INSULATION JUST GOT COOLER

Performance of ArmaGel® for LNG in Tropical Climates

www.armacell.com




KAEFER

armacell®

MAKING A DIFFERENCE AROUND THE WORLD

Customer	Armacell Group
Contact details	Mark Swift - mark.swift@armacell.com
Test specimen	ArmaGel DT cold and acoustic system
Project No.	2021-12391-GG
Start date	5th October 2021
End date	5th November 2021
Date and Revision	27th June 2023, REV 004

1. CONTENTS

2. AIM OF THE TRIAL

The aim of the test was to verify the behavior of a cold and acoustic insulation system for LNG under tropical conditions. Particular attention was paid to the thermal behaviour and system integrity during service.

The insulation system tested in cooperation between KAEFER and Armacell offers the advantage of combining both cold and acoustic properties in one construction.

3. PREPARATION

Preliminary adhesion tests of diverse tapes and glues were made.

Armacell and KAEFER developed together the application of spray glue as a best practice..

3.1. HANDLING AND SAFETY

All the materials were installed in accordance with procedures and application guides recommended by manufacturers, safety data sheets, as well as PPE / RPE guidance.

The standard industrial working practices were followed during the application. Local and union recommendations for the installation of the insulation system must be followed.

To ensure worker safety, the use of FFP2 or FFP3-masks, latex gloves and coveralls were incorporated.

4. GENERAL TEST DESCRIPTION

4.1. TEST SPECIMEN

The tested system consisted of the following materials:

- ArmaGel® DT, Armacell: Insulation Mats in 10- and 20-mm thickness
- Vaporstop, TEMATI: vapour barrier
- ArmaSound Barrier E, Armacell: Noise barrier 4 mm thickness
- TEMBUTIL sheet

To test the cold insulation system, a pipe with a nominal diameter of 10" (273 mm) was selected, see Figure 1. A T-piece was welded in the middle of the total length and the entire pipe was placed on two PIR-supports with a connected wooden structure. The ends of the pipe were closed with screw flanges and thermally insulated with Armaflex LTD and Armaflex HT. The ends and the PIR-supports were not subject of this study.

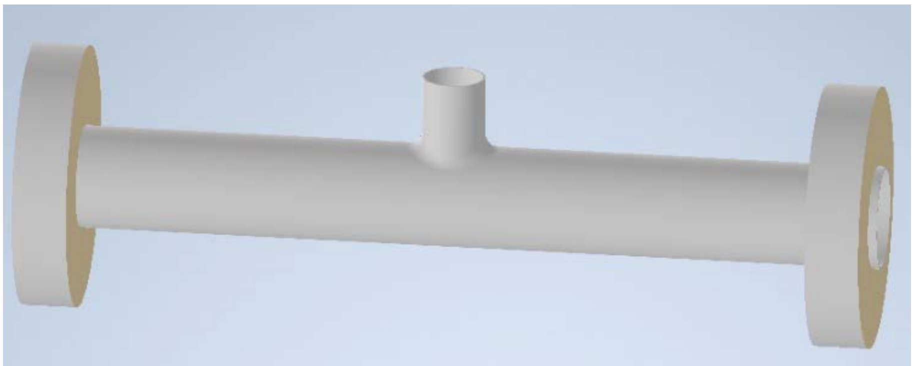


Figure 1: CAD View of the test rig, pipe closures missing.

Water can penetrate the insulation through open areas at joints and, in worst case, meet the insulated component. Especially in systems with temperature fluctuations, the pumping effect can occur, whereby water is transported into the insulation and can only flow away with difficulty, it can accumulate between the layers and depending on the local temperature, icing could occur.

4.2. BOUNDARY CONDITIONS

The selected boundary conditions for the test according to the specification of the LNG project in tropical areas (e.g. LNG Mozambique) were:

- Ambient temperature: **32 °C**
- Air humidity: **88 % r. H**
- Service temperature: **-164 °C**

5. TEST METHOD

5.1. METERIALS

Within the scope of this project, an insulation system for acoustic insertion loss class D2 according to Shell DEP 30.46.00.31 was selected as test specimen. According to the agreement between KAEFER and Armacell, it was necessary to install the following materials to fulfill the requirements of a typical LNG insulation specification for high temperature and high humidity environment, see Table 1.

