

What Insulates Is Not the Snow but the Air It Holds

— Fresh snow (density 100) conducts at **0.069330** W/(m K), **1/32.02** of ice — 30 cm of it equals **17.31** cm of glass wool — packed to density 500 it conducts **6.3645** times as well — [Paper 451]

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— *From thinking to syncing.* —

Abstract

That snow is warm is called a curiosity. This paper shows that what insulates is not the snow but the air inside it—so the same snow, once packed, conducts **6.3645** times as well. No new theorem or law is claimed. First, fresh snow conducts at **0.069330** W/(m K), **1/32.02** of ice (Section 2). Second, at density 100, **0.8909** of the volume is air (Section 3). Third, this is the core of the paper. 30 cm of fresh snow equals **17.31** cm of glass wool, within the practical range of housing insulation (Section 2). Fourth, packed to density 500, the conductivity rises by a factor of **6.3645** (Section 2). Fifth, the measured value lies between the series bound **0.029141** and the parallel bound **0.265258** (Section 3). Sixth, the separator is whether the material insulates or the structure does (Section 4).

Keywords: snow, thermal conductivity, thermal insulation, air, rule of mixtures.

Scope of this paper (scope note): No new theorem or law is claimed—the density dependence of the thermal conductivity of snow and the series and parallel bounds of mixture rules are all standard. No building is designed—choice of insulation, installation and condensation control are not the subject. No snow shelter is described—safety, ventilation and avalanche hazard are not the subject. Vapour transport is excluded—sublimation and recondensation can carry heat through snow and are not always negligible, but only conduction is treated here. One empirical fit is fixed—a quadratic in density is used; coefficients vary between sources. Relation to earlier papers: Paper 450 showed that the same span of days carries maturity differing threefold—there too, one name covered two quantities. Paper 300 showed that common root and distinct root can be decided—“snow as a material” and “snow as a structure” are distinct roots by that criterion. Paper 447 showed that added workers flow out of the exit—there too, structure and not quantity was at work. What is added is giving the conductivity at four densities, giving the glass-wool equivalent as 17.31 cm, giving the porosity as 0.8909, bracketing the measurement between the series and parallel bounds, and placing the separator at material versus structure.

1. Notation and the Question

Setting: Take the thermal conductivity of snow as a quadratic in the density ρ [kg/m³],

$$k(\rho) = 0.138 - 1.01 \times 10^{-3} \rho + 3.233 \times 10^{-6} \rho^2$$

with $k_i = 2.22$ for ice and $k_a = 0.026$ W/(m K) for air. A layer of thickness d has thermal resistance $R = d/k$.

Observation 1.1

That snow is warm is called a curiosity. Snow is made of ice at 0°C—and the intuition says a cold thing cannot warm.

Observation 1.2

But it does not warm; it fails to let heat out. The question is not temperature but conductivity—and that is set by structure, not by what snow is made of.

Question: How much does it insulate, and what decides that.

2. Fresh Snow Conducts a Thirty-Second of Ice

Computation 2.1: Take the conductivity at four densities.

Density [kg/m ³]	Conductivity [W/(m K)]
100 (fresh)	0.069330
200	0.065320
300	0.125970
500 (packed)	0.441250

Observation 2.2

Fresh snow conducts $1/32.02$ of ice. 0.069330 against 2.22 —a factor of 32 between two things made of the same substance.

Observation 2.3

Packing makes it conduct 0.441250 at density 500 , 6.3645 times fresh snow—tread the snow down and the insulation falls.

Observation 2.4

And still it is under half of ice. 0.441250 against 1.11 —until it is fully compacted, air remains.

Observation 2.5

But between 100 and 200 in the table the value dips. From 0.069330 to 0.065320 —this quadratic has a minimum of 0.059118 at density 156.2017 .

Observation 2.6

That is an artefact of the fit, not a property of snow. Fitting a quadratic reverses the direction at the edge of its range—“packing makes it conduct” holds only above 156 ; below that the fit guarantees nothing.

Observation 2.7

This is where the form of the fit can reverse the conclusion. Read as monotone, it says the opposite across 100 to 200 —it is worth checking numerically that one has not stepped outside the fit.

Computation 2.8: Convert the resistance of 30 cm of fresh snow into a thickness of housing insulation.

$4.3271 \text{ m}^2\text{K/W}$, which as glass wool ($0.040 \text{ W}/(\text{m K})$) is $0.1731 \text{ m} = 17.31 \text{ cm}$.

Observation 2.9

Almost exactly the thickness put into a house wall. Between 10 and 20 cm—30 cm of snow is insulation in fact, not in metaphor.

Observation 2.10

Against concrete the ratio is **23.08**. At the same 30 cm—here I first estimated “over 40 times” and was wrong; the computed value is 23.08.

3. Porosity 0.8909 — What Insulates Is the Air

Computation 3.1: Take the porosity of snow at density 100.

$1 - 100/917 = \mathbf{0.8909}$: 89 per cent of the volume is air.

Observation 3.2

It is mostly air. Ice is only 11 per cent—what is called “snow” is, in substance, air that holds its shape.

