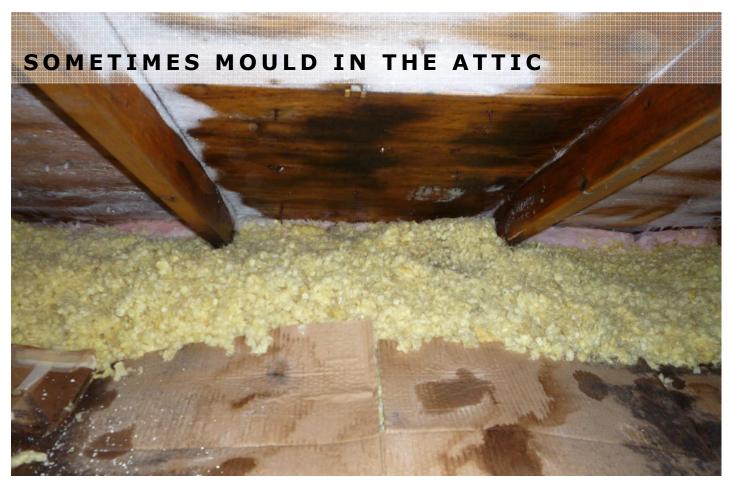
What's so bad about ice? It's serious when insurance companies get called in.

Southface









From inside the attic, a look towards the eaves. This sheathing will need to be replaced.





THREE CASE STUDIES FROM A NORTHERN CLIMATE

Let's examine the consequences of 3 cases where HVAC equipment was installed in unconditioned spaces.

1st Mr. Foam's moisture issues.

2nd Mrs. Fish's crawl space pond.

3rd Mr. Mouse's bone-chilling crawl.











MR. FOAM'S CONCERNS:

Mr. Foam's contractor renovated the 80 year old luxury home with lots of mechanical equipment; some in the basement, some in a "Dog House".

No expense was spared; quality gear and quality products were selected.

The complaint: it was too dry in the house. As a man of character Mr. Foam prefers solid wood to particle boards & plywoods and the exquisite finishes were cracking at 25%RH.





WHAT'S A 'DOG HOUSE'?



It's the easy answer to "Where do I put all this mechanical gear?"

The dog, like the doghouse is always given short shrift...

Dog houses are quickly built, leaky, poorly insulated and nobody ever inspects it.

How about a tour?













An ERV and 6 inline exhaust fans.







An A/C air handler and a pair of Honeywell steam humidifiers (note leak on right unit).









The main door out of the dog house into the attic, and the floor ceiling hatch from the living space into the dog house. Southface



WHAT DID WE SEE? - A SEA of FOAM!

We saw lots of foam; blue (2 lbs/closed cell), beige (½ lbs/open cell) covering the entire attic floor and some kit foam to boot.

Some vertical foamed "solar tubes."

Un-insulated, leaky dog house door.

100's of meters of metal ducts spray foamed both against the attic floor or suspended from the rafters.





Again, "Where's the moisture?"

Mr. Foam was paying to keep the living space in the house warm and humid (aiming for 55%RH).

Sounds reasonable.





THE KEY IS IN THE ATTIC

"The good stuff is always in the attic; never give up the chance to have a look in there!"

Mentor Dave Baerg





FOUND THE MOISTURE!



It's condensed in the attic's wood structure!

Yes that's an MC of 22 on a cold dry winter's day.























SO WHAT HAPPENED?

How did the output of two Honeywell steam generators end up in Mr. Foam's attic and not his living space?





"WHY'D THE MOISTURE MOVE?"

With the air handler running nearly all the time (it was controlled by the humidistat) the pressure inside the dog house was nearly 8 Pa of pressure!

The attic had hundreds of feet of foamed duct runs from 16"x16"trucks to 4" diameter.

That's a lot of joints to seal.







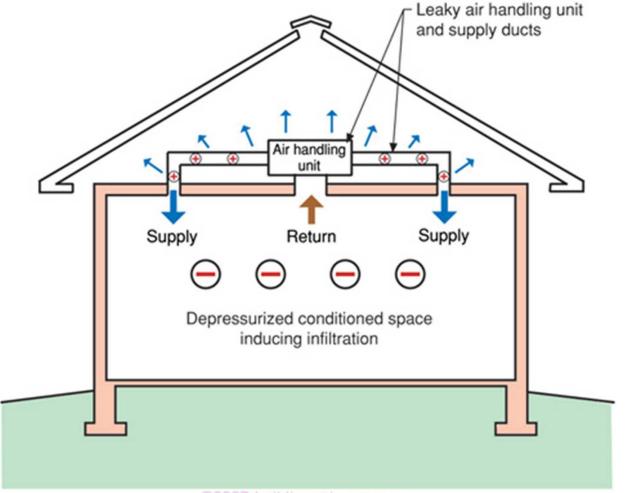
THE PRESSURE DID IT!

