FIRE PROTECTION JUST GOT SMARTER

ArmaGel® HTF

Technical Specification Guide

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Fire Protection and Insulation Combined

Our vision has always been to create innovative, technical insulation solutions and components to conserve energy and make a difference around the world. With ArmaGel® HTF we are going one step beyond into the future. ArmaGel HTF is an advanced insulation material which additionally provides fire protection - especially for hydrocarbon pool fires to avoid escalation of the fire event, allow emergency responders to safely conduct their jobs, reduce the risk of shut-downs and protect assets.

A sustainable one-step solution for fire protection and thermal insulation.

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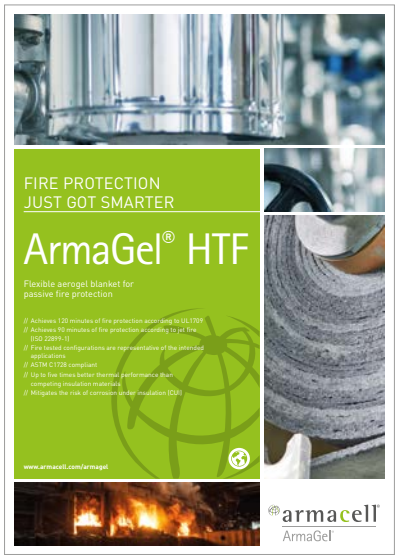
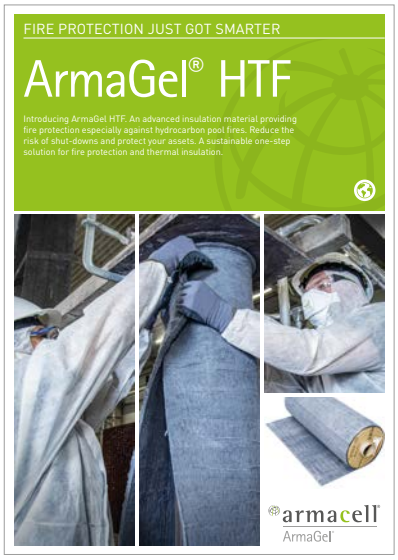
This brochure is a compendium of technical and application documents.



1.Technical Datasheet



2. Marketing Brochure

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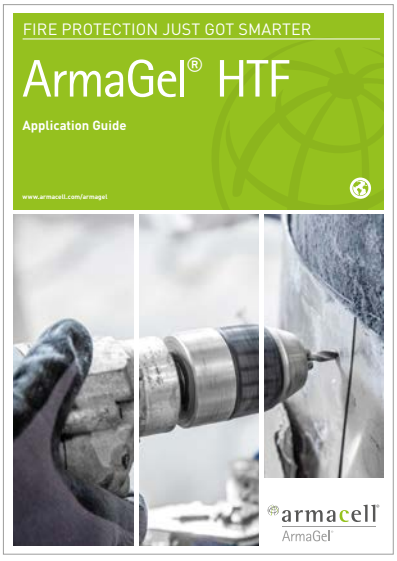
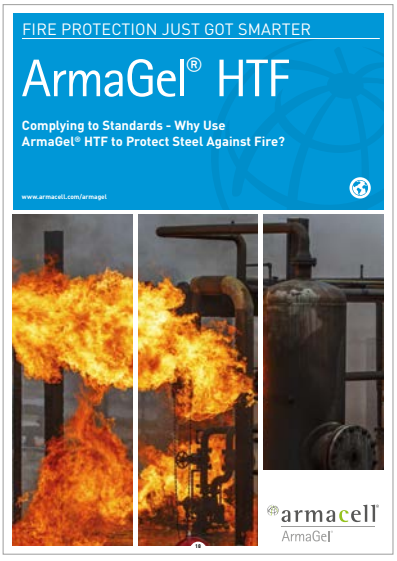


4. Application Manual



5. White Paper

FIRE PROTECTION JUST GOT SMARTER

ArmaGel® HTF

Flexible aerogel blanket for passive fire protection

// Achieves 120 minutes of fire protection according to UL1709
// Achieves 90 minutes of fire protection according to jet fire (ISO 22899-1)
// Fire tested configurations are representative of the intended applications
// ASTM C1728 compliant
// Up to five times better thermal performance than competing insulation materials
// Mitigates the risk of corrosion under insulation (CUI)

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TECHNICAL DATA – ARMAGEL HTF

Brief description	ArmaGel HTF is a flexible aerogel blanket designed for passive fire protection meeting UL 1709 standard. Jet fire tested according ISO 22899-1. ArmaGel HTF is compliant with ASTM C1728, Type III, Grade 1A.
Material type	Aerogel blanket
Colour	Grey
Special features	ArmaGel HTF provides excellent passive fire protection and superior thermal performance with maximum operational use temperature up to 650 °C (1200 °F).
Product range	Sheets in rolls in 10 mm (0.4 in) thickness and width of 1.5 m (59 in). For further details, please refer to the product range tables at the end of this document.
Applications	Passive fire protection and thermal insulation of pipework and equipment in Energy and industrial process facilities.
Installation	For industrial applications, it is recommended to consult the relevant Armacell application manual(s). Please consult our Technical Services for further information and support.

Property	Value/Assessment										Standard/Test method
Temperature range[*1/2/3]											
Max. service temperature	+650 °C			+1200 °F							Tested according to ASTM C411 and ASTM C447
Thermal conductivity											
Thermal conductivity[*4] (metric units)	θm	+24	+38	+93	+149	+204	+260	+316	+371	[°C]	Tested according to ASTM C177[4]
	λd ≤	0.021	0.022	0.023	0.025	0.029	0.032	0.036	0.043	[W/(m·K)]	
Thermal conductivity[*4] (imperial units)	θm	+75	+100	+200	+300	+400	+500	+600	+700	[°F]	
	λd ≤	0.14	0.15	0.16	0.18	0.20	0.22	0.25	0.30	[Btu·in/(h·ft²·°F)]	
Temperature resistance											
Hot surface performance[*2]	Pass										Tested according to ASTM C411
Linear shrinkage under soaking heat	< 2% in width and length // Pass										Tested according to ASTM C356
Water absorption	Pass										Tested according to ASTM C1763
Fire performance & approvals											
Surface burning characteristics	≤ 5 flame spread index ≤ 10 smoke development										Tested according to ASTM E84
Fire resistance	Tested configurations for UL1709 compliance[5]:										Officially tested at UL according to UL1709

Tested configuration	Fire rating	Outer diameter [min.]	Wall thickness [mm]	Hp/A Value [m⁻¹]	ArmaGel® HTF [mm]
Pipe 8"	120	219.1	3.68	276.4	10 x 10mm
Pipe 8"	120	219.1	6.3	163.4	7 x 10mm
Pipe 8"	120	219.1	14.2	74.8	4 x 10mm
Pipe 8"	90	219.1	6.3	163.4	5 x 10mm
Standard steel beam W10x49 (in x lb/ft)	120	-	-	177.3	3 x 10mm[6]

Tested configurations for jet fire compliance (ISO 22899-1)[7]: — Officially tested at Efectis/France according to ISO 22899-1

Tested configuration	Fire rating	Outer diameter [min.]	Wall thickness [mm]	Hp/A Value [m⁻¹]	ArmaGel® HTF [mm]
Pipe 8"	90	219.1	6.3	163.4	5 x 10mm

