Historic England
Traditional roofs: Repair and conservation
Church House, London, 3 March 2020

Moisture-related risks in roof spaces: *principles and effect of modern practices*

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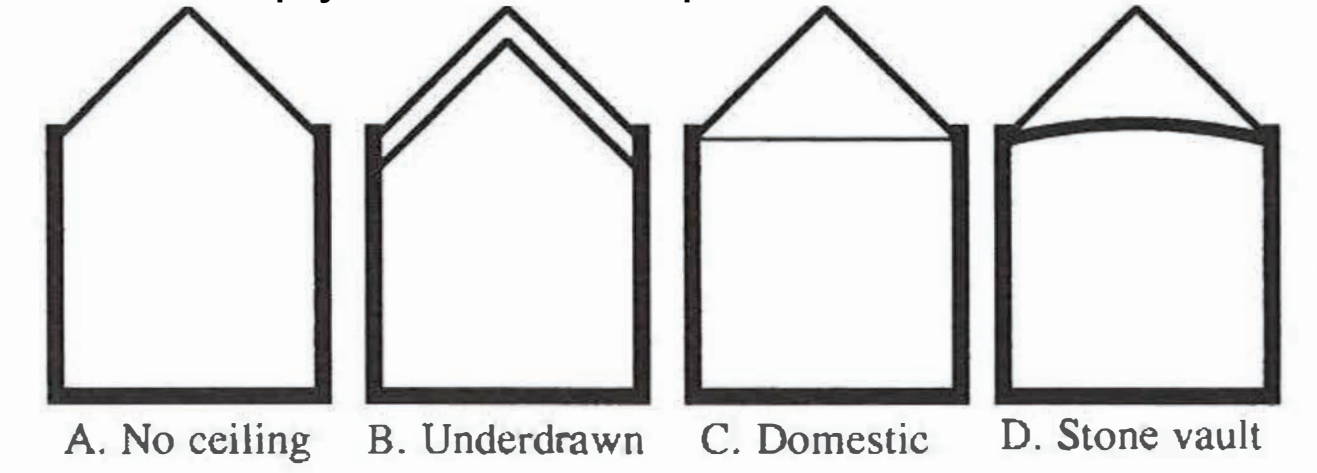
Structure of the talk

1. BACKGROUND
2. ROOF INSULATION: *Some modern practices*
3. INTERNAL ENVIRONMENT: *What might have changed?*
4. SOME EXAMPLES *for domestic pitched roofs*
5. CONCLUSIONS
6. DISCUSSION

1
BACKGROUND

Summary of current position

- Traditional roofs often lasted well, *with appropriate maintenance.*
- *Even without good maintenance,* many lasted quite well too.
- Many do not comply with modern practice.



- *"Improvements" have sometimes created new problems.*

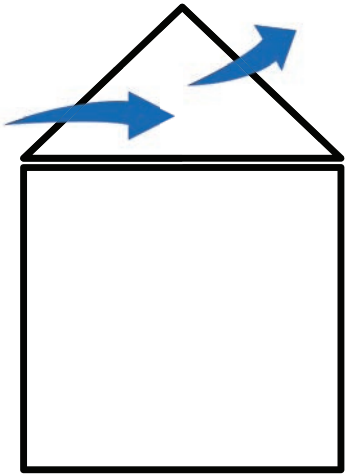
SOURCE: B Bordass, English Heritage Research Transactions, Volume 1, *Metals* (April 1998), figure 4, page 36.

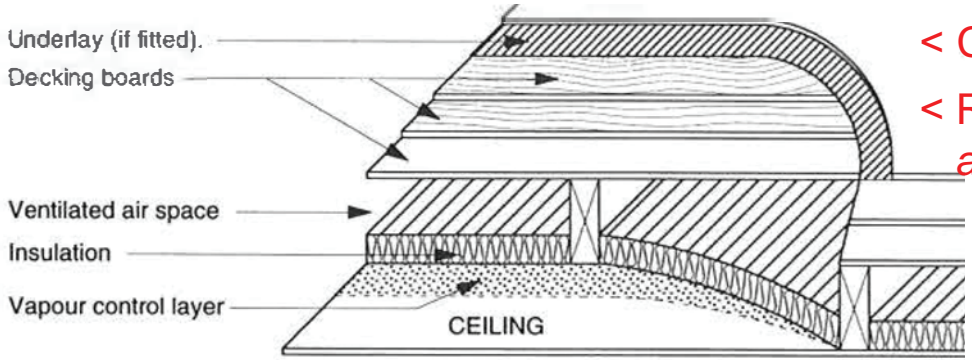
2
ROOF INSULATION
some modern practices

Roof insulation: Some modern principles:
"COLD ROOF"

Insulation above Air and Vapour Control Layer (AVCL) on top of ceiling.
Roof void above well-ventilated by outside air.

- Double-pitched roofs: *Normally works well.*
- Single-pitched roofs: *Need enough ventilation.*
- Flat roofs: *Prone to moisture problems.* ***Avoid.***





< Covering may fail, *lead is prone to this.*

< Roof deck may decay, *from moisture accumulation, locally or generally.*

< Is the ventilation adequate?
< Is the AVCL effective?