Computation 3.3: Bracket it between the two mixture bounds.

Model	Conductivity [W/(m K)]
Series (lower)	0.029141
Measured (fit)	0.069330
Parallel (upper)	0.265258

Observation 3.4

The measurement lies between them. 2.3792 times the lower, 0.2614 of the upper—within what two components, ice and air, can account for.

Observation 3.5

Sitting near the lower bound means the heat is going around the ice skeleton. In parallel the ice would be a short cut, and it is not—disconnected grains of ice float in the air.

Observation 3.6

Packing connects the ice and moves it towards the upper bound. This is why the quadratic climbs steeply with density—a factor of 6.3645 from 100 to 500 is not a linear rise.

4. The Separator

The separator: does the material insulate, or the structure.

Observation 4.1

If the material insulates, the same substance always insulates the same. Ice is ice—one number, 2.22, suffices.

Observation 4.2

If the structure insulates, the same substance varies with its arrangement. A factor of 32, from 0.069330 to 2.22—the name of the material does not settle how heat passes.

Observation 4.3

These are distinct roots by the criterion of Paper 300. Both are called “the conductivity of snow”—one a property of a substance, one of a substance paired with a density.

Observation 4.4

The same shape as Paper 450. There, “28 days” was not a quantity without a temperature—here “snow” is not a quantity without a density. In both, the name does not name the quantity.

Observation 4.5

So designing insulation is not choosing a material but trapping air. Glass wool, foam and down work on the same principle—a structure that holds air still.

Observation 4.6

To be honest—vapour transport is not included. Sublimation and recondensation carry heat through snow and are not negligible under a steep gradient—only conduction has been looked at.

Observation 4.7

One last thing—the coefficients of the fit vary between sources. The direction—that it moves strongly with density—is firmer than the factor of 32 itself—and the conclusion that structure does the insulating does not depend on the choice of coefficients.

5. Roll Call and Closing

1. Fresh snow is **0.069330 W/(m K)** (Computation 2.1): **1/32.02** of ice.
2. **0.441250** at density 500 (Computation 2.1): **6.3645** times as conductive.
3. Still under half of ice (Observation 2.4): **air remains**.
4. **30 cm** equals **17.31 cm** of glass wool (Computation 2.8): **the core**.
5. **23.08** times concrete (Observation 2.10): **my estimate was wrong**.
6. Porosity **0.8909** (Computation 3.1): **mostly air**.
7. Series **0.029141**, parallel **0.265258** (Computation 3.3): **measurement between**.
8. Near the lower bound (Observation 3.5): **the ice is not connected**.
9. The separator is material or structure (Observation 4.3): **distinct roots by Paper 300**.
10. Insulation is trapped air (Observation 4.5): **not a choice of material**.

Closing: That snow is warm is called a curiosity—snow is made of ice at 0°C, and the intuition says a cold thing cannot warm. But it does not warm; it fails to let heat out. The question is not temperature but conductivity, and that is set by structure, not by what snow is made of. The amount of insulation is large—fresh snow conducts at **0.069330 W/(m K)**, which is **1/32.02** of ice: a factor of 32 between two things made of the same substance. 30 cm

has a resistance of $4.3271 \text{ m}^2\text{K/W}$, which as glass wool is **17.31 cm**—almost exactly the thickness put into a house wall, so 30 cm of snow is insulation in fact, not in metaphor. Against concrete the ratio is **23.08**; here I first estimated “over 40 times” and was wrong. And packing makes it conduct: 0.441250 at density 500, **6.3645** times fresh snow, so treading the snow down costs the insulation. What insulates is the air—at density 100 the porosity is **0.8909**, so 89 per cent of the volume is air and only 11 per cent is ice. What is called “snow” is, in substance, air that holds its shape. Bracketed by the mixture bounds—series 0.029141, measured 0.069330, parallel 0.265258—it lies between them, within what ice and air alone can account for. Sitting near the lower bound means the heat goes around the ice skeleton: in parallel the ice would be a short cut, and it is not, because disconnected grains of ice float in the air. Packing connects them and moves the value towards the upper bound, which is why a factor of 6.3645 from 100 to 500 is not a linear rise. One thing separates them—does the material insulate, or the structure. If the material insulates, the same substance always insulates the same and one number, 2.22, suffices. If the structure insulates, the same substance varies with its arrangement across a factor of 32, and the name of the material does not settle how heat passes. They are distinct roots by the criterion of Paper 300, one a property of a substance and one of a substance paired with a density. It is the same shape as Paper 450, where “28 days” was not a quantity without a temperature: here “snow” is not a quantity without a density. So designing insulation is not choosing a material but trapping air—glass wool, foam and down all work by holding air still. To be honest—vapour transport is not included. Sublimation and recondensation carry heat through snow and are not negligible under a steep gradient; only conduction has been looked at. One last thing—the coefficients of the fit vary between sources. The direction is firmer than the factor of 32 itself, and the conclusion that structure does the insulating does not depend on the choice of coefficients.

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