If the difference between the outside air and the dog house was 8 Pa, the pressure between the duct's inside and the atmosphere was even greater.

Every time the air handler went on - which was always because they were calling for more humidity - a large fraction of moist warm air was pushed into the cold attic.







Remember this slide?

www.buildingscience.
com BSD-102:
Understanding Attic
Ventilation

©2007 buildingscience.com

Note: Colored shading depicts the building's thermal barrier and pressure boundary. The thermal barrier and pressure boundary enclose the conditioned space.





"...Spray foam should fix it!..."

The contractor thought he could count on high tech solutions to work around bad design.

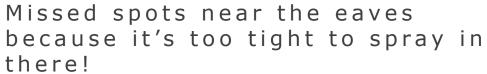
Expensive Spray foam will fail as spectacularly as any other cheaper material if not installed properly.

Hire an experienced sprayer, inspect and <u>test</u> the work!













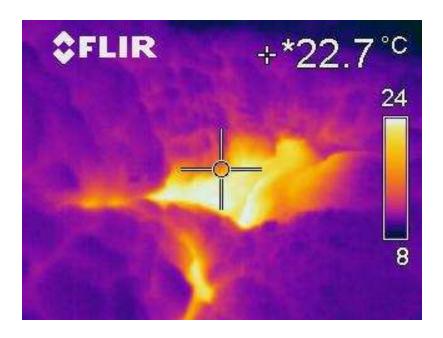


Many 'blisters' (painted orange) were found throughout the ½ pound foam. When presurised they leaked a lot of air. Foam was unattached or delaminated.





WHERE DID THE FOAM FAIL?



The blisters were nearly 14°C hotter than the surrounding foam.





NOTES ON SPRAY FOAM

Foam adhesion needs a clean, dry, unfrozen and preferably even substrate.

An attic floor is rarely a clean, even substrate.

New ductwork can be coated with a fine oil.

The sprayer needs to spray the face of the substrate in question squarely with as much as 3' of clearance. Ducts shoved in the eaves won't be done well.





MORAL OF THE STORY?

Ducts in attics, no matter how much money you throw at them are a design flaw that can compromise the structure of the home in no time.

Or....

Inspect the work you commission for quality with a blower door and IR camera.











MRS. FISH'S CONCERNS:

Her siding contractor refused (wisely) to re-side the house because the 1970's OBS sheathing was black and rotting.

Mrs. Fish said it smelled stuffy even a bit moldy in-house.

Mrs. Fish couldn't get humidity below 80% in winter. Note the house was not air tight.







OSB WITH MC OF 80*!!

Good for "shrooms", bad for sheathing.

*Let's just say an MC of 20-30 is leads to decomposition, and the wood was damp to the touch.





DOWN THE HATCH WE GO...

Note the fan?







EMPLOYEE OF THE MONTH: SHERVIN AKHAVI







SEE ANYTHING FISHY?