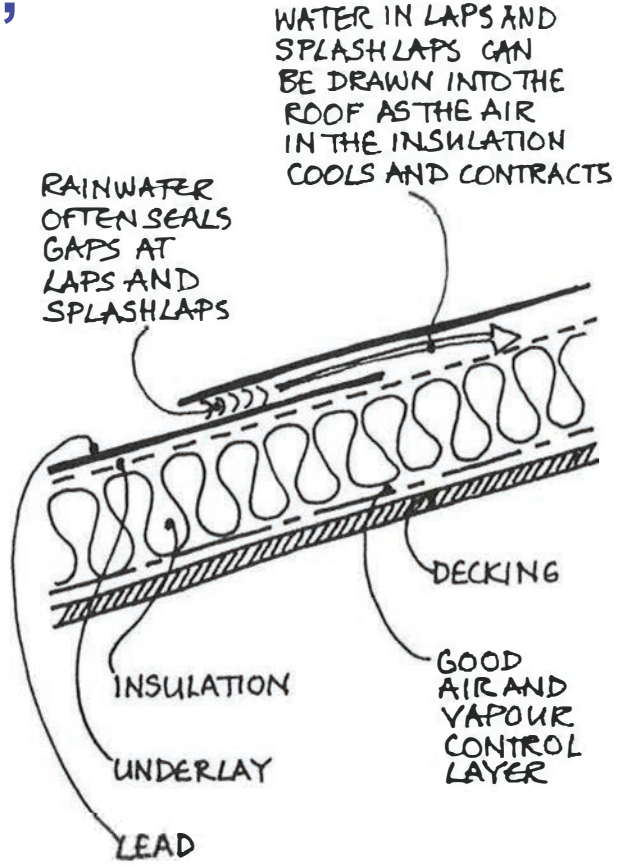
SOURCE of lower diagram: English Heritage Research Transactions, Volume 1, *Metals* (April 1998), figure 3, page 32.

Roof insulation: Some modern principles
"WARM ROOF"

Insulation goes directly below roof covering with an AVCL under that.

Any void spaces between this and the ceiling are within the thermal envelope, *so should not be ventilated by outside air.*

- *Works with loosely-fitting tiles and slates, but there may be issues at the perimeter.*
- *Does not suit roofs clad in lead or other discontinuous materials which fit together with small gaps, which rainwater can seal and then enter by "thermal pumping". Pumping of air alone can sometimes cause problems too.*

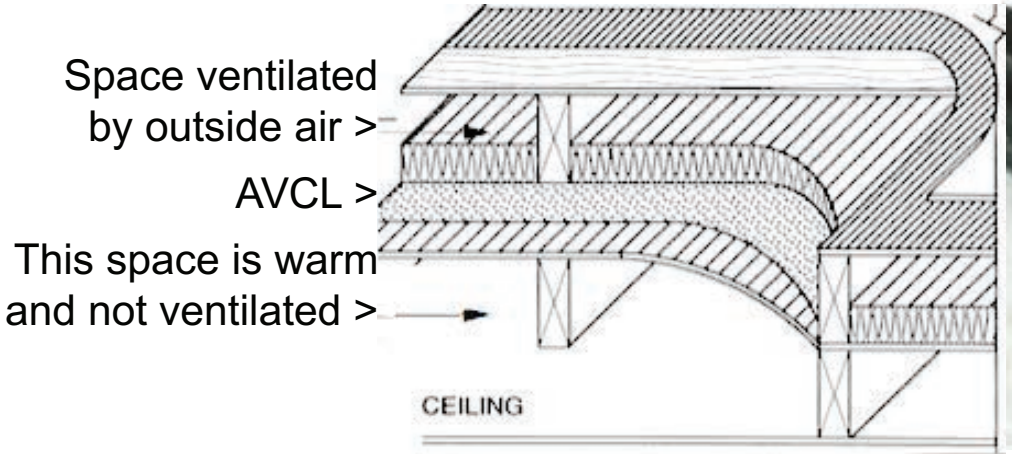


SOURCE: English Heritage, *Lead Roofs on Historic Buildings, Advisory Note* (1997), figure 4.

Roof insulation: Some modern principles
"VENTILATED WARM ROOF" *for lead*

Actually a thin sandwich "cold roof" !

- Needs adequate ventilation *(as with single-pitch "cold roofs").*
  Ideally 50 mm for steep pitch > 25° , 100 mm for shallow pitch, 150 mm if flat.
- AVCL needs to be detailed and installed carefully: *even small air leaks and/or poorly-ventilated pockets can cause local underside corrosion of lead.*