Density			
Nominal density	180 kg/m³	11 lb/ft³	Tested according to ASTM C303
Mechanical properties			
Compressive strength*[8]	>3 psi/ 20.7 kPa	at 10% compression	Tested according to ASTM C165
Classifying the flexibility of mineral fibre blankets	Flexible		Tested according to ASTM C1101
Corrosion mitigation			
Stress corrosion cracking	Insulation for use over austenitic steel: no cracks, passed		Tested according to ASTM C692, ASTM C795
Corrosiveness of steel	Passed, Mass Loss Corrosion Rate (MLCR) not exceeding that of 5 ppm chloride solution on carbon steel coupon		Tested according to ASTM C1617, procedure A
Other technical features			
Weather resistance	In all industrial applications the outer layer of the material must be protected with an adequate covering like metal jacketing, or preformed UV-cured GRP (Glass-Reinforced Plastic) cladding. Please contact Technical Services for guidance on the temperature limitations and specific construction considerations which need to be made for each jacketing system.		
Passive fire protection	In passive fire protection applications the outer layer of the material must be protected with an adequate metal jacketing. Please contact Technical Services for guidance.		
Health aspects	Neutral, asbestos free.		
Hydrophobic	Yes		
Water vapour sorption	⩽ 5% by weight		Tested according to ASTM C1104
Fungal resistance	No growth		Tested according to ASTM C1338
Storage	Material shall be stored indoors, in clean and dry conditions, away from direct sunlight.		
Shelf (storage) life*[9]	Max. 3 years		

1. For temperatures below or above those published please contact Technical Services to request the corresponding technical information.
2. For operating temperatures above 400 °C (752 °F) a metallic foil barrier with 0.05 mm (0.002 inch) thickness must be additionally installed between the two outmost layers of ArmaGel HTF. For details please contact Technical Services.
3. For live line installations please refer to the ArmaGel HTF application guide.
4. Thermal conductivity tested under a load of 1.5 kPa (0.22 psi).
5. All fire tests have been officially conducted at a UL laboratory under full witnessing by UL.
6. For the installation procedure please contact Technical Services for guidance.
7. The fire test has been officially conducted at a Efectis /France laboratory under full witnessing by Efectis and UL. Fire rating for test criteria (temperature increase on steel pipe below <538°K) was 90 minutes. No integrity failure was noticed during the full test period of 180 minutes.
8. Test performed with a preload of 2 psi.
9. Shelf life (maximum storage time) is limited in order to make sure that only currently manufactured products are applied on projects. This limitation is restricted solely to storage of the product and does not affect the lifetime of product after it has been installed.

Sheets

		Metric sizes				Imperial sizes			
		Nominal thickness	**Width**	**Length**	**Content per roll**	**Nominal thickness**	**Width**	**Length**	**Content per roll**
		[mm]	**[m]**	**[m]**	**[sqm]**	**[in]**	**[in]**	**[ft]**	**[sq ft]**
Standard Rolls	**AGF-10-00/150S**	10	1.5	8	12	0.4	59	26.3	129.2
Jumbo Rolls	**AGF-10-00/150P**	10	1.5	40	60	0.4	59	131.2	645.8
Tolerances	**Thickness tolerances**			10 mm (0.4 in) nominal thickness			± 2.5 mm		
	Width tolerances						± 3%		
	Length tolerances						± 5%		

FIRE PROTECTION JUST GOT SMARTER

ArmaGel® HTF

Introducing ArmaGel HTF. An advanced insulation material providing fire protection especially against hydrocarbon pool fires. Reduce the risk of shut-downs and protect your assets. A sustainable one-step solution for fire protection and thermal insulation.

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A sustainable one-step solution for fire protection and thermal insulation.

ArmaGel® HTF

ArmaGel HTF is a new generation of aerogel fire protection blanket. A reliable solution for superior thermal insulation for high-temperature applications up to 650 °C (1200 °F). ArmaGel HTF provides additional fire protection to reduce the risk of shut-downs. Officially tested up to 120 minutes, compliant with UL 1709. ArmaGel HTF is easy to install, flexible and environmentally safe. The perfect solution for applications where both, thermal insulation and fire protection, is required.

Passive Fire Protection

Thermal

Hydrophobic

Learn more.

AEROGEL

Used by NASA to bring home a piece of a comet because it's strong enough to stop a bullet in its track, aerogel offers an uncanny array of physical properties - thermal, acoustical – and so holds incredible potential for insulation uses. As the name suggests, aerogel is a solid derived from gel in which the liquid component of the gel has been replaced with air making it dry and porous. In fact, over 90 percent of the volume is empty space making aerogel the world's lightest solid material. It's also 1,000 times less dense than glass, making it the world's lowest density solid material.

YOUR BENEFITS

// One-step solution
Advanced insulation material which additionally provides fire protection - reduce the risk of shut-downs in case of fire and protect assets.

// Fire Protection
Passive Fire Protection with aerogel technology. UL1709 compliant. Jet fire tested according ISO 22899-1.

// Superior thermal Insulation
For hot conditions up to 650°C (1200°F). Up to five times better thermal performance than competing insulation materials.

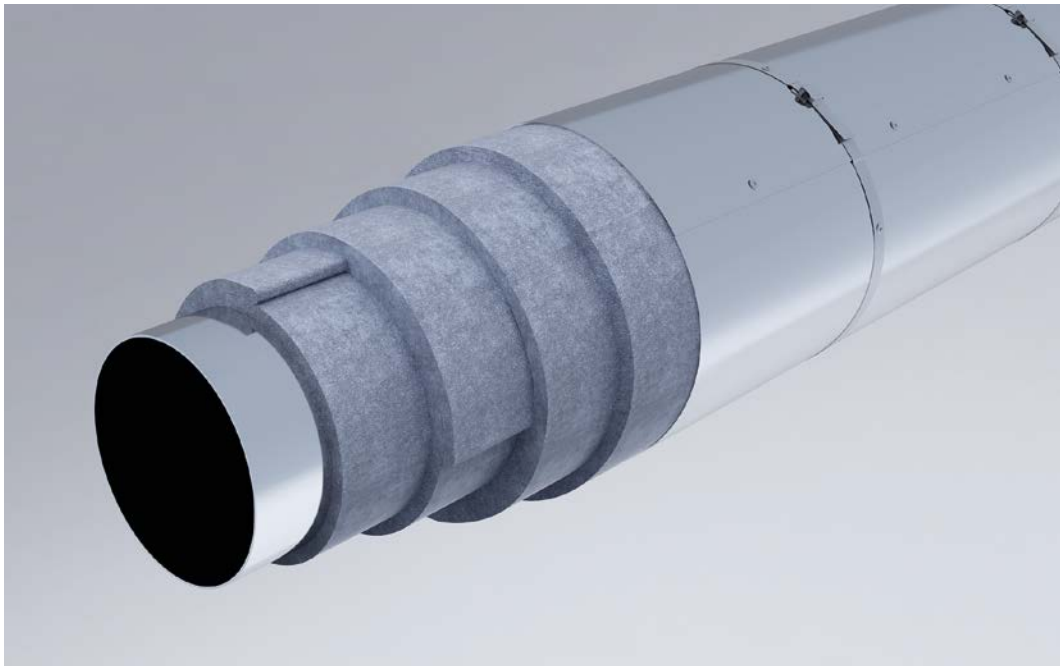
// Cost efficient solution
Reduce labour cost. Reduce maintenance costs. The ideal choice for specifiers and contractors.

// CUI defence
Mitigates the risk of corrosion under insulation (CUI).