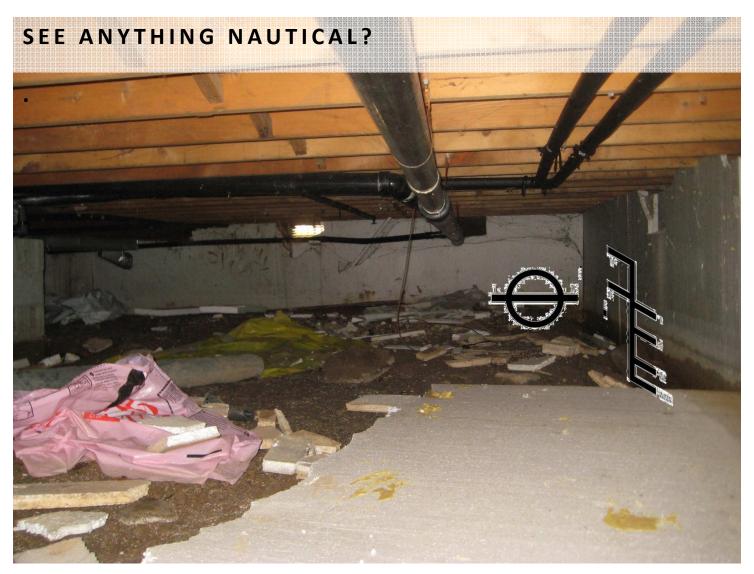






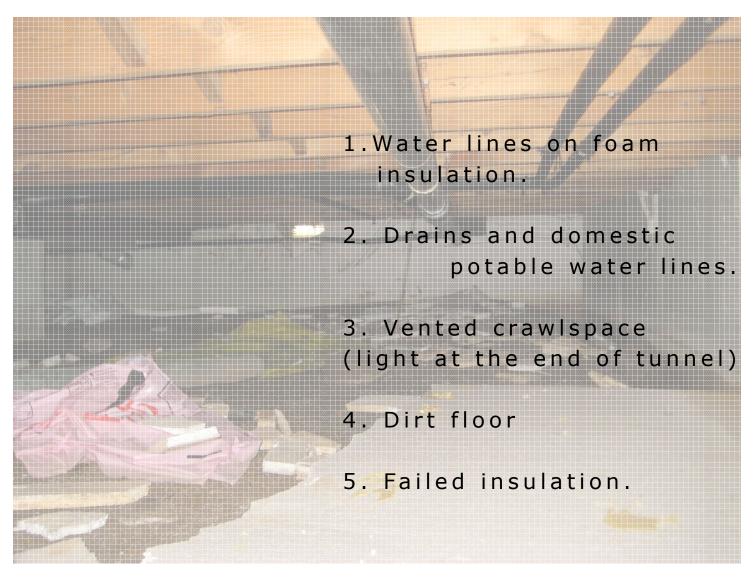












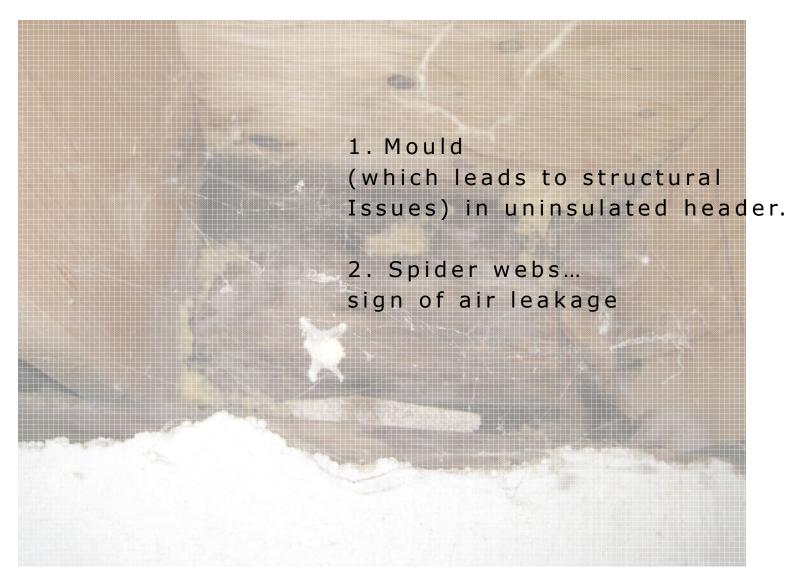












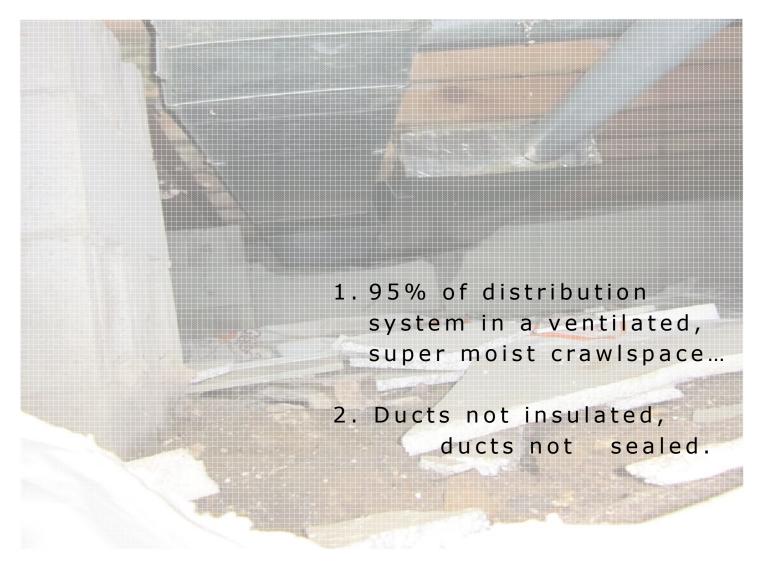
















Result of Ducts in unconditioned space?