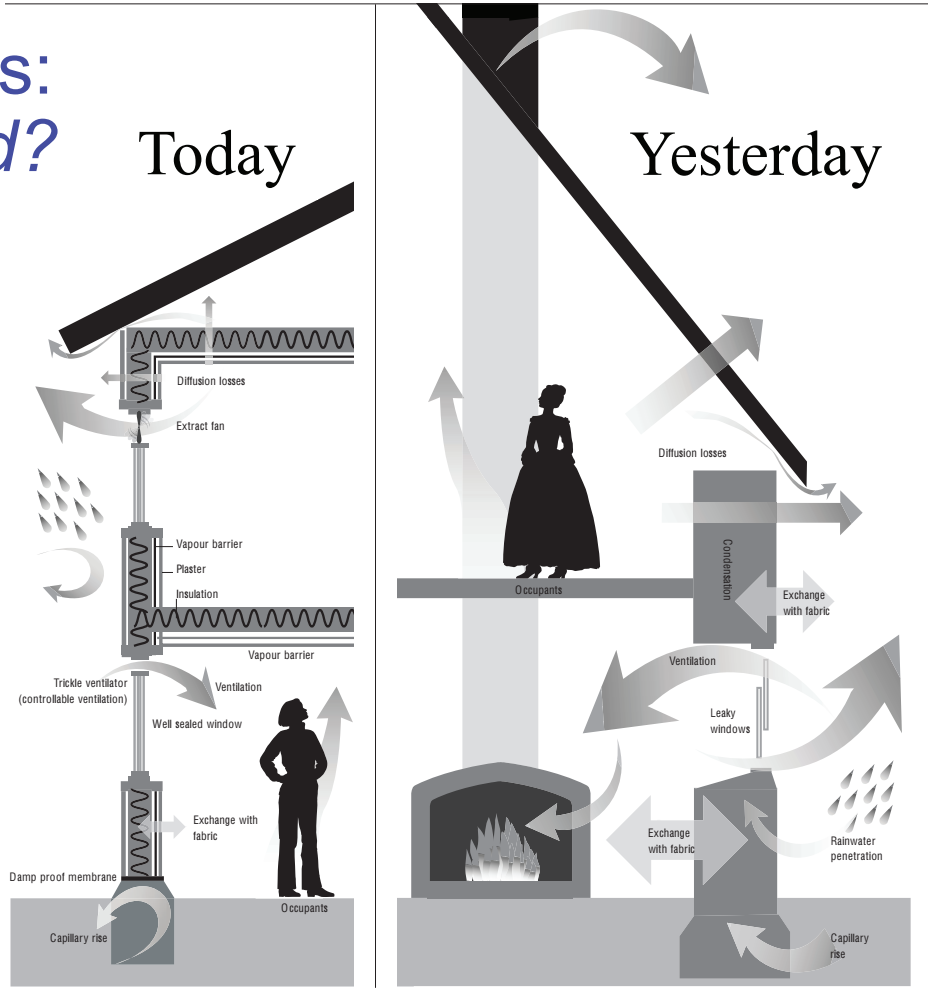


SOURCES: English Heritage Research Transactions, Volume 1 (1998) figure 3, page 32 and Lead Advisory Note (1997), figure 16.

3
INTERNAL ENVIRONMENT
What might have changed?

People and Technologies: *What may have changed?*

- Occupancy and habits.
- Moisture generation.
- Heating and ventilation.
- Services and holes for them.
- Less permeable building materials and finishes: *reduces "sponge effects".*
- "Improvements" *that may compromise mechanisms which used to be protective.*

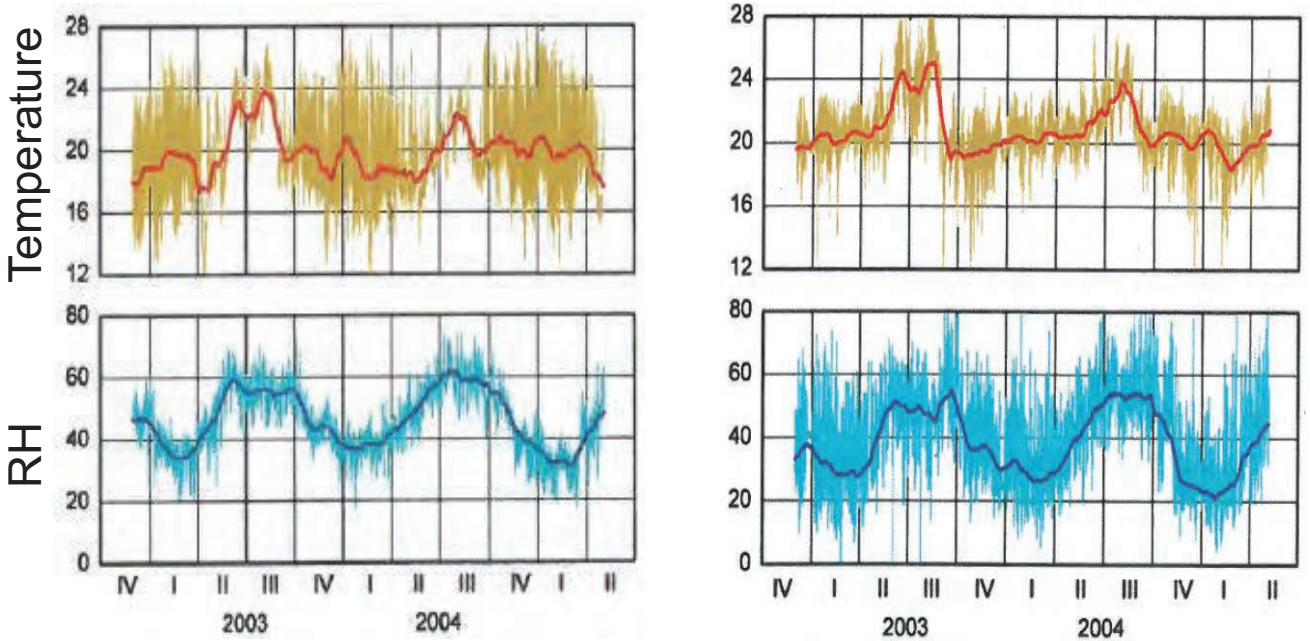


SOURCE: English Heritage, *Building Regulations and Historic Buildings* (2002), figure 3.