// Easy and reliable installation
Highly flexible aerogel blanket material. No curing or drying time. No banding systems required to install ArmaGel HTF blankets.

// Hydrophobic and breathable
Repels liquid water, but allows vapour to escape, helping to keep equipment drier for longer.

// High temperature application
Fire protection for applications with operating temperature up to 650 °C.



ArmaGel® HTF

Instructions for use

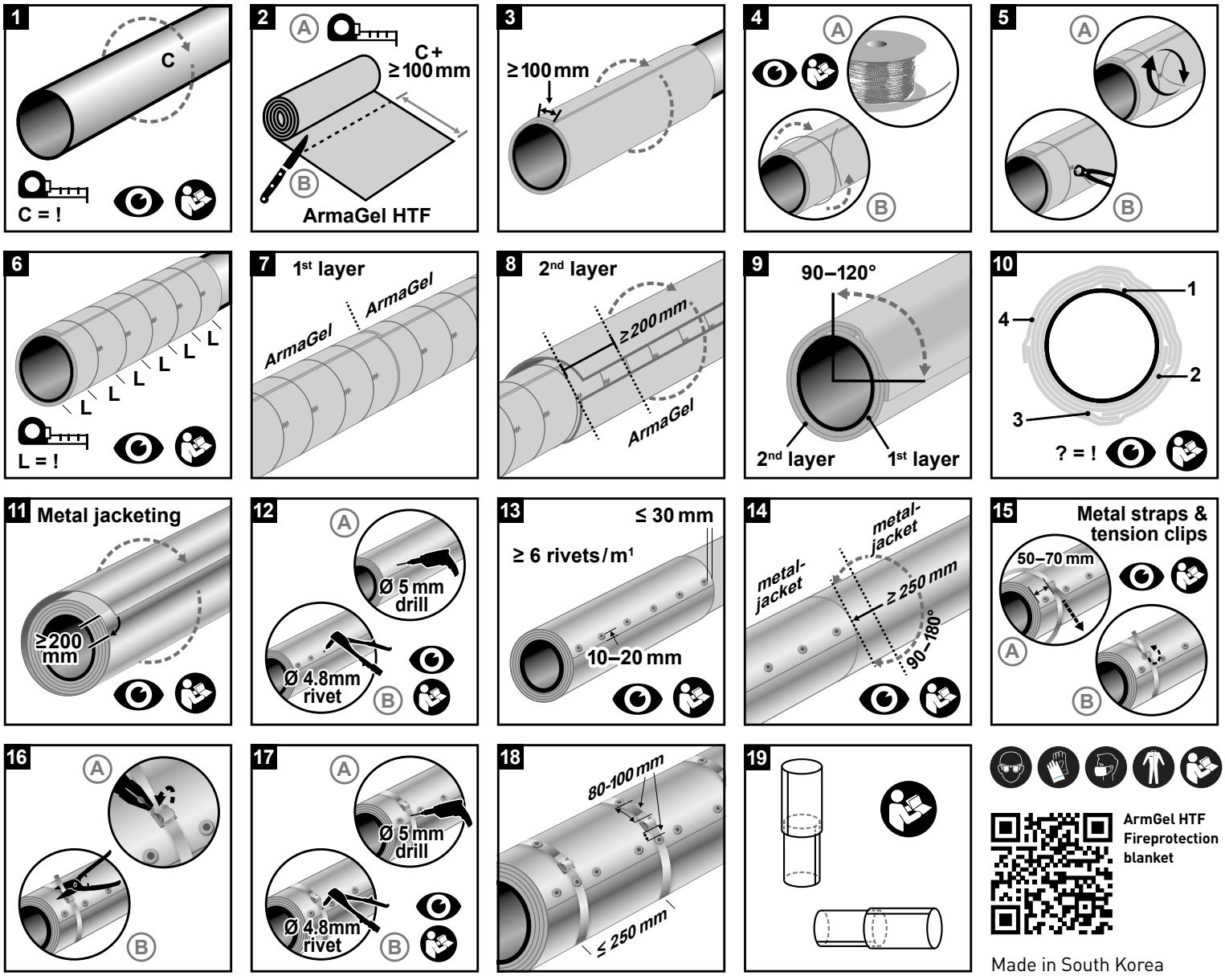
Fire protection aerogel insulation blanket
Brandschutz-Aerogel-Dämmmatte
Matelas isolant en aérogel pour la protection incendie
Manta aislante de aerogel para protección contra incendios

// **EN** For professional use only. Before handling and for specific application details, refer to third party publishing listed, and national approvals / assessments and Armacell product literature.

// **DE** Nur für gewerbliche Anwender. Vor Gebrauch und für spezifische Anwendungshinweise lesen Sie veröffentlichte Listungen von Fremdüberwachern, nationale Zulassungen / Bewertungen und Armacell Produktbeschreibungen.

// **FR** Seulemet pour utilisateurs professionnels. Avant tout utlisation et pour tout détail concernant une application, se référer à la liste de publications des tierces parties, aux approbations / évaluation nationales et à la documentation Armacell.

// **ES** Solamente para los usuarios profesionales. Antes de usar y para detalles específicos de aplicación, véase el listado publicado por terceros, las aprobaciones / evaluación nacionales y la información que acompaña al product Armacell.



ArmGel HTF Fireprotection blanket

Made in South Korea

Note:

- Wrap ArmaGel tightly to avoid gaps or voids.
- For applications with jet fire requirements, the penultimate layer of ArmaGel HTF needs to be fixed additionally with metal straps. For the outer jacketing the distance between the metal straps should be max. 200 mm. For details please refer to relevant third party listings or contact Technical Services.
- For operating temperatures above 400 °C (752 °F) a metallic foil barrier with 0.05 mm (0.002 inch) thickness must be additionally installed between the two outmost layers of ArmaGel HTF. For detail please contact Technical Services,
- For live line installations please refer to the ArmaGel HTF application guide.

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Consumption Guide

The sections of insulation shall include a minimum 100 mm overlap around the circumference, applicable to all insulation layers.

Cut ArmaGel blanket into sections with the sizing dimensions that are equal to the length of the steel pipe specimens considering an 100 mm overlap plus an additional compensation factor (50 mm for 1st layer, 60 mm layer for 2nd layer, 70 mm for 3rd layer,...)

Required circumference length of ArmaGel HTF =

circumference based on outside diameter
+ compensation factor for overlapping (see table below)
+ overlap (100 mm)

Example for steel pipe with outside diameter of 219.1 mm

Layer	Outside diameter w/o considering overlapping (mm)	Circumference based on outside diameter (mm)	Compensation factor for overlapping (mm)	Overlap (mm)	Required circumference length of ArmaGel HTF (mm)
1	219,1	688	50	100	838
2	239,1	751	60	100	911
3	259,1	814	70	100	984
4	279,1	877	80	100	1057
5	299,1	939	90	100	1129
6	319,1	1002	100	100	1202
7	339,1	1065	110	100	1275

Note: the above table is only an example. On jobsite deviations from the calculation model above could be possible. Therefore, for every layer the needed circumference length of ArmaGel HTF needs to be determined before cutting.

ArmaGel® HTF

Application Steps

Installation Method of ArmaGel® HTF insulation blankets on steel pipes

Cut and fabricate sections of ArmaGel HTF blanket to the required number of layers requirement (see approval). The sections of insulation shall include a minimum 100 mm overlap around the circumference and an additional compensation factor, applicable to all insulation layers (see consumption guide).

All insulation sections when installed shall have no visible gaps showing the bare steel specimen surface.