The insulation system was divided into two inspection zones (section 1 and section 2), see Figure 2. Section 2 had an additional vapor barrier as shown in 2, see light blue lines.

Layer	Section 1 Material Designation	Section 2 Material Designation	Material Source	Thickness [mm]
1	ArmaGel DT	ArmaGel DT	Armacell	20
2	ArmaGel DT	ArmaGel DT	Armacell	20
3	ArmaGel DT	ArmaGel DT	Armacell	20
4	ArmaGel DT	ArmaGel DT	Armacell	10
4.1	Vaporstop	Vaporstop foil (Mylar foil)	TEMATI	0.05
5	ArmaGel DT	ArmaGel DT	Armacell	20
6	ArmaGel DT	ArmaGel DT	Armacell	10
6.1		Vaporstop foil (Mylar foil)	TEMATI	0.05
6.2	ArmaSound Barrier E	ArmaSound Barrier E	Armacell	4
7	ArmaGel DT	ArmaGel DT	Armacell	20
7.1	Tembutil Sheet	Tembutil-IF Sheet	TEMATI	1.05
7.2	ArmaSound Barrier E	ArmaSound Barrier E	Armacell	4

Table 1: System materials

The actual thickness of the insulation materials was exactly at the nominal value, so it was not necessary to take production tolerances into account.

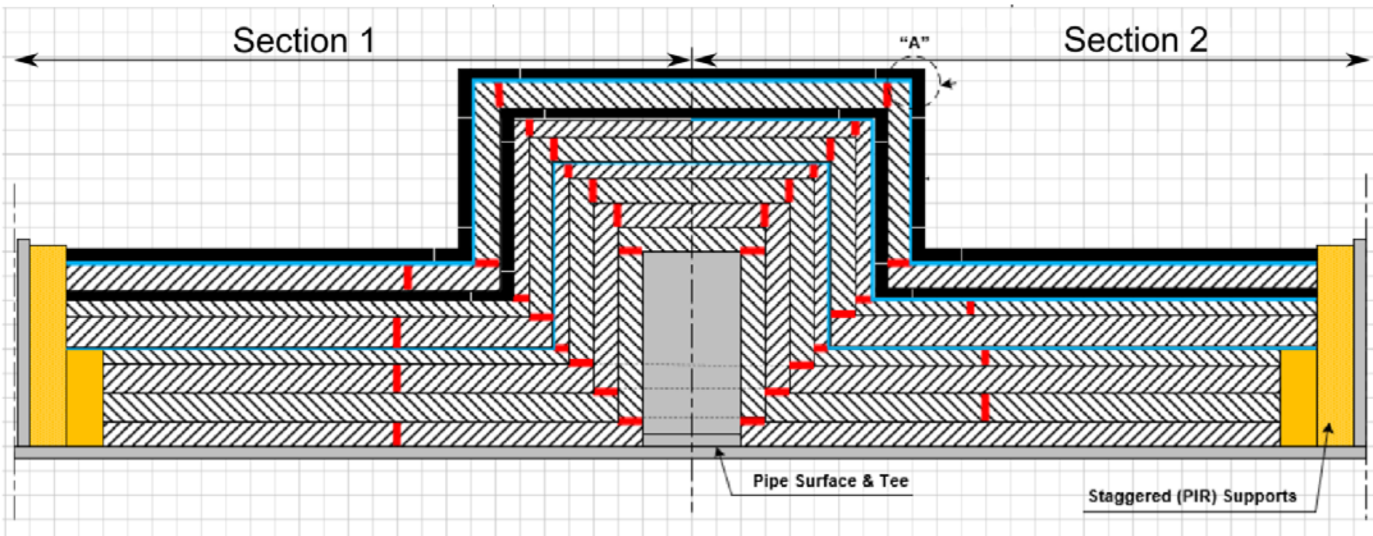


Figure 2: Inspection zones: section 1 and section 2

In addition, following auxiliary materials were used for the installation:

- Coroplast Aluminum tape, 50 and 75 mm
- Filament tape, 19 mm
- Tembutil-IF tape, 100 mm
- Glukon Spray adhesive
- PIR support, PUREN PIR, 47 - 52 kg/m³
- Foster Cryogenic Adhesive 90 66
- Sealing: ArmaChek Mastic grey
- Tembutil-IF Sheet
- Metallic banding

The materials were sourced jointly by Armacell and KAEFER.

5.2. ASSEMBLY

The installation process was carried out under tropical conditions inside the climate chamber (32 °C and 88 % r. h.) and was performed by Armacell. The KAEFER Lab team installed the thermocouples between the layers.

The installation was carried out according to the installation instructions provided by Armacell.

5.2.1. Preparation for assembly

Local requirements by German law were followed for this test. If this information is used for other countries, please check local regulations/recommendations.

A selection of safety equipment was made available to the participants of the installation outside the climatic chamber:

- FFP2 and FFP3-masks
- Goggles (closed and sealed)
- Coverall for chemical applications
- Latex gloves

A cut station was prepared in the climate laboratory to reduce the contamination of the lab with the released dust. For that, a tent of 2 x 2 m was placed near the chamber, see Figure 3. A vacuum cleaner with HEPA filter for fine particles was prepared to keep the working areas clean.

The insulation material and all ancillaries were placed in the climate lab near the cutting station.

The test specimen was placed in the climate chamber and all the sensors were pre-installed for a quick installation, see Figure 3.

Figure 3: Test specimen in the climate chamber

To simulate the real system, pipe supports were included according to industry standard design, see Figure 4. These supports were located adjacent to the existing supports on the pipe for the measurement

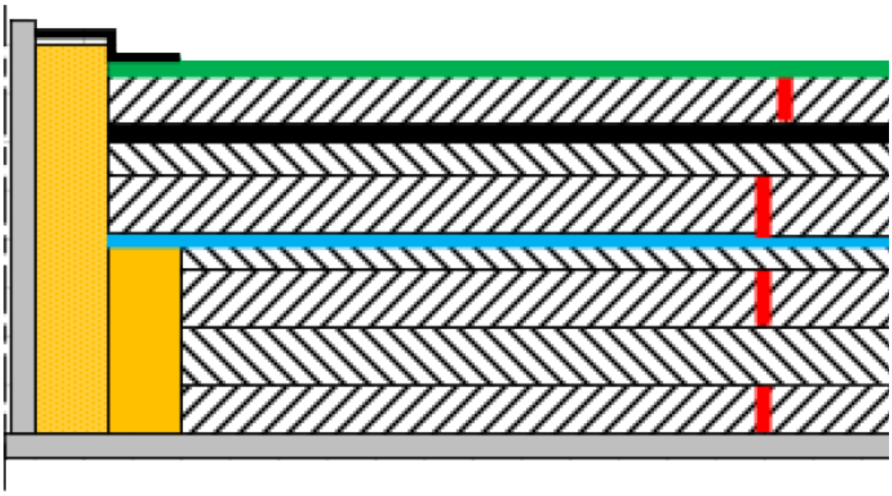


Figure 4: Pipe Supports

Through the supports, the thermocouples will be guided out of the system. The passage of the thermocouples could be a source of error; therefore, it was of great importance to achieve a watertight seal between the supports and at the inlet and outlet of the thermocouples.

The pipe supports were produced at KAEFER by milling. To guarantee the seal of the thermocouples, channels were proportioned on the front side of the supports to the size of the cables, see principle drawing Figure 5.

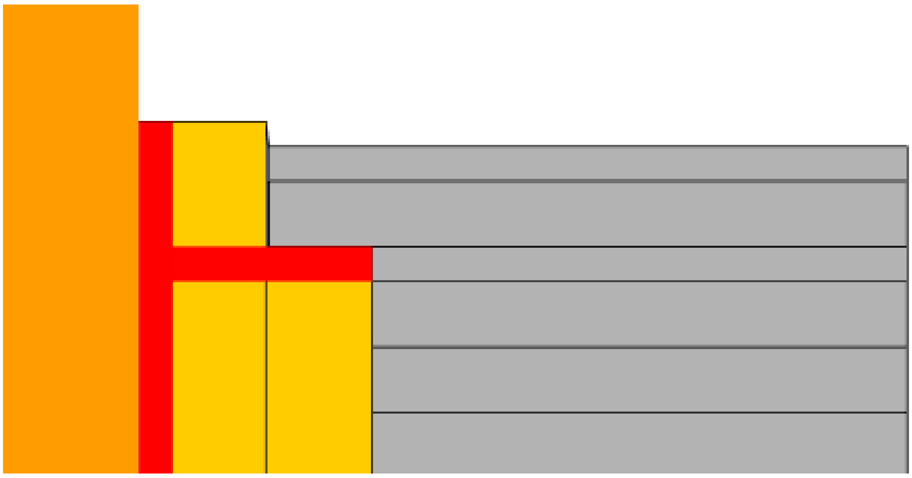


Figure 5: Principle drawing of the channeling

The pipe supports were fabricated together with the necessary channels to guide the thermocouples to the outside. The channels were drilled at 0°, 90°, 180° and 270° in each layer, passing through the support and being led vertically outwards as shown in red, Figure 6.

The supports were sealed with Foster products and mounted to the pipe. After assembly of the insulation system and sensors, the channels were sealed using PUR glue (Macroplast 8160).

5.2.2. Installation of the insulation

The installation process of the test specimen was started by removing the material from its packaging and cleaning away residual dust deposited on the surface using a microfibre cloth.

The cleaned insulation blankets were cut at the cutting station by knives and cutters as well as by using a metal profile as template, see Figure 6.

Figure 6: Cutting process using cutter and template

The measurement of the diameter and other geometries was performed using material strips directly on the test specimen, see Figure 7. For lineal measurements a measuring tape was used.

Figure 7: Measuring the diameter using material strips

More complicated geometries were measured and cut freehand, always using a 45°-angle. The cuts fitted perfectly into each insulated element providing full sealing of the joints and the 45°-cut offered a better contact of the faces and kept dust release to a minimum.

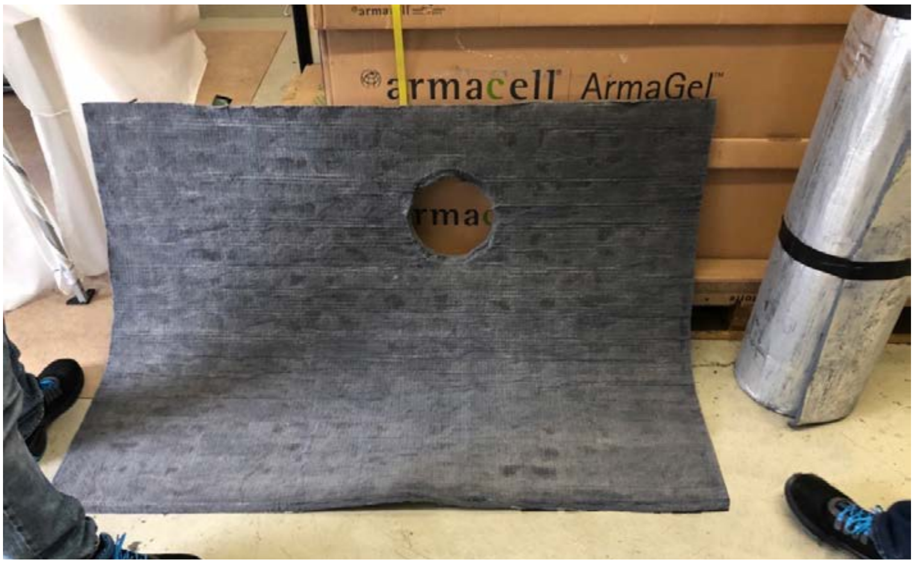


Figure 8: Freehand cut for the T-piece

After cutting, the material was cleaned using again microfiber cloths and then transported into the climatic chamber.

The blankets were put in position over the tube and held in place with reinforced tapes. The joints were then cleaned again, and a thin layer of spray adhesive was applied before sealing the joints with aluminium tape. The spray adhesive ensured the adhesion of the aluminium tape by encapsulating any residual dust from the material.

All joints, longitudinal and radial, were carefully closed with aluminium tapes, see Figure 10. After the installation of an insulation layer, the thermocouples were attached using masking tape, see blue tape in Figure 9.

Figure 9: First insulation layer

In case the aluminium film covering the material was damaged during installation or transport, spray adhesive was applied and then repaired with aluminium tape, see Figure 10.

Figure 10: Repair of superficial damage. Left: spray adhesive, right: aluminium adhesive tape

The adhesion process with spray and then tape was also used to glue the vapour barrier of aluminium film and the butyl. The only difference with the insulation layers was that, for the Tembutil and for the vapour barrier, the tape used was also Butyl, see Figure 11.

Figure 11: Installation of the vapour barrier

On top of the last Tembutil layer, two sensors for moisture detection (KAEFER HydLocatorTM) were installed: one at 12 o'clock and one at 6 o'clock, see Figure 12.

Figure 12: Sensor for humidity detection. Left: sensor at 12 o'clock, right: sensor at 6 o'clock

The final layer which was the acoustic barrier was held in place during installation using duct tape and finally secured with metal banding. The overlap was glued with spray adhesive, see Figure 13.

As the test was carried out in the narrow climatic chamber, the clips were covered with aluminium tape to avoid possible issues for the lab personal.

Figure 13: Installation of the Acoustic Barrier

5.3. SENSOR SYSTEM AND MEASUREMENTS

Thermocouples were selected for monitoring the temperatures. In total, 54 thermocouples were located for this study. The thermocouples were installed in the pipe supports, in section A and B as well as in the T-piece see Figure 14.

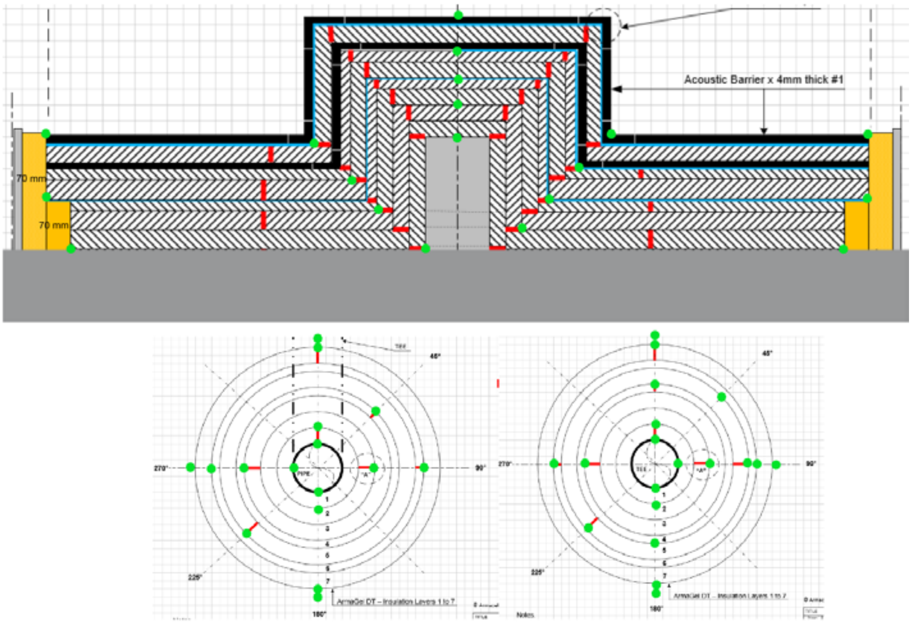


Figure 