Sponge Effects of hygroscopic materials
e.g. timber, lime plaster, porous brick and stone

Traditional brick house
with masonry stove

Modern concrete house
with central heating



<< Data shown by quarter from October 2002 to June 2005. The peaks represent the summers.

<< *The fluctuations in RH are much greater in the modern house, which has less porous materials and finishes,* ***increasing condensation risk***

SOURCE: Fraunhofer Institute, Germany via Thomas Gärtner

4
SOME EXAMPLES
for domestic pitched roofs

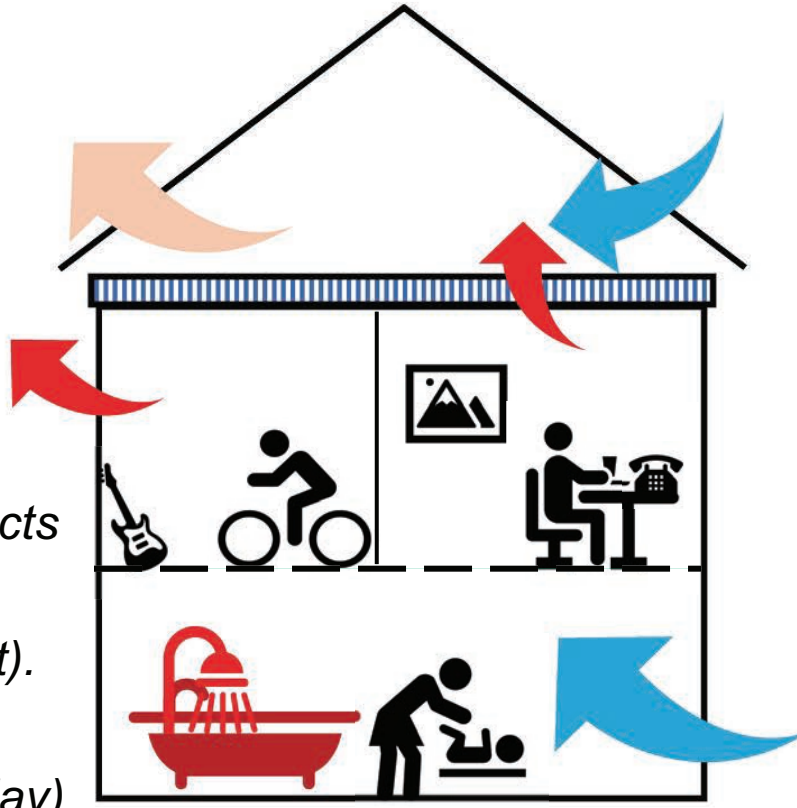
A simple steady-state model: *House and roofspace*

INPUTS

- Indoor temperature and moisture generation.
- Outdoor temperature and relative humidity.
- Air infiltration into house and roofspace.
- Air transfer between house and roofspace.
- Ceiling and roof insulation U-values.

CALCULATED *with no dynamic or sponge effects*

- Indoor relative humidity (RH) and dew point.
- Heat transfer to roofspace *(conduction + vent).*
- Roofspace temperature, RH and dew point.
- Maximum moisture deposition potential *(kg/day).*



Simple model results
Version 1: Typical older house *with typical updates*

ture build-up.
atively dry atmosphere.

IN HE's MONITORED HOUSES

Occupancy	Low
Indoor conditions	
Temperatures	Normal 17-22 C
Moisture	5 kg/day or less
Insulation *(W/m2K)*	
Ceiling U-value	0.2 to 1.0
Rafter level	none, say 5.0
Air infiltration and ventilation	
Into house	0.3 to 1 ac/h
Through ceiling	0 to 0.5 ac/h
Into roofspace	2 to 15 ac/h

Simple model results
Version 2: With higher occupancy, *so more moisture*

Slight moisture build-up.
High RH in house, 81%.

2. Typical older building, high occupancy

INPUT VALUES:

7.0 Outdoor Temperature *(C)*
100% Outdoor Relative Humidity *(RH)*

Indoor conditions

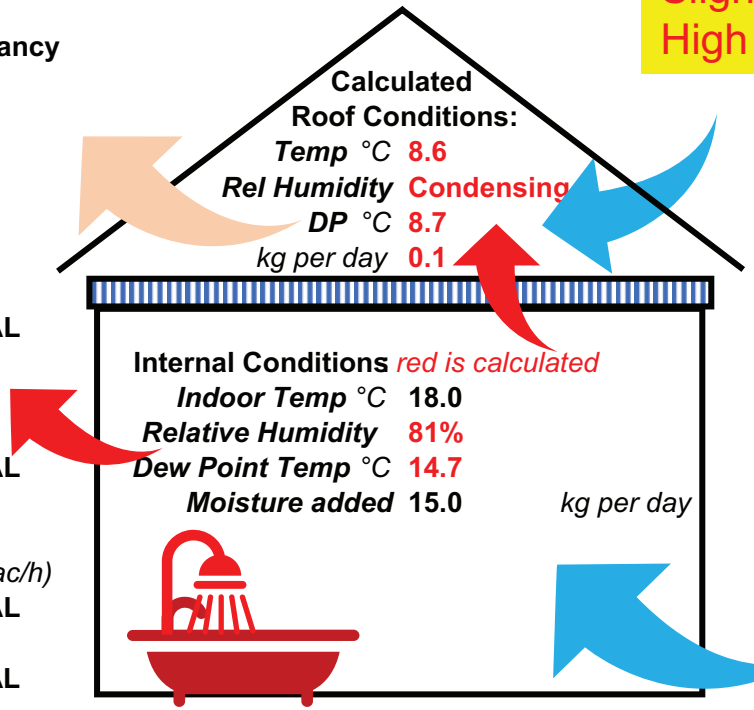
18.0 Inside Temperature *(C)* **TYPICAL**
15.0 *kg/day moisture added* **HIGH**