Mrs. Fish was unintentionally paying to import crawl space air - through unsealed ductwork - which included mould and lots of moisture, into living space.

In turn, that high moisture content being driven into the outside walls because of poor air barrier details, led to the deterioration of her sheathing.



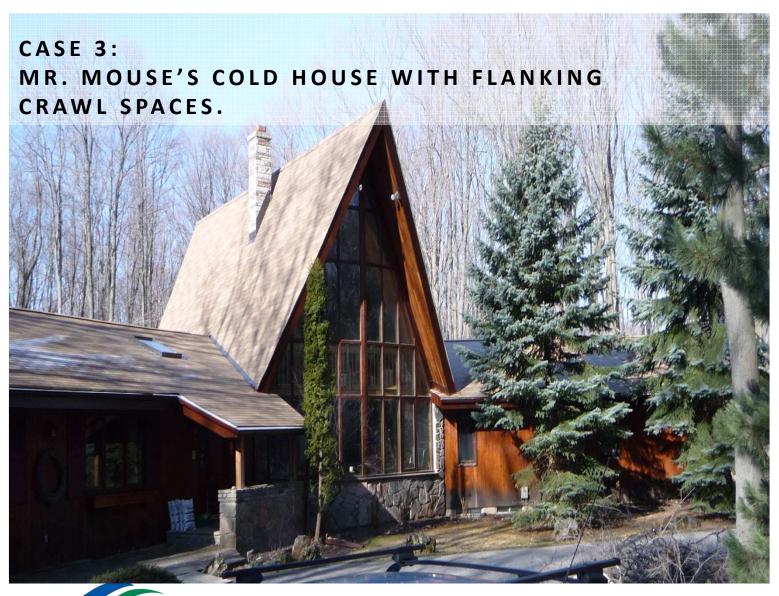


MORAL OF THE STORY?

Ducts in wet crawl spaces are detrimental to health and risk reducing the longevity of the structure.









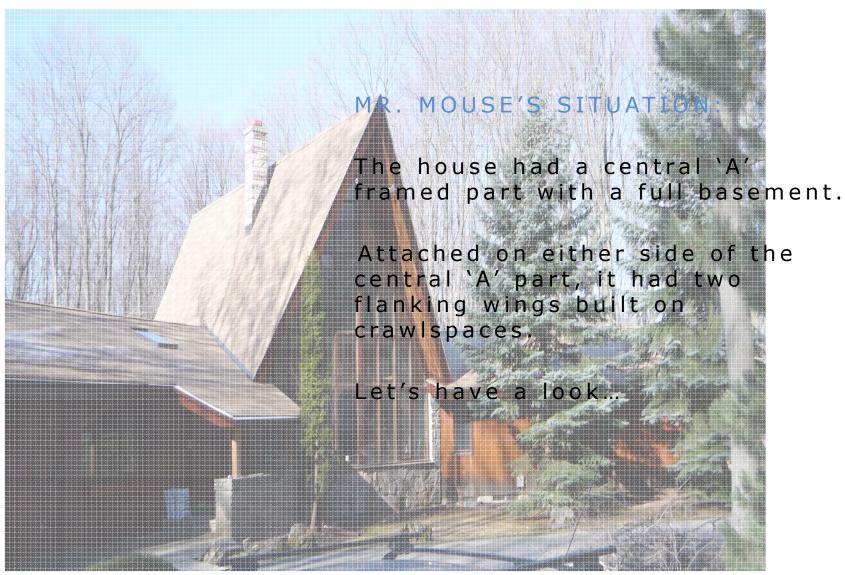


MR. MOUSE'S ISSUES:

On cold days, the house even with two generously sized, two stage furnaces could not keep the house comfortable.