The ArmaGel insulation is tightly wrapped around the length and contour of the specimen in one full length of blanket (to avoid gaps and voides) - applicable for all insulation layers.

The ArmaGel insulation shall be secured tightly around the steel specimen circumference with industry standard stainless steel insulation binding wire (stainless steel grade 304 or 316) of minimum 0.8 mm in diameter at maximum 200 mm on center for inner layers and 100 mm for the outmost layer.

Install ArmaGel insulation on the same layer using a butt joint.

Stagger the butt joint between layers by a minimum of 200 mm.

All overlapping seams contained within the insulation layers shall be staggered by a minimum of 90° to 120° throughout for each consecutive layer.

Consult the approval and UL listing to determine the amount of insulation layers for the required fire rating relative to the steel member dimensions.

For applications with jet fire requirements, the penultimate layer of ArmaGel HTF need to be fixed additionally with metal straps (16 mm wide industry standard, with thickness of 0.75 mm, tightened with stainless steel tenstion clips, stainless steel grade 304 or 316). For details please refer to relevant third party listings or contact Technical Services.

Fixing and Securing of Stainless Steel Metal Cladding

Fabrication / design & installation of metal cladding

The insulated pipe has to be covered with metal cladding casing installed around the final insulation: use pre-rolled manufactured 0.6 mm thick stainless steel (stainless steel grade 304 or 316).

The cladding shall be installed in sections. Metal jacketing should be staggered. The longitudinal overlapping of jacketing should be ≥ 250 mm. Overlaps around the circumference of the cladding sections shall be a minimum of 200 mm.

For vertical applications, the 1st metal cladding section shall be installed at the bottom of the insulated specimen first, the following metal sections where applicable shall be overlapped facing in a downwards direction as per industry standard (roof tile effect).

Use of blind stainless steel rivets

All metal cladding shall be fixed and secured with 4.8 mm diameter – stainless steel countersunk type pop rivets (stainless steel grade 304 or 316) in pre-drilled 5 mm diameter holes.

Install ≥ 6 rivets/m[1] along the edge of the jacketing. Distance of the first rivet to the edge of the jacketing is ≤ 30 mm. Distance of the rivets to the long edge of the jacketing is 10 to 20 mm.







Use of stainless steel restraining bands and tension clips

All metal cladding shall also be additional secured with 16 mm wide industry standard stainless steel bands and tension clips (stainless-steel grade 304 or 316). Excess length of the band needs to be cut off.

Distance between the bands should be ⩽ 250 mm, the distance of the first band to the edge of the jacketing is 50 to 70 mm.

4.8 mm diameter rivets are installed in pre-drilled 5 mm diameter holes, at a distance of 80 to 100 mm left and right from the clip.

For applications with jet fire requirements for the outer jacketing the distance between the metal straps (16 mm wide industry standard, with thickness of 0.75 mm, tightened with stainless steel tension clips, stainless steel grade 304 or 316) should be max. 200 mm.






Note:

All high-temperature insulation materials may release traces of organic residues during initial commissioning and exposure to high temperatures. This process may be accompanied by the emission of gaseous products and their oxidation, and consequently, a short-term exothermic reaction, which may be accompanied by a specific odour, smoke release, and in extreme cases glowing and/or flaming.

1. To ensure that any self-heating and/or exothermic reaction for operating temperatures above 400 °C is kept within an acceptable range, the following application instructions shall be followed:
   a. All layers of ArmaGel HTF shall be installed and secured tightly to avoid any visible gaps between layers and along all longitudinal and circumferential joints.
   b. The metallic foil (e.g. aluminium stainless steel foil) shall be installed between the two outmost layers of the ArmaGel HTF construction.
   c. The cladding system shall be fully installed before operating the pipe equipment.
2. Do not apply ArmaGel HTF on live pipe equipment when operating above 350 °C and ensure that the insulation system is complete before turning the pipe/equipment on.
3. Do not apply ArmaGel HTF with a total thickness of more than 80mm without first contacting Armacell technical support.
4. The service temperature and application temperatures defined above do not reflect the performance under the fire conditions as per UL 1709 and ISO 22899-1.

ArmaGel® HTF

Approved Systems

ArmaGel® HTF system configuration

The ArmaGel® HTF system consists of multiple layers of the blanket, depending on the required fire rating and dimensions of the pipe. As per industry standards, a stainless steel outer jacketing system is being applied to cover the entire surface area of the ArmaGel HTF blankets.

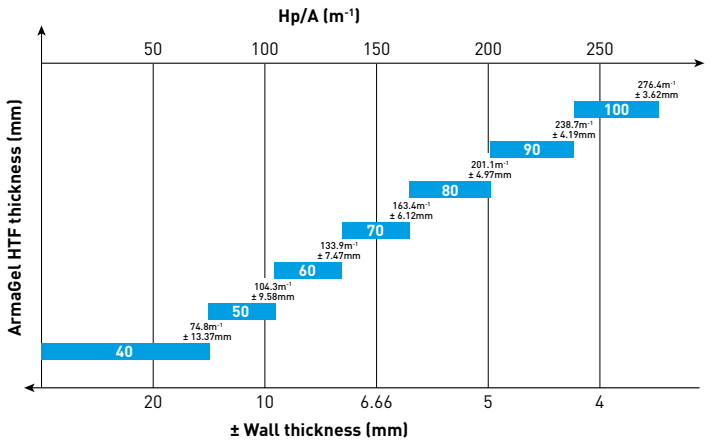
As outlined on page 19 (see chapter "Complying to standards – Why use Armagel HTF to protect steel against fire?", paragraph "Steel mass and Heated perimeter"), industry practice is to fire test a structural steel column having an Hp/A value of 159 m^{-1}. In order to provide a benchmark with this industry practice, ArmaGel HTF has been tested using the nearest possible Hp/A value of a pipe section, being a 8" x SCH 20 (Hp/A = 163 m^{-1}). To demonstrate compliance for lower wall thickness pipes, an 8" x SCH 80 has also been successfully fire tested (Hp/A = 75m^{-1}).

Tested and certified configurations for UL1709 compliance[1,2]

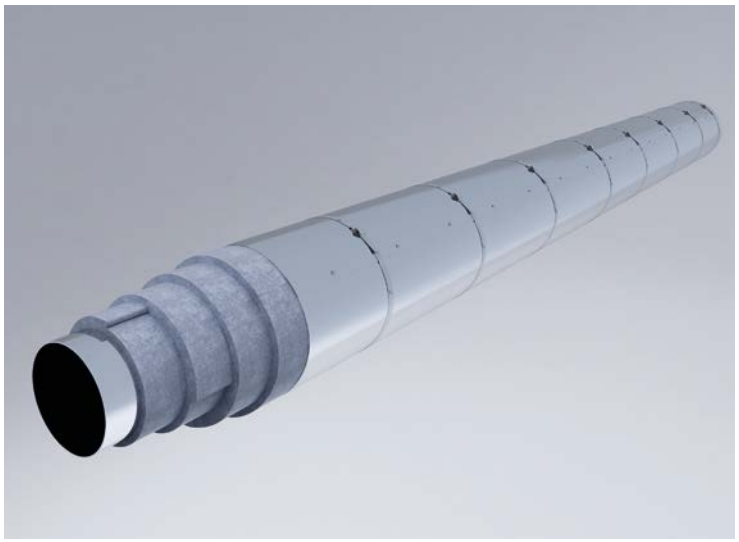
Tested configuration	Fire rating [min.]	Outer diameter [mm]	Wall thickness [mm]	Hp/A Value [m^{-1}]	ArmaGel® HTF
Pipe 8"	120	219.1	3.68	276.4	10 x 10mm
Pipe 8"	120	219.1	6.3	163.4	7 x 10mm
Pipe 8"	120	219.1	14.2	74.8	4 x 10mm
Pipe 8"	90	219.1	6.3	163.4	5 x 10mm
Standard steel beam W10x49 (in x lb/ft)	120	-	-	177.3	3 x 10mm

[1] All fire tests have been officially conducted at a UL laboratory under full witnessing by UL.
[2] For the installation procedure please contact Technical Services for guidance.