Insulation U-values *(W/m2K)*

1.0 Ceiling level **TYPICAL**
5.0 Rafter level **NONE**

Air infiltration *(Air Changes per Hour ac/h)*

0.5 *Outside-Inside* **TYPICAL**
50% *Leaves via ceiling* **HIGH**
5.0 *Outside-Roofspace* **TYPICAL**



IN HE's MONITORED HOUSES

Occupancy Low

Indoor conditions

Temperatures Normal 17-22 C
Moisture 5 kg/day or less

Insulation *(W/m2K)*

Ceiling U-value 0.2 to 1.0
Rafter level none, say 5.0

Air infiltration and ventilation

Into house 0.3 to 1 ac/h
Through ceiling 0 to 0.5 ac/h
Into roofspace 2 to 15 ac/h

Simple model results
Version 3: Insulate the ceiling

Significant moisture build-up,
potentially 4.1 kg per day.

3. Typical older building, high occupancy, insulated ceiling

INPUT VALUES:

7.0	Outdoor Temperature *(C)*	
100%	Outdoor Relative Humidity *(RH)*	

Indoor conditions

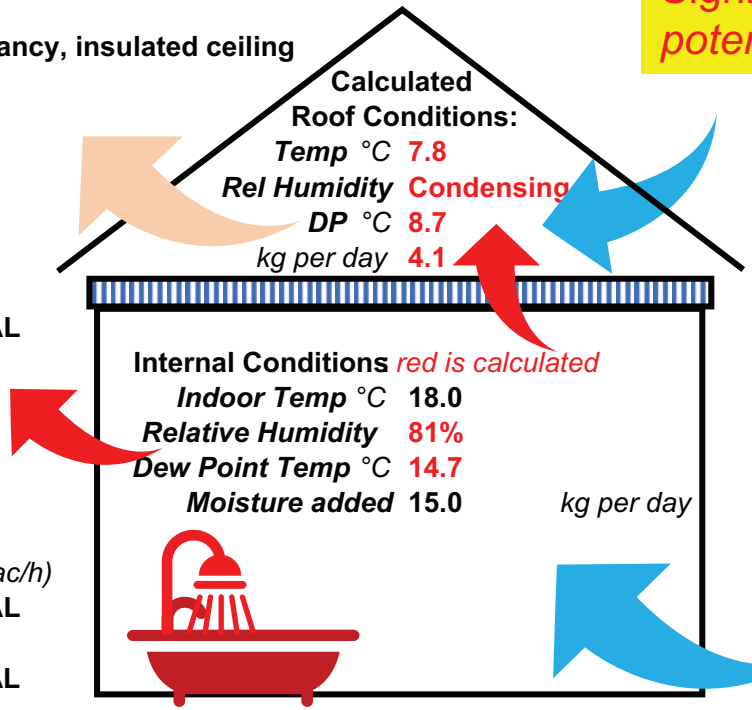
18.0	Inside Temperature *(C)*	**TYPICAL**
15.0	*kg/day moisture added*	**HIGH**

Insulation U-values *(W/m2K)*

0.2	Ceiling level	**HIGH**
5.0	Rafter level	**NONE**

Air infiltration *(Air Changes per Hour ac/h)*

0.5	*Outside-Inside*	**TYPICAL**
50%	*Leaves via ceiling*	**HIGH**
5.0	*Outside-Roofspace*	**TYPICAL**



IN HE's MONITORED HOUSES

Occupancy	Low

Indoor conditions

Temperatures	Normal 17-22 C
Moisture	5 kg/day or less

Insulation *(W/m2K)*

Ceiling U-value	0.2 to 1.0
Rafter level	none, say 5.0

Air infiltration and ventilation

Into house	0.3 to 1 ac/h
Through ceiling	0 to 0.5 ac/h
Into roofspace	2 to 15 ac/h

Simple model results
Version 4: Seal the insulated ceiling

Moisture build-up in Version 3 has stopped, *but air in roof is on verge of saturation.*

4. Older building, high occupancy, insulated, sealed ceiling

INPUT VALUES:

7.0	Outdoor Temperature *(C)*	
100%	Outdoor Relative Humidity *(RH)*	

Indoor conditions

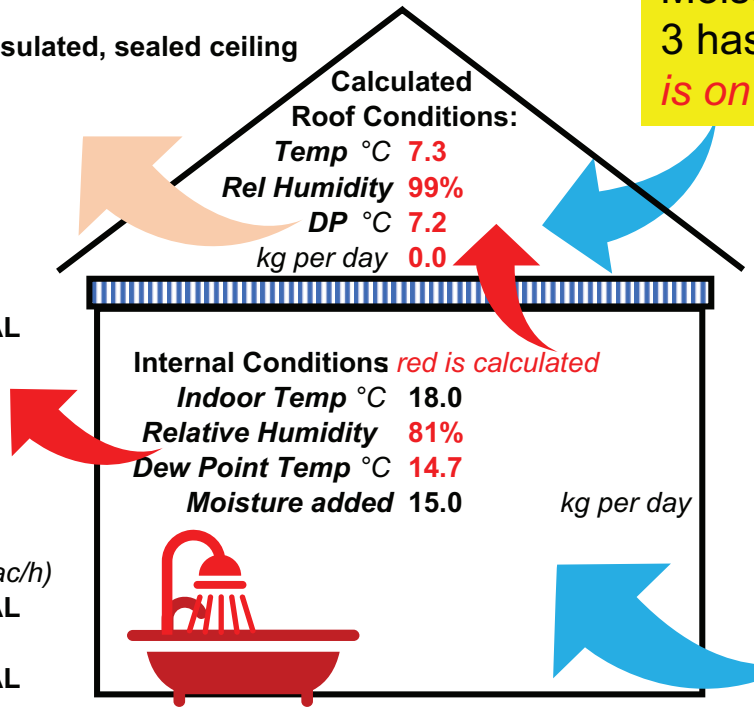
18.0	Inside Temperature *(C)*	**TYPICAL**
15.0	*kg/day moisture added*	**HIGH**

Insulation U-values *(W/m2K)*

0.2	Ceiling level	**HIGH**
5.0	Rafter level	**NONE**

Air infiltration *(Air Changes per Hour ac/h)*

0.5	*Outside-Inside*	**TYPICAL**
5%	*Leaves via ceiling*	**SMALL**
5.0	*Outside-Roofspace*	**TYPICAL**



IN HE's MONITORED HOUSES

Occupancy	Low

Indoor conditions

Temperatures	Normal 17-22 C
Moisture	5 kg/day or less

Insulation *(W/m2K)*

Ceiling U-value	0.2 to 1.0
Rafter level	none, say 5.0

Air infiltration and ventilation

Into house	0.3 to 1 ac/h
Through ceiling	0 to 0.5 ac/h
Into roofspace	2 to 15 ac/h

Simple model results
Version 5: Increase roof ventilation, keep leaky ceiling

Moisture build-up much less than in Version 3, *but ceiling needs to be made tighter too.*

5. Older building, high occupancy, insulated ceiling, draughty roof

INPUT VALUES:

7.0	Outdoor Temperature *(C)*	
100%	Outdoor Relative Humidity *(RH)*	

Indoor conditions

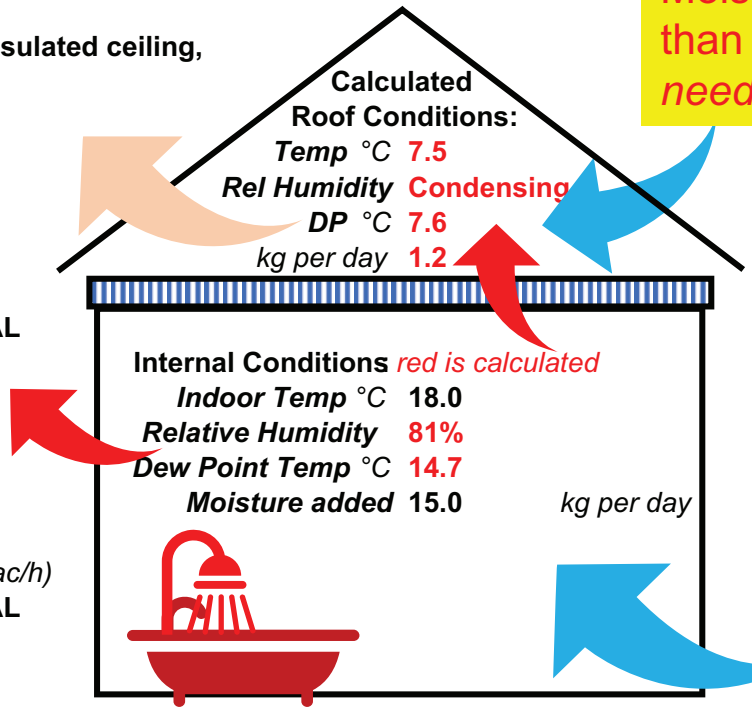
18.0	Inside Temperature *(C)*	**TYPICAL**
15.0	*kg/day moisture added*	**HIGH**

Insulation U-values *(W/m2K)*

0.2	Ceiling level	**HIGH**
5.0	Rafter level	**NONE**

Air infiltration *(Air Changes per Hour ac/h)*

0.5	*Outside-Inside*	**TYPICAL**
50%	*Leaves via ceiling*	**HIGH**
15.0	*Outside-Roofspace*	**HIGH**



IN HE's MONITORED HOUSES

Occupancy	Low

Indoor conditions

Temperatures	Normal 17-22 C
Moisture	5 kg/day or less

Insulation *(W/m2K)*

Ceiling U-value	0.2 to 1.0
Rafter level	none, say 5.0

Air infiltration and ventilation

Into house	0.3 to 1 ac/h
Through ceiling	0 to 0.5 ac/h
Into roofspace	2 to 15 ac/h

Simple model results
Version 6: Increase interior ventilation

Vent rate doubled to 1.0 ac/h. Interior RH drops to 65% from 81%. No roof moisture build-up.