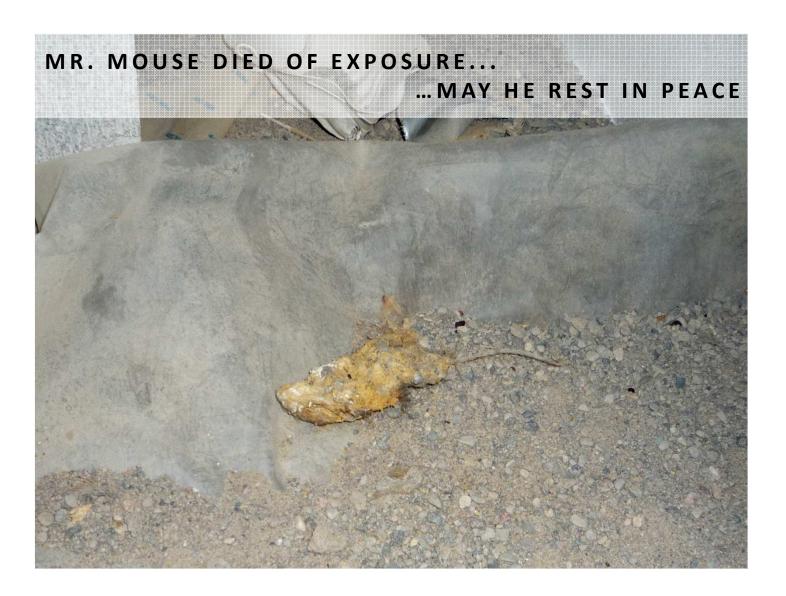


- 2. Get this: Floor cavity is insulated, ducts are not! Bare copper water lines!!
- 3. Ducts not air sealed or insulated.
- 4. Space was IAQ nightmare.

The crawl space shown above was twice as big in area. The same situation on the other side of the house.



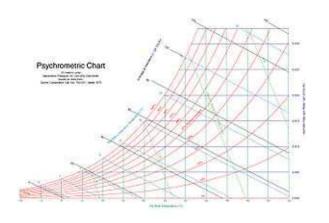








RESULT OF DUCTS IN UNCONDITIONED SPACE?



<u>Heating season loss:</u>

Phenomenal loss of efficiency as ducts are bare, leaky and outside.

Cooling season loss:

The return side of the ducts in that super humid crawl means the AC has to surmount not only the sensible but the huge amount of latent heat added in the form of humidity.





MORAL OF THE STORY

Ducts in unconditioned crawl spaces will cost you a lot of money and make you very uncomfortable!





IF THESE 3 CASE STUDIES TELL US SOMETHING...

WHAT IS IT?







Keep the duct work inside the thermal envelope, and <u>design</u> a better system.





DUCTS OUTSIDE THE ENVELOPE ARE A DESIGN ISSUE THAT'S ALIVE AND WELL NOW.



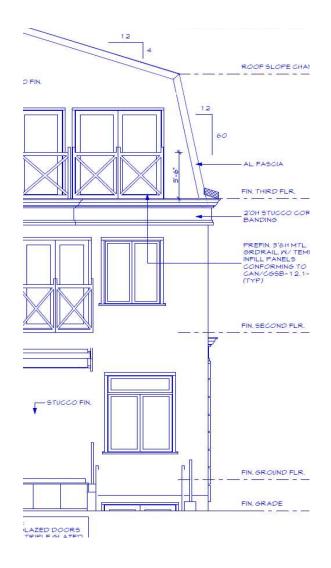












MANSARDS ARE TRICKY

Mansard roofs are complicated for many reasons and often suffer from ice damming as a general design flaw.

Mansards were for tax evasion, not northern climate.

Before you touch an attic in a Mansard style house, get a 2nd opinion.







INDOOR POOLS

Residential pools are not for the faint hearted.

Before you start a pool project get experienced help in designing the system.

Note the large sky lights (condensation traps) and large HVAC ducts.





SEPARATE POOL FROM HOUSE!



Though barely visible in this photo, a supply register was piped into each sky light box to stops the perpetually forming condensation on the skylight.

Note the source of conditioned air to those skylight boxes...

The duct goes from inside the thermal envelope, crosses into an unconditioned space (in this case a flat roof) then distributed to each skylight tube.





IT'S RAINING IN MY BEDROOM...



Everything went well that summer until the cold fall came around...





Before you do this...



This roof top furnace and A/C system was installed because the owner didn't want unsightly bulkheads/drop soffits inside.





...CONSIDER MINI-SPLIT HEAT PUMPS



Instead of the "Space-Pak" A/C system with sprawling 2" ducts littering the attic floor, install mini split heat pumps.