Technical offering for UL1709 – 120min pipe designs



[1] All fire tests have been officially conducted at a UL laboratory under full witnessing by UL.



For **ArmaGel HTF thickness' 40 mm, 70 mm and 100 mm** official fire tests have been conducted at the UL laboratory, fully in accordance with UL1709.

For **ArmaGel HTF thickness' 50 mm and 60 mm as well as 80 mm and 90 mm**, the values have been interpolated based on the results of the official UL1709 fire tests, in accordance with appendix A1 of UL1709.

Fire performance & approvals		
Surface burning characteristics	≤ 5 flame spread index ≤ 10 smoke development	Tested according to ASTM E84
Fire resistance	Tested configurations for jet fire compliance (ISO 22899-1)[6]:	Officially tested at Efectis/France according to ISO 22899-1

Tested configuration	Fire rating	Outer diameter [min.]	Wall thickness [mm]	Hp/A Value [m^{-1}]	ArmaGel® HTF [mm]
Pipe 8"	90	219.1	6.3	163.4	5 x 10mm

ArmaGel HTF Jet fire test at Efectis/France, officially witnessed by Efectis/France and UL Europe. The below pictures were taken during the test.

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Complying to Standards - Why Use ArmaGel® HTF to Protect Steel Against Fire?

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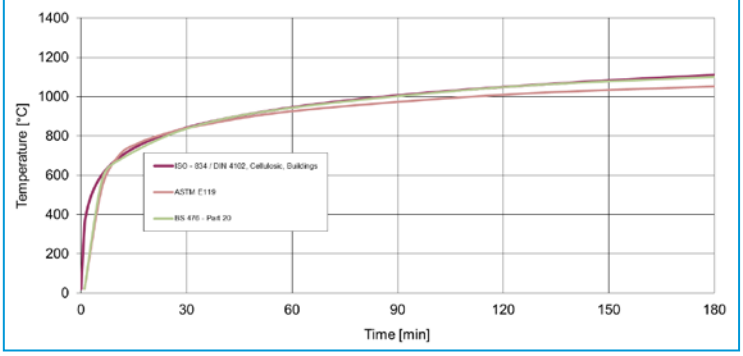
Complying to Standards – Why Use ArmaGel® HTF to Protect Steel Against Fire?

1. Fire growth rates and fire curves

The devastating effects that fires can have on assets and buildings are commonly known. Not only are fires, and predominantly smoke and toxic gases, lethal for the humankind, the temperatures associated with such fires can make process equipment and piping systems collapse and fail, and cause load bearing structures to collapse.

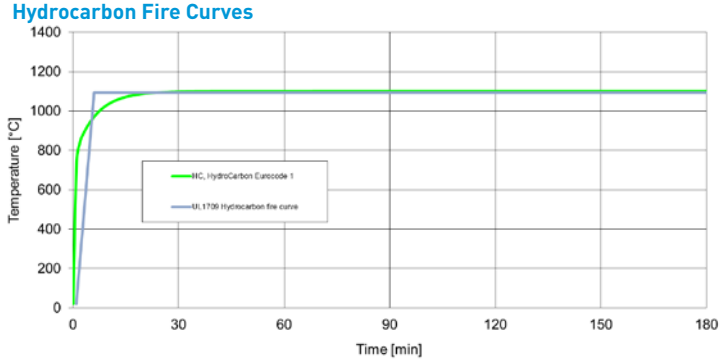
Fires in commercial or residential buildings have in common that the combustibles are mainly cellulosic based materials. Such fires have a moderate fire growth rate and maximum temperature. The time – temperature development (the fire curve) of such fires is regulated in several global and national standards, such as ISO-834, ASTM E119, BS 476-20 and AS 1503.4. These fire curves are based on the burning rate of general building materials and building contents, and are often referred to as Standard Fire Curve or Cellulosic Fire Curve.

Cellulosic Fire Curves



However, industrial fires are completely different, and much more severe, compared to the fires in commercial or residential buildings, as described above. Fires in oil and gas plants, refineries, petrochemical installations etc. are often based on liquid hydrocarbons, gasses or chemicals. The calorific value of such combustibles, expressed in kcal/m^3 or BTU/ft^3, is much higher than those of cellulosic materials, and therefore the fire growth rate and maximum temperature generated by the fire are much higher. Also, these combustibles are almost unlimitedly available in an industrial plant, so the fire duration will be extended as well. The fire curve which represents such fire scenarios is regulated in UL1709, as well as by the Eurocode. Such fire scenarios represent a hydrocarbon pool fire in the open field, reflecting a fuel spill which forms a fuel reservoir and then ignites. These fire curves are often referred to as Hydrocarbon Fire Curve or Pool Fire Curve. The same regulated fire curves are used for on-shore and off-shore facilities. These fire scenarios are known for having a very steep temperature increase in the first minutes. For example, the UL1709 fire curve reaches 1093°C within 5 minutes and remains stable for the duration of the fire test at this temperature. This thermal shock poses a particular challenge to most building materials and it requires specifically designed products and engineered systems to survive such fires and protect the asset from failure or collapse.

Hydrocarbon Fire Curves

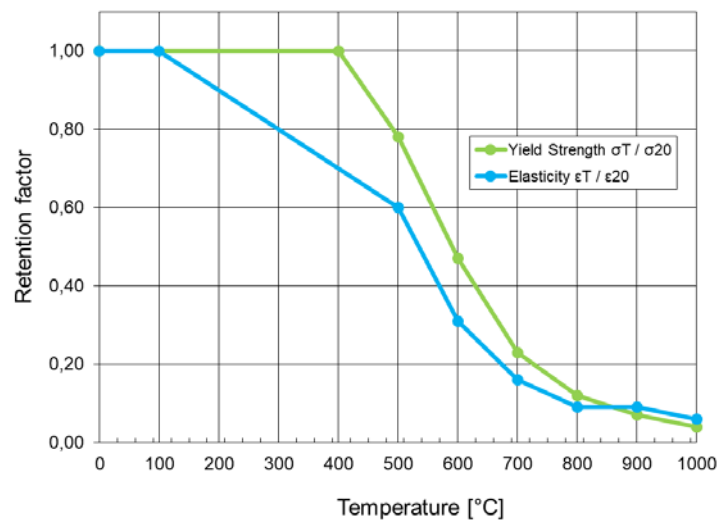


Stakeholders in the oil and gas, petrochemical sector are commonly aware of such fire risks and are risk adverse for very good reasons. Industrial fires pose a direct risk to those working at the facility, and the risk of downtime, or even a total-loss of the entire facility, has to be mitigated as well for economic reasons.

2. Why protect steel against fire?

Even though steel is a non-combustible product, the loss of strength and stiffness when exposed to fire temperatures is significant. The Eurocode 3 provides retention values for both yield strength and elasticity, as a function of temperature, compared to the values at an ambient temperature of 20°C. The Eurocode 3 retention values are very similar to the ones listed in ATSM A36.