6. Older building, high occupancy, insulated ceiling, draughty roof, more interior ventilation

INPUT VALUES:

7.0	Outdoor Temperature *(C)*	
100%	Outdoor Relative Humidity *(RH)*	

Indoor conditions

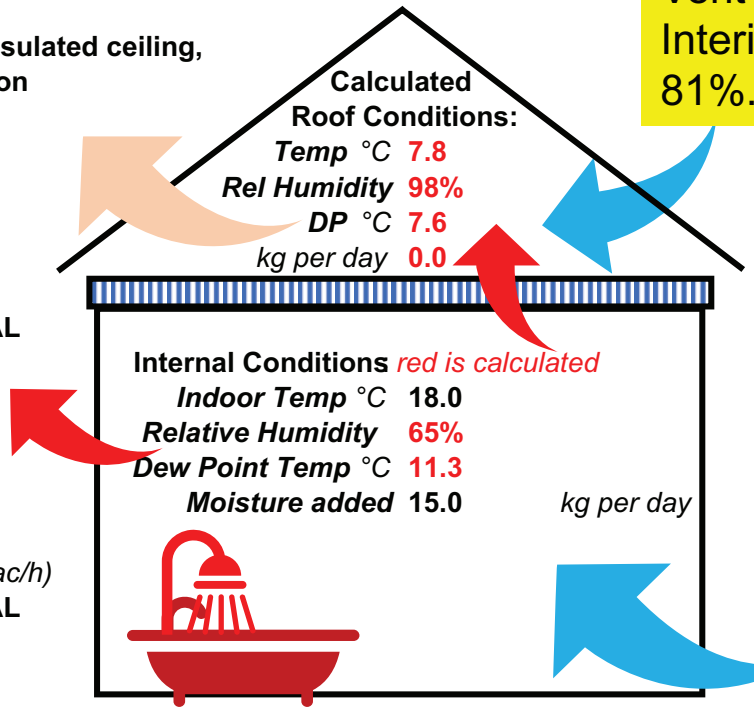
18.0	Inside Temperature *(C)*	**TYPICAL**
15.0	*kg/day moisture added*	**HIGH**

Insulation U-values *(W/m2K)*

0.2	Ceiling level	**HIGH**
5.0	Rafter level	**NONE**

Air infiltration *(Air Changes per Hour ac/h)*

1.0	*Outside-Inside*	**TYPICAL**
50%	*Leaves via ceiling*	**HIGH**
15.0	*Outside-Roofspace*	**HIGH**



IN HE's MONITORED HOUSES

Occupancy	Low

Indoor conditions

Temperatures	Normal 17-22 C
Moisture	5 kg/day or less

Insulation *(W/m2K)*

Ceiling U-value	0.2 to 1.0
Rafter level	none, say 5.0

Air infiltration and ventilation

Into house	0.3 to 1 ac/h
Through ceiling	0 to 0.5 ac/h
Into roofspace	2 to 15 ac/h

Simple model results
Version 7: Remove half moisture at source

Similar effect to doubling vent rate, but more economical. Roof air closer to saturation.

7. Older building, high occupancy, insulated ceiling, draughty roof, half moisture removed at source

INPUT VALUES:

7.0	Outdoor Temperature *(C)*	
100%	Outdoor Relative Humidity *(RH)*	

Indoor conditions

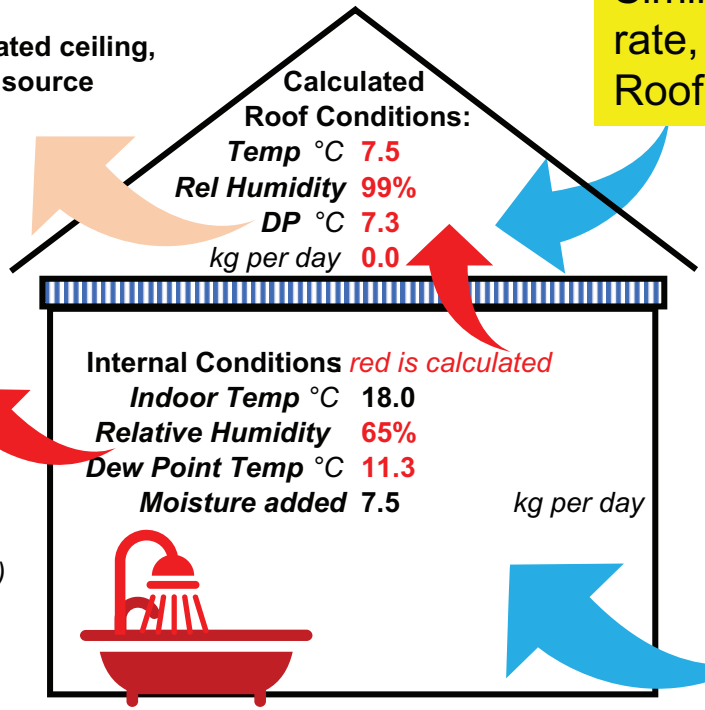
18.0	Inside Temperature *(C)*	**TYPICAL**
7.5	*kg/day moisture added*	**TYPICAL**