The efficiencies (up to 26 SEER) are ~10 SEER higher than conventional systems. Add to that the 3 SEER you gain for not putting the ducts in the attic to get 13 SEER higher than a "Space Pak".



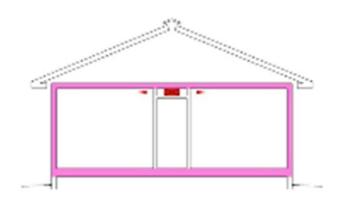


IF YOUR LOOKING FOR ALTERNATIVES TO ATTICS & CRAWLS...

Here are some suggestions that move the thermal barrier out of keep the ducts in.







OPTION 1: DROP CEILING IN HALL FOR THE TOP FLOOR APPARTMENT OR BUNGALOW WITH SLAB ON GRADE

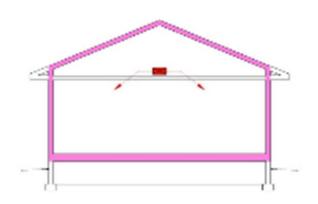
Using the central hall ceiling as a race way for ducting works well especially when the heating cooling loads are small, the windows highly efficient and the supply grill can be located on the wall top along the hall as opposed to "washing the outside wall and window to prevent condensation.

Drawing by created by Earth Advantage Institute (EAI) www.ductsinside.org





OPTION 2: CATHEDRALISE ATTIC



This is a great option for existing homes that have expensive finishes in them and the expense and disruption of running ductwork in the existing thermal boundary is prohibitive.

Get the building inspector on side before you start, use two pound spray foam, clean the outside wall top plates and foam weld from top plate to top plate.

Inspect and test your foam once installed using either or a combination of Infrared thermography and the blower door.

Drawing by created by Earth Advantage Institute (EAI) www.ductsinside.org





WHEN TURNING YOUR ATTIC INTO A "CATHEDRAL" OR CONDITIONED SPACE:

Most rafters aren't deep enough to accommodate enough insulation to meet minimum R-values required by code, especially if the rafter bays includes a ventilation channel.

The foam in this case should be 2 pound foam which is less permeable to vapour diffusion to make a 'hot roof'.

Fiberous batts need a super air tight vapour barrier and you will have to vent the roof deck. This option is not practical if you have trusses.

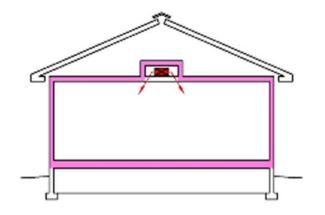












OPTION 3: CUSTOM TRUSSES FOR THE BUNGALOW ON GRADE.

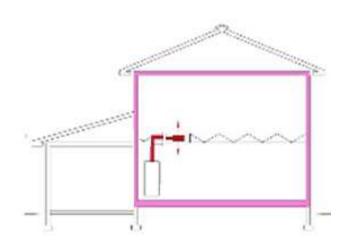
Having trusses manufactured with a chase along the central part of the ceiling like a "coffered" style indent

Drawing by created by Earth Advantage Institute (EAI) www.ductsinside.org





OPTION 3: FLOOR JOIST CAVITY



Wood web engineered joists cost on average \$1.50ea more than dimensional lumber for the same span, are always straight, have a huge surface to nail/crew to and have lots of room for the plumber, electrician and HVAC trades to share.

Edited drawing by created by Earth Advantage Institute (EAI) www.ductsinside.org











STILL WANT DUCT WORK IN THERE?

5 rules that will make ductwork in unconditioned spaces better:

- 1. Seal all joints and penetrations through the thermal boundary.
- 2. Test and confirm minimal leakage.
- 3. Insulate all duct surfaces with more than code minimums.
- 4. Infrared scan your insulated ducts by a qualified professional.
- 5. Keep ducts low to the attic floor so you can either 'foam weld' them to the attic floor or mound them with R60+ of cellulose.







PARTING WORDS...

If your name is on the job, inspect and test your work!

For an excellent treatise on the subject please refer to:

Earth Advantage Institute (EAI) www.ductsinside.org.





MORE GREAT LINKS

Martin Holladay www.GreenBuildingAdvisor.com

John Straub and Joe Lstiburek www.buildingscience.com





QUESTIONS?

Thanks for listening.

We hope you enjoyed and learned something from this session.

Please visit us at:

www.southface.org

www.bluegreengoup.ca







