# Economic Insulation Thickness for a Pipe

Insulation thickness that gives the lowest yearly cost of heat lost plus insulation, for a hot pipe, with heat loss by ISO 12241 and insulation cost by capital recovery.

**Method:** ISO 12241 heat loss; Capital recovery factor

## Input parameters

Unit system: SI

| Parameter | Value | Unit |
|---|---|---|
| Pipe outer diameter | 168.30 | mm |
| Insulation thermal conductivity | 0.045000 | W/(m·K) |
| Pipe (process) temperature | 180.00 | °C |
| Ambient temperature | 30.000 | °C |
| Emissivity of the cladding | 0.10000 | |
| Operating hours per year | 8,000.0 | h |
| Cost of heat in fuel, per kWh (your currency) | 2.5000 | |
| Efficiency of the heat supply (boiler) | 85.000 | % |
| Installed insulation cost per m³ (your currency)<br>Material, cladding and labour, per cubic metre of insulation. | 40,000 | |
| Interest rate | 10.000 | % |
| Life of the insulation, years | 10.000 | |

## Calculated results

| Parameter | Value | Unit |
|---|---|---|
| Economic insulation thickness | 98.484 | mm |
| Heat loss per metre at that thickness | 50.360 | W/m |
| Yearly cost of heat lost, per metre | 1,184.9 | |
| Yearly cost of the insulation, per metre | 537.33 | |
| Total yearly cost per metre | 1,722.3 | |

**Notes for this case**

- The cost curve is flat near the optimum: the next standard thickness up is usually the practical choice.

## Formula and method

$$C_t(t) = \frac{q'(t)\, t_y}{\eta_b} c_h + CRF \cdot c_i \frac{\pi}{4}\left[(D_o + 2t)^2 - D_o^2\right]$$

$$CRF = \frac{i(1+i)^n}{(1+i)^n - 1}$$

$$t_{opt} = \arg\min C_t(t)$$

### Variables

| | | |
|---|---|---|
| $D_o$ | pipe outer diameter | m |
| $\lambda$ | insulation thermal conductivity | W/(m·K) |
| $T_i$ | pipe temperature | K |
| $T_a$ | ambient temperature | K |

| | | |
|---|---|---|
| $\varepsilon$ | cladding emissivity | - |
| $t_y$ | operating hours per year | s |
| $c_h$ | cost of heat in fuel per kWh | currency/kWh |
| $\eta_b$ | efficiency of the heat supply | - |
| $c_i$ | installed insulation cost per m³ | currency/m³ |
| $i$ | interest rate | - |
| $n$ | insulation life | years |
| $t$ | insulation thickness | m |
| $q'$ | heat loss per metre (ISO 12241) | W/m |
| $CRF$ | capital recovery factor | 1/year |
| $t_{opt}$ | economic thickness | m |
| $C_h$ | yearly heat cost per metre | currency/(m·year) |
| $C_i$ | yearly insulation cost per metre | currency/(m·year) |
| $C_t$ | total yearly cost per metre | currency/(m·year) |

### Method and standards

Heat loss per metre for each thickness is found by ISO 12241 (conduction through the insulation, natural convection and radiation from the cladding). The yearly heat cost uses the hours, the heat price and the supply efficiency; the insulation is annualised with the capital recovery factor. A golden-section search finds the thickness with the lowest total.

### Assumptions and limits

- Horizontal pipe in still air (ISO 12241).
- Insulation cost proportional to volume.
- Single layer; constant prices over the life.
- Insulation cost proportional to volume, with no fixed cladding or labour cost per metre (a fixed cost does not move the optimum but adds to the total).
- No inside film or pipe-wall resistance: the pipe surface is taken at the process temperature (slightly conservative).

### References

- ISO 12241 heat loss
- Capital recovery factor

## Report details

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|---|---|
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| Release checks | 3 reference cases of this calculator, computed independently, are checked on every release |

Results are for engineering estimation. Verify critical designs against the referenced standards and your own data.

### This calculator online

https://calc.firecad.com/mechanical/heat-transfer/economic-insulation-thickness

Open this case on calc.firecad.com →

Reopens the calculator with the inputs of this report.