The First Layer and the Second Are Worth Different Amounts, Because a Resistance You Cannot Take Off Sits in the Denominator

— the first layer multiplies the heat loss by **0.415094**, the second by only **0.630952** and the third by **0.730435**, and a body-surface resistance of **0** makes the ratio exactly **0.500000** — the separator is whether the thing insulated already carries a resistance that cannot be removed — [Paper 730]

Yuuki YAMAGISHI (山岸 勇輝)
Yamagishi Complexity Torus Lab, Japan
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— From thinking to syncing. —

Abstract

Clothing insulation adds up in clo units. Warmth does not.The flattening is traced to a fixed resistance, confirmed by setting that term to zero.No new theorem or law is claimed. First, the total resistance rises in equal steps——0.110000, 0.265000, 0.420000, 0.575000 m²K/W (Section 2). **Second, and this is the core. Yet the heat loss flattens out——the first layer gives 0.415094, the second only 0.630952 and the third 0.730435** (Section 2). **Third, the cause can be confirmed to be the fixed term——setting the body-surface 0.11 to 0 makes the first-to-second ratio exactly 0.500000** (Section 2). **Fourth, on a curved surface the gain is smaller still——doubling the thickness raises the resistance by 1.580858 on a cylinder against 1.714286 on the flat-plate estimate** (Section 3). **Fifth, on something thin the direction reverses——the critical radius is 0.004000 m, and for a radius of 0.002 m the resistance is smallest at exactly that outer radius** (Section 3). **Sixth, the separator is whether the thing being insulated already carries a resistance that cannot be removed——if it does, the first layer is worth most; if not, every layer is worth the same** (Section 4). **Keywords**: clo value, resistances in series, body-surface resistance, critical radius, why the effect flattens, what adds and what does not.

Scope of this paper (scope note): **No new theorem or law is claimed——the definition of the clo, the series addition of thermal resistances and the critical radius of a cylinder are all standard (Gagge 1941, Incropera and DeWitt 2002).No precision is claimed for representative values——1 clo = 0.155 m²K/W is a defined value, but the body-surface 0.11 m²K/W, a conductivity of 0.04 W/mK, a surface coefficient of 10 W/m²K and a radius of 0.05 m are order-of-magnitude values.Moisture is not treated——sweat, vapour transport and vapour resistance are not treated; only dry heat is considered.Wind is not treated——the change in surface coefficient with wind is not treated.Compression is not counted——that layers under others are crushed thinner is mentioned only.No real garment is claimed——clo values of particular garments are not treated.Relation to earlier papers**: **Paper 451 showed that what insulates is not the snow but the air it holds, deriving thermal resistance from thickness and converting 30 cm of fresh snow to 17.31 cm of glass wool——there the resistance of one layer was the subject. Here we count what happens as layers are added. The resistance of one layer, and the order in which layers are added.**What is added is **quantifying the flattening layer by layer**, **confirming its cause by setting the fixed term to zero**, **putting the curved-surface loss of gain at 1.580858 against 1.714286**, **showing the critical radius of 0.004000 m to coincide with the minimum of resistance**, and **placing the separator on whether an unremovable resistance is already present**.

1. Notation and the Question

Setting: **thermal resistances add in series and the heat loss is their reciprocal. The body surface already carries a resistance that cannot be taken off.**

$$R_{\text{total}} = R_s + n\,R_{\text{clo}}, \qquad \text{loss} = \frac{1}{R_{\text{total}}}, \qquad R_{\text{cyl}} = \frac{\ln(r_2/r_1)}{2\pi k} + \frac{1}{2\pi r_2 h}$$

R_s is the body-surface resistance and $R_{\text{clo}} = 0.155$ m²K/W. The cylindrical expression carries the growth of the outer area with r_2.

Question: **if clo values add, does warmth add too?**

2. Equal Steps in Resistance, Unequal Steps in Effect

Computation 2.1: **the total resistance and heat loss were derived layer by layer.**

layers	total resistance	loss	against the previous
0 clo	0.110000	9.090909	—
1 clo	0.265000	3.773585	0.415094
2 clo	0.420000	2.380952	0.630952
3 clo	0.575000	1.739130	0.730435
4 clo	0.730000	1.369863	0.787671

Observation 2.2

this is the core: the resistance rises evenly and the effect does not.The first layer gives 0.415094 and the second only 0.630952——the same 0.155 is added each time, and it is worth different amounts.

Observation 2.3

the cause can be confirmed.Setting the body-surface 0.11 to 0 makes the first-to-second ratio exactly 0.500000——comparing 0.630952 with the fixed term against 0.500000 without it shows the flattening to come from that term.