Structural steel
Relative loss of strength and stiffness



A key takeaway from the graph above is that, for example, at a fire temperature of 600°C the yield strength of steel has been reduced by more than 50% of the yield strength at ambient temperature, and the elasticity is only 30% of the ambient value. Another example: at 1000°C fire temperature, both the yield strength and elasticity have been reduced by over 90% of the ambient value.

As stated previously, fire temperatures increase very rapidly in the first few minutes of a fire, especially industrial fires which reach nearly 1100°C within 5 minutes. Leaving steel members fully exposed to such fire temperatures, would include a significant risk to deflection and structural collapse of the steel members, early on in the fire event.

For the reasons described above, industry practice is to protect critical steel members against fire risks by means of the application of passive fire protection systems. This is being regulated by industrial fire standards which are being addressed in the next paragraph.

3. Governing industrial fire standards

3.1.UL1709

UL1709 [Rapid Rise Fire Tests of Protection Materials for Structural Steel] is the most commonly used fire standard, referred to in technical specifications by the oil majors, FEED engineers and EPC's. The current version of UL1709 is the 5th edition, issued in February 2017.

The basics of a compliance fire test to UL1709-05 is that, when exposed to the UL1709 fire curve, the average temperature of the thermocouples installed on the steel test specimen shall not exceed 538°C, and none of the thermocouples shall exceed a maximum recording of 649°C. For further details on the test procedure, reference is made to the UL1709-05 standard.

On their webpage **https://www.ul.com/resources/testing-and-certification-steelwork-fire-protection**, UL acknowledges the fact that the UL1709 standard gets adopted increasingly. At the same time, non-UL test laboratories which are not accredited for UL1709 fire testing, seem to have different interpretations of the intended test methodology. On the referenced webpage, UL addresses some of the misinterpretations and provides clarity on some key principles of the fire test method. UL states:

3.1.1. Furnace calibration

The current method for calibrating the furnace requires a single calibration column to be placed centrally within the furnace chamber. This is intended to reflect what will happen in the subsequent type of testing, thereby exposing the sample under test to the same thermal dose as the calibration column and ensuring a high level of consistency in evaluating the protection system from test to test. It is not intended that more than one specimen is included in the furnace at the same time as this will result in one or more sides of the columns being shielded from some of the heat within the furnace chamber such that the intended Time-Temperature (t-T) and heat flux exposure to the specimen is not replicated. This practice is also likely to result in some columns being nearer to the walls of the furnace chamber, which can also result in a lower thermal dose on the protection system under evaluation.

3.1.2. Furnace thermocouples

According to UL 1709, the furnace should be calibrated using eight thermocouples at a maximum distance of 102 millimetres from the exposed face of the specimen. That means eight thermocouples per column to ensure that the furnace temperature is controlled such that the test specimen is exposed to the intended t-T curve. These thermocouples must also be evenly distributed throughout the furnace to ensure an even evaluation of the thermal dose during the test. Uneven distribution of the thermocouples within the furnace chamber is likely to cause a heat gradient, causing uneven heating of the column(s).

3.1.3. Furnace control

As with most furnace testing, there are variables due to the very nature of the equipment being used. The Standard provides guidance on the level of acceptable variation, in particular with the temperature within the furnace chamber. The intention is that the tolerances are there as guidance to compensate for fluctuation and not to be used in continuous operation. In the ideal test, the tolerances would not be used and would operate within the mean values. To operate the furnace such that it runs toward the lower or upper tolerances will give a lack of consistency between tests as well as between protective systems being evaluated. This is of particular concern when the lower range of tolerance is targeted. This practice should not be followed, and test data generated via a test operated at the lower end of the tolerances throughout the test should be treated cautiously with the understanding it may not perform as other products evaluated to the prescribed fire curve.

3.1.4. Specimen thermocouples

UL 1709 is clear in the number of thermocouples to be used on each specimen. There are a number of reasons why this should be followed, not least to provide a consistent approach to the evaluation of the protective system. In some cases, we are aware that less than the number of required thermocouples are used on the test specimen(s). While this is not in accordance with the standard requirements, the greater concern is there may be a part of the protective system that gets overlooked because of the reduced number of specimen thermocouples. Given that this test is only evaluated to temperature limits rather than the structural limits, it is imperative that all instruments are installed as required such that a representative sampling across the full test specimen is captured. Chapter 5 of the Standard is clear that 20 specimen thermocouples should be used per column. As with the furnace control matter discussed above, data produced using less than 20 thermocouples per column should be treated with caution and considered not compliant with the requirements of the test standard.

3.1.5. Protective system

In all fire tests, the tested system should be representative of what will be used in the final installation on site. If changes are made to what was tested and certified, there will likely be an impact on performance. This means it is critical that the details of the tested system are recorded accurately and are then installed in practice as required in the certification documentation. If these details are not followed, there may be a loss of fire performance and a threat to life safety.

For instance, in cases where a stainless steel wrap is added to columns for the test, even though it does not have a high thermal insulation value, the addition of the casing will add thermal protection to the steel column. It will do this by creating an air gap that insulates the column and by stopping the convection of hot gases in the furnace, which otherwise might have penetrated the protective system. This is just one example where a small element of the protective system, one that may appear to add little or no thermal resistance, can be critical to the system's overall fire performance and proven by way of fire testing. Therefore the full configuration of the protective system, as tested, shall be installed on-site as well to help ensure the required fire safety levels are provided.

3.1.6. Durability

Often the protective products tested and certified to UL 1709 will be placed in harsh environments when placed in practice. It is for this reason that the Standard mandates durability testing that simulates these harsh environments be performed on all protection systems intending to be certified to UL 1709. The durability testing is conducted to UL 2431, the Standard for Safety for Durability of Fire Resistive Coatings and Materials, and the protection systems must comply with all requirements for Material Classification Category I-A: Outdoor, Heavy Industrial as prescribed in the Standard. The individual listing on UL's Product iQTM database will indicate the protection system's compliance with these durability testing requirements.

3.1.7. Official material sampling by UL for fire testing purposes

In addition to the clarifications above, provided by UL, UL also insists and ensures that the products which will be used for the actual UL1709 fire test(s), are being independently selected by a UL representative at the vendors factory. This aims to ensure that the tested product quality and specifications are representative for the actual products which are supplied and installed on-site.

4. Steel member dimensions and fire performance

Zooming into the failure mechanisms of steel members when exposed to fire, two parameters play a pivotal role: the steel mass of a steel member and the heated perimeter of the passive fire protection system.

4.1. Steel mass

The heating rate of a steel member is impacted by the steel mass of that particular steel member. A steel member can be a critical process equipment pipe, a load bearing steel column or beam. The more steel mass a steel member contains, the longer it takes for it to heat up. Vice versa, a steel member which holds a very small mass, will be heated up very quickly. This is why, in fire test standards the value of steel mass is included in the fire performance analyses of passive fire protection systems.

The European Standard refers to the value A, being the cross-sectional area of the steel section [m^2]. UL1709 refers to the value W, being the weight per linear foot [lb]. Regardless of the unit, both standards acknowledge that the amount of steel is a relevant parameter to assess the fire performance of a steel member.