Insulation U-values *(W/m2K)*

0.2	Ceiling level	**HIGH**
5.0	Rafter level	**NONE**

Air infiltration *(Air Changes per Hour ac/h)*

0.5	*Outside-Inside*	**TYPICAL**
50%	*Leaves via ceiling*	**HIGH**
15.0	*Outside-Roofspace*	**HIGH**



IN HE's MONITORED HOUSES

Occupancy	Low

Indoor conditions

Temperatures	Normal 17-22 C
Moisture	5 kg/day or less

Insulation *(W/m2K)*

Ceiling U-value	0.2 to 1.0
Rafter level	none, say 5.0

Air infiltration and ventilation

Into house	0.3 to 1 ac/h
Through ceiling	0 to 0.5 ac/h
Into roofspace	2 to 15 ac/h

Simple model results
Version 8: Still OK in colder weather *(zero outside)*

8. Older building, high occupancy, insulated ceiling, draughty roof, half moisture removed at source, colder

INPUT VALUES:

0.0	Outdoor Temperature *(C)*	
100%	Outdoor Relative Humidity *(RH)*	

Indoor conditions

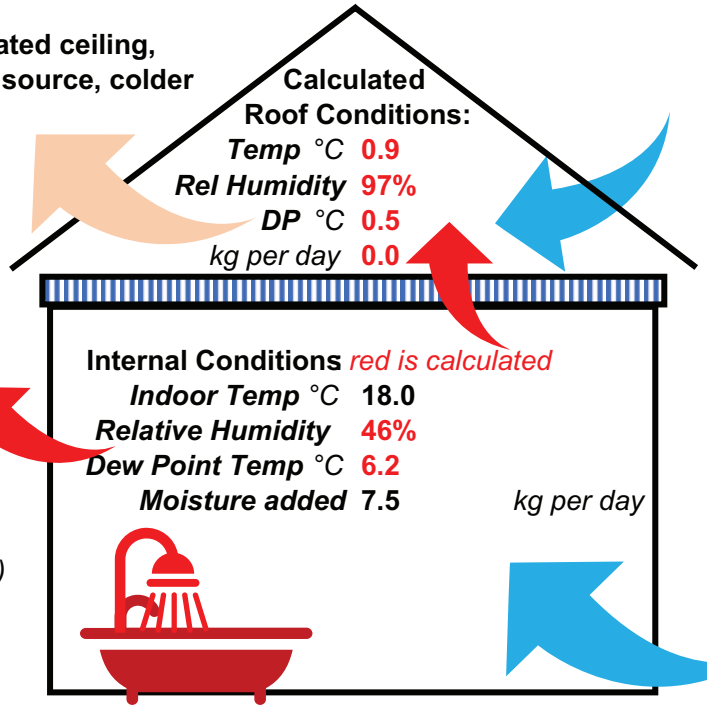
18.0	Inside Temperature *(C)*	**TYPICAL**
7.5	*kg/day moisture added*	**TYPICAL**

Insulation U-values *(W/m2K)*

0.2	Ceiling level	**HIGH**
5.0	Rafter level	**NONE**

Air infiltration *(Air Changes per Hour ac/h)*

0.5	*Outside-Inside*	**TYPICAL**
50%	*Leaves via ceiling*	**HIGH**
15.0	*Outside-Roofspace*	**HIGH**



IN HE's MONITORED HOUSES

Occupancy	Low

Indoor conditions

Temperatures	Normal 17-22 C
Moisture	5 kg/day or less

Insulation *(W/m2K)*

Ceiling U-value	0.2 to 1.0
Rafter level	none, say 5.0

Air infiltration and ventilation

Into house	0.3 to 1 ac/h
Through ceiling	0 to 0.5 ac/h
Into roofspace	2 to 15 ac/h

5
CONCLUSIONS

CONCLUSIONS: *It all depends …*

- Roofspaces may often have **high relative humidities** in winter, *but the timber may still be OK, as Brian Ridout will tell you.*
- It is a good idea to **remove moisture at source** from wet areas *(e.g. kitchens, bathrooms and laundries).*
- The **more you insulate the ceiling, the tighter** it needs to be. *Airtight is often more important than vapour-tight: beware holes!*
- Many old buildings cope quite well without special measures, *but*
- **Occupancy** can have a big effect: particularly in rented housing - *occupancy may be high and doesn't "own" any resulting problems.*
- So landlords may need to be cautious.

AFTERWORD: *Sponge effects can improve the situation*

- The modelling did not include sponge effects, *which may often increase a building's robustness to moisture-related problems.*
- Building scientists are increasingly aware of the performance and benefits of transfusive construction, which most older buildings had.
- *but modern finishes can undermine this with low vapour permeance.*
- Previous monitoring for English Heritage and Historic England showed benefits of moisture storage in solidly-constructed roofs, *e.g. summer drying-out. Extra ventilation made roofs damper in autumn.*
- Sponge effects can also cause problems, *e.g. in occasionally-heated buildings, which may self-humidify as they are heated up: this can distil moisture from the occupied spaces into the roof.*

DISCUSSION

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