Observation 2.4

so what “one more layer” is worth depends on how many are already on.The first layer over bare skin is worth much; the fourth little——it is correct to speak of clo values adding, and incorrect to speak of warmth adding.

3. On a Curved Surface, Less Still

Computation 3.1: insulation of varying thickness was wrapped on a cylinder of radius 0.05 m, beside a flat-plate estimate.

thickness	cylinder	flat-plate estimate
0.010 m	0.990693 m K/W	1.114085 m K/W
0.020 m	1.566145 m K/W	1.909859 m K/W
0.040 m	2.515568 m K/W	3.501409 m K/W

Observation 3.2

doubling the thickness raises the cylinder’s resistance less.1.580858 against the flat plate’s 1.714286——every added layer enlarges the outer area, partly cancelling the resistance gained.

Observation 3.3

on something thin the direction reverses.The critical radius is the conductivity over the surface coefficient, 0.004000 m——wrapping a radius of 0.002 m, the resistance is smallest at exactly 0.004000 m, and up to there wrapping increases the loss.

Observation 3.4

a human arm is far past the critical radius.A radius of 0.05 m is more than ten times 0.004000 m——so clothing always warms; the reverse happens for things like thin wire.

Observation 3.5

the two flattenings have different sources.One comes from the fixed term in the denominator, the other from the growth of the outer area——both take the form “the added resistance does not count in full”, but they are removed differently.

4. The Separator

> **Observation 4.1**
>
> **the separator is whether the thing being insulated already carries a resistance that cannot be removed.If it does, the first layer is worth most; if not, every layer is worth the same——“add clo and you add warmth” may be said only in the second case.**

> **Observation 4.2**
>
> **beside Paper 451.Paper 451 showed that what insulates is not the snow but the air it holds——there the resistance of one layer was the subject. Here the order of adding is. One layer, and the order.**

> **Observation 4.3**
>
> **what is not said.Moisture, wind, compression and real garments are not treated, and four representative values are held fixed——what is shown is the line between what adds and what does not.**

5. Roll Call and Closing

1. **loss 9.090909 at 0 clo** (Computation 2.1): **the unremovable part only.**
2. **3.773585 at 1 clo** (Computation 2.1): **the first layer.**
3. **a ratio of 0.415094** (Computation 2.1): **it counts for much.**
4. **the second gives 0.630952** (Computation 2.1): **the core.**
5. **the third 0.730435** (Computation 2.1): **flatter still.**
6. **0.500000 with no fixed term** (Observation 2.3): **the cause confirmed.**
7. **cylinder 1.580858** (Observation 3.2): **thickness doubled.**
8. **flat plate 1.714286** (Observation 3.2): **the estimate overstates.**
9. **critical radius 0.004000 m** (Observation 3.3): **thin things reverse.**
10. **an unremovable resistance** (Observation 4.1): **the separator; Paper 451.**

Closing: **The first layer and the second are worth different amounts, because a resistance you cannot take off sits in the denominator.With 1 clo $= 0.155$ m²K/W and a body-surface resistance of 0.11 m²K/W, the total rises in equal**

steps, 0.110000, 0.265000, 0.420000, 0.575000, while the loss falls unevenly: 9.090909, 3.773585, 2.380952, 1.739130 W/(m²K)——the first layer gives 0.415094, the second only 0.630952, the third 0.730435.That the cause is the fixed term can be confirmed by setting it to zero, which makes the first-to-second ratio exactly 0.500000——comparing 0.630952 with it against 0.500000 without it shows where the flattening comes from.On a curved surface the outer area grows too, so doubling the thickness raises the resistance by only 1.580858 against the flat-plate estimate of 1.714286——every added layer enlarges the outer area, partly cancelling the resistance gained.On something thin the direction reverses——the critical radius is 0.004000 m, and for a radius of 0.002 m the resistance is smallest at exactly that outer radius, so up to there wrapping increases the loss. A human arm at 0.05 m is more than ten times past it, so clothing always warms.The separator is whether the thing being insulated already carries a resistance that cannot be removed.Placed among the earlier papers——Paper 451 treated the resistance of one layer; here the order of adding is treated.To be honest——moisture, wind and compression are not treated, and four representative values are held fixed.

References

1. Gagge, A. P., Burton, A. C., & Bazett, H. C. (1941). A practical system of units for the description of the heat exchange of man with his environment. *Science*.
2. Incropera, F. P., & DeWitt, D. P. (2002). *Fundamentals of Heat and Mass Transfer*. Wiley.
3. Yamagishi, Y. (2026). *What Insulates Is Not the Snow but the Air It Holds* [Paper 451]. Zenodo. 10.5281/zenodo.22732772

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