4.2. Heated perimeter

The surface area of the passive fire protection system, which gets heated by the fire, will transfer the temperature to the steel member, through a combination of radiation, convection and conduction. The surface area is referred to as the heated perimeter. The larger the heated perimeter, the faster a steel member will be heated up.
In fire test standards, the value of the heated perimeter is included in the fire performance analyses of passive fire protection systems.

The European Standard refers to the value Hp, being the perimeter exposed to fire [m^1]. UL1709 refers to the value D, being the heated perimeter [inch]. Regardless of the unit, both standards acknowledge that the heated perimeter is a relevant parameter to assess the fire performance of a steel member.

4.3. Steel mass and Heated perimeter

The European Standard applies the Hp/A [m^{-1}] value as a reference to the massivity of a steel member. A higher Hp/A value means that a member is more vulnerable to be heated up faster. That member has a relatively high heated perimeter or a relatively low steel mass, or both. A lower Hp/A value means that a steel member can withstand the fire somewhat longer, before it reaches critical failure temperatures.

UL1709 expresses the massivity of a steel member as W/D [lbs/inch]. A steel member with a higher W/D value will take longer to be heated up. That steel member has a relatively high steel mass or a relatively low heated perimeter, or both.
Regardless of the unit, both standards acknowledge that the ratio of steel mass and heated perimeter is a relevant ratio to assess the fire performance of a steel member.

For UL1709 fire testing of structural steel columns as per industry practice, the selected typical steel member dimension is W10x49, which is a wide flange beam (10 inch wide), weighing 49 lbs/feet. The corresponding massivity values are Hp/A = 159 m^{-1} or W/D = 0,84 lbs/inch.

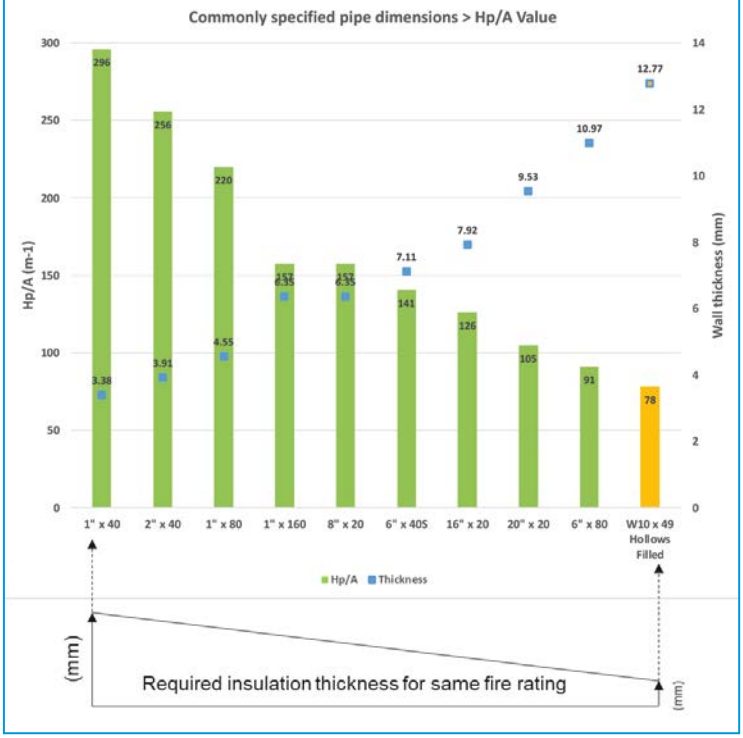
5. Critical process equipment piping systems

In industrial facilities, critical process equipment piping systems are pivotal to ensure smooth operations, maintain process temperatures at the required levels and avoid downtime. Piping systems are therefore equipped and protected against a number of potential exposures and deterioration, such as corrosion prevention, thermal insulation for operational use, protection against cryogenic spill, passive fire protection, acoustic insulation, impact protection and others. As space is very often limited in industrial facilities, stakeholders are requesting manufacturers of such protective products to develop multi-purpose systems which meet the requirements of multiple industry standards. By combining the compliance to multiple standards into one system, the space required for the full protection package on the pipe is being reduced, the system gets easier and cheaper to maintain and will be more economical from a material purchasing and labour cost point of view.

5.1. Massivity of pipe sections

Compared to structural steel wide flange beams, pipe sections intrinsically have a lower steel mass and a relatively large heated perimeter. This results in higher Hp/A values and therefore a higher vulnerability to being heated up in fire conditions, beyond the thermal failure criteria of UL1709 as outlined in paragraph 3.1 above.
To maintain fire safety designs of fire requirements on critical process equipment piping systems at the required level, fire rated pipe designs shall be treated differently as opposed to fire rated designs for structural steel wide flange beams. The graph below holds an overview of commonly specified pipe dimensions and their associated Hp/A values, compared with the Hp/A value of a W10x49 wide flange beam.

Commonly specified pipe dimensions > Hp/A Value



The impact of lower a wall thickness on the increasing Hp/A value is clearly demonstrated. Consequently, a higher Hp/A value leads to larger thickness of the insulation material, required to achieve the same fire rating. Comparing commonly specified pipe designs to the W10 x 49 wide flange beam, as per industry practice for structural steel members, it's clear that the Hp/A value of the beam is not at all

representative for Hp/A values found for pipe designs. Insulation thicknesses obtained from fire test data on beams are therefore not suitable for pipe applications. If applied incorrectly, the insulation thickness derived from fire test data on beams will be insufficient to achieve the intended fire protection levels on a specific pipe configuration, in which case the intended safety requirements are not met, exposing the facility and its users to premature failure and collapse of the equipment at hand.

6. Calculating Hp/A values in the Energy sector

6.1. Preamble

In the Energy sector, a variety of critical process equipment, having different shapes and dimensions, require passive fire protection means. It's mainly the shapes which can cause challenges in determining the Hp/A value. This chapter provides clarification and support in accurately calculating Hp/A values for pipes, vessel skirts, vessels and spheres. It also provides a simplified calculation method for each of these items, for quick Hp/A assessments.

6.2. Pipes / Vessel skirts / Vessels

Even though the dimensions of these 3 items can differ considerably, the Hp/A calculation principle is equal for all of them.

All systems consist of a single skin cylindrical steel shape which is protected by a means of passive fire protection. Regardless of the dimensions, the formulas used for the Hp/A calculation remain the same. Note that the longitudinal dimension of the pipe, vessel or vessel skirt is irrelevant for Hp/A calculations.

The Hp/A calculation of pipe-like configurations addresses the 2-dimensional cross section of the pipe-like design. The Hp value (heated perimeter), for a pipe-like Hp/A calculation, has the unit [m^1] and the A value (steel mass) has the unit [m^2], resulting in a unit [m^{-1}] for Hp/A.

The attached formulas offer a detailed calculation method by taking the pipe Outer Diameter (OD) and Inner Diameter (ID) into account. It also offers a simplified calculation method by only taking the pipe wall thickness (or the thickness of the vessel skirt or vessel) into account. The latter method can be used for quick Hp/A calculations, but the detailed method provides 100% accuracy.

6.3. Spheres

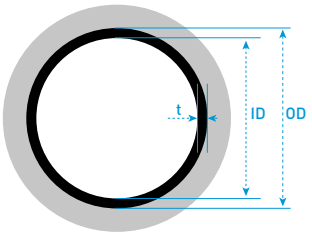
Mathematically, the Hp/A calculation of spheres is different from pipes, especially because a sphere has to be considered as a 3-dimensional object, whereas pipes can be addressed only 2-dimensionally.

