INSUduct™ Thermal Performance Report

Compliance Evaluation: BS 5422:2023 / BS EN ISO 12241 Framework
Assessment Scope: Stationary Water Freeze Protection (12-Hour Target at -10°C Ambient)

1. Executive Summary

This evaluation verifies the transient thermal response of the INSUduct™ external containment system incorporating an internal stagnant air gap. Two hardware configurations are analyzed: the baseline **26mm OD Pipe** (4.5mm air gap) and the upscaled **32mm OD Pipe** (1.5mm air gap), both enclosed within a fixed-dimension external box housing 35mm of InVento Optima FRN insulation. When factoring in the high thermal resistance of the trapped air layer, **both configurations comfortably pass the statutory 12-hour freeze protection benchmark** starting from a standard +5°C baseline.

2. System Layer & Thermal Resistance Profiles

Thermal calculations are derived via radial heat transfer modeling using layer-specific thermal conductivity (λ) values and standard boundary surface resistances under sheltered, still-air conditions (h_{se} = 8.0 W/m²K).

Layer Description	26mm OD Pipe Option	32mm OD Pipe Option
1. Internal Fluid Core	20mm ID Water Column (0.314 L/m)	26mm ID Water Column (0.531 L/m)
2. PE Pipe Wall (λ = 0.38 W/mK)	3.0mm wall thickness	3.0mm wall thickness
3. Stagnant Air Gap (λ = 0.024 W/mK)	4.5mm layer clearance	1.5mm layer clearance
4. Insulation (λ = 0.030 W/mK)	35mm InVento Optima FRN	35mm InVento Optima FRN
5. Outer Protective Shell	3.0mm rigid plastic	3.0mm rigid plastic
Total System Radial Resistance (R_{total})	**8.31 m·K/W**	**6.91 m·K/W**

3. Comprehensive Thermal Performance Matrix

Timeline metrics quantify **Phase 1** (sensible cooling from initial temperature to 0°C) and **Phase 2** (latent phase change until 50% ice volume forms) at a continuous ambient exposure of -10°C.

Pipe & Initial Temp Baseline	Phase 1 (Cool Down)	Phase 2 (50% Freeze)	Total Time to Benchmark	Compliance Status (12h Limit)
26mm OD Pipe (+5°C Modern Std)	1.23 hrs	12.11 hrs	**13.34 hrs**	**PASSED** (+1.34h)
26mm OD Pipe (+4°C Physical Mid)	0.98 hrs	12.11 hrs	**13.09 hrs**	**PASSED** (+1.09h)
26mm OD Pipe (+2°C Legacy/Bylaw)	0.49 hrs	12.11 hrs	**12.60 hrs**	**PASSED** (+0.60h)
32mm OD Pipe (+5°C Modern Std)	1.73 hrs	17.02 hrs	**18.75 hrs**	**PASSED** (+6.75h)
32mm OD Pipe (+4°C Physical Mid)	1.38 hrs	17.02 hrs	**18.40 hrs**	**PASSED** (+6.40h)

32mm OD Pipe (+2°C Legacy/Bylaw)	0.69 hrs	17.02 hrs	**17.71 hrs**	**PASSED** (+5.71h)

4. Critical Engineering Dynamics & Regulatory Context

The Water Volume Domination Effect: Upgrading to the 32mm OD pipe restricts the air gap space from 4.5mm down to 1.5mm, which diminishes total system thermal resistance. However, because a 26mm internal fluid core holds **69% more thermal water mass** (0.531 L/m vs 0.314 L/m), the immense increase in required latent heat energy significantly outpaces the drop in insulation performance. This drives the total freeze resilience up to an exceptional 17.7–18.7 hours.

Evolution of the BS 5422 Temperature Baseline: Historical revisions of British Standard 5422 (1977 and 1990 iterations) calculated frost safety parameters using a highly conservative initial fluid temperature baseline of **+2°C**. The standard formally transitioned to a **+5°C** reference baseline in the **BS 5422:2001 revision**, an engineering baseline explicitly preserved through the 2009 and contemporary **BS 5422:2023** frameworks. The inclusion of the internal air gap in this design means the INSUduct™ assembly clears the 12-hour requirement across all legacy (+2°C) and modern (+5°C) regulatory frameworks.

Water Bylaws & Local Site Risk: While a system may easily satisfy modern building codes using the +5°C standard baseline, localized UK Water Authorities, municipal water bylaws, or specialized site insurance clauses frequently enforce a rigid, worst-case +2°C design threshold. This document confirms that both physical configurations remain fully insulated against these localized parameters.

5. Convection Note (Internal Boundary Conditions)

Where external service pipework penetrates a property within 1.0 metre of ground level, localized temperature differentials (sub-zero outdoor temperatures vs. 10–16°C indoor ambient rooms) will trigger **natural buoyancy-driven convection currents (thermosiphoning)** within the water column. Liquid reaches its peak density at +4°C, meaning cooling fluid in the external line naturally drops, actively pulling warm fluid from the property core outward. While this mechanism dynamically delays frost formation in the real world, standard engineering validation (including BS EN ISO 12241 metrics listed above) assumes a completely static, stagnant fluid state to represent a worst-case building power failure scenario.