The Hp value (heated perimeter), for a sphere Hp/A calculation, has the unit [m^2] and the A value (steel mass) has the unit [m^3], resulting in a unit [m^{-1}] for Hp/A.

The attached formulas offer a detailed calculation method by taking the spheres Outer Diameter (OD) and Inner Diameter (ID) into account. It also offers a simplified calculation method by only taking the spheres wall thickness into account. The latter method can be used for quick Hp/A calculations, but the detailed method provides 100% accuracy.

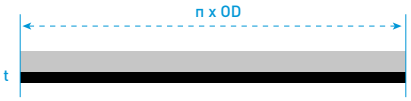
Pipes / Vessel skirts / Vessels

Detailed calculation



$$Hp/A = \frac{4 \times OD}{(OD^2 - ID^2)}$$

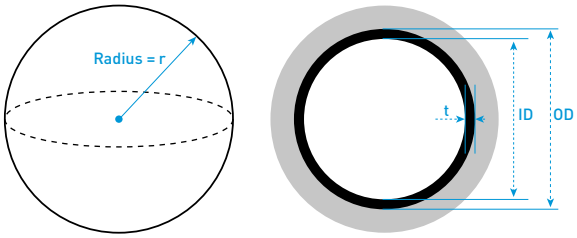
Simplified calculation



$$Hp/A = \frac{1}{t}$$

Spheres

Detailed calculation



$$Hp/A = \frac{3 \times \left(\frac{OD}{2}\right)^2}{\left[\left(\frac{OD}{2}\right)^3 - \left(\frac{ID}{2}\right)^3\right]}$$

Simplified calculation

$$Hp/A = \frac{1}{t}$$

7. Introducing ArmaGel® HTF

With the statements made in paragraph 5 in mind, Armacell has developed a unique, state-of-the-art fire rated aerogel blanket, which is officially tested at the UL firetesting facilties to be fully complaint with UL1709, plus it has been tested in accordance with the aerogel product standard ASTM C1728-21 [Standard Specification for Flexible Aerogel Insulation], Type III, Grade 1, Category A.

Using a patented technology, ArmaGel® HTF has proven to maintain its fire integrity for over 180 minutes, when exposed to the UL1709 fire curve. Applied as a pipe insulation configuration, the ArmaGel® HTF system meets the UL1709 criteria for the duration of 120 minutes and the system complies to the requirements of UL2431.

The targeted application of ArmaGel® HTF is to protect critical process equipment piping systems against fire, combined with thermal insulation properties required to keep the line temperature at the specified levels. Reference to paragraph 3.1.5. above, ArmaGel® HTF has therefore been fire tested and certified as a pipe insulation configuration, ensuring that the tested system is representative of the actual application in the field.

Being tested at the official UL fire testing laboratories, the ArmaGel® HTF system fully complies with the UL1709 and UL2431 requirements, including the key principles of the fire test method, as referred to in paragraph 3.1.

ArmaGel® HTF:

a. is the only aerogel based blanket material which holds an official UL1709 listing at UL Product IQ, and
b. is the only UL1709 listed aerogel based blanket material for the intended application of fire rated pipe insulation, and
c. complies with the requirements of the aerogel product standard ASTM C1728-21, Type III, Grade 1, Category A.

8. ArmaGel® HTF system configuration

The ArmaGel® HTF system consists of multiple layers of the blanket, depending on the required fire rating and dimensions of the pipe. As per industry standards, a stainless steel outer jacketing system is being applied to cover the entire surface area of the ArmaGel® HTF blankets. For further construction details of the system, reference is made to the ArmaGel® HTF installation manual.

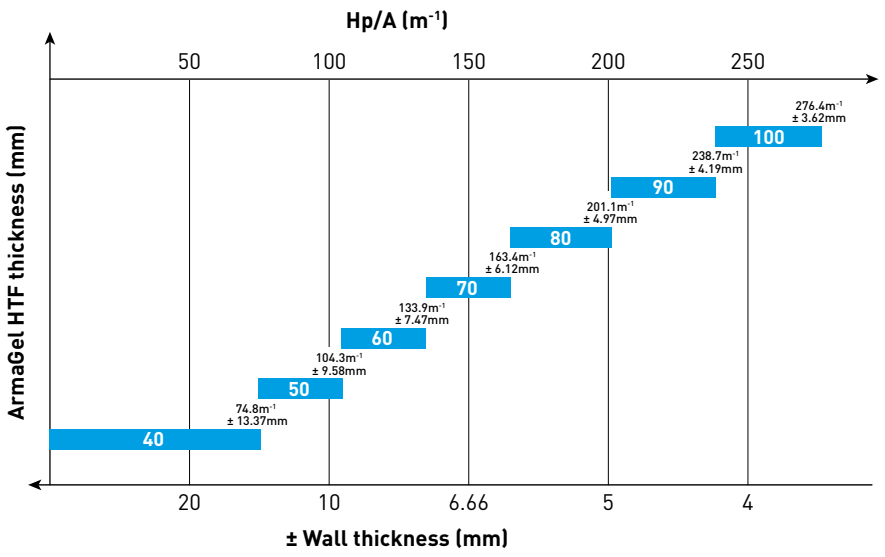
As outlined in paragraph 4.3 above, industry practice is to fire test a structural steel column having an Hp/A value of 159 m^{-1}. In order to provide a benchmark with this industry practice, ArmaGel® HTF has been tested using the nearest possible Hp/A value of a pipe section, being a 8" x SCH 20 (tested Hp/A = 164.3 m^{-1}). To demonstrate compliance for higher wall thickness pipes, an 8" x SCH 80 has also been successfully fire tested (Hp/A = 74.8 m^{-1}).

Tested and certified configurations for UL1709 compliance[1,2]

Tested configuration	Fire rating [min.]	Outer diameter [mm]	Wall thickness [mm]	Hp/A Value [m^{-1}]	ArmaGel® HTF
Pipe 8"	120	219.1	3.68	276.4	10 x 10mm
Pipe 8"	120	219.1	6.3	163.4	7 x 10mm
Pipe 8"	120	219.1	14.2	74.8	4 x 10mm
Pipe 8"	90	219.1	6.3	163.4	5 x 10mm
Standard steel beam W10x49 (in x lb/ft)	120	-	-	177.3	3 x 10mm

[1] All fire tests have been officially conducted at a UL laboratory under full witnessing by UL.
[2] For the installation procedure please contact Technical Services for guidance.

Technical offering for UL1709 – 120min pipe designs



For **ArmaGel HTF thickness' 40 mm, 70 mm and 100 mm** official fire tests have been conducted at the UL laboratory, fully in accordance with UL1709.

For **ArmaGel HTF thickness' 50 mm and 60 mm as well as 80 mm and 90 mm**, the values have been interpolated based on the results of the official UL1709 fire tests, in accordance with appendix A1 of UL1709.

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ABOUT ARMACELL

As the inventor of flexible foam for equipment insulation and a leading provider of engineered foams, Armacell develops innovative and safe thermal and mechanical solutions that create sustainable value for its customers. Armacell's products significantly contribute to global energy efficiency making a difference around the world every day. With more than 3,300 employees and 27 production plants in 19 countries, the company operates two main businesses, Advanced Insulation and Engineered Foams, and generated net sales of EUR 806 million and an adjusted EBITDA of EUR 121 million in 2022. Armacell focuses on insulation materials for technical equipment, high-performance foams for acoustic and lightweight applications, recycled PET products, next-generation aerogel technology and passive fire protection systems.

For more information, please visit:
www.armacell.com/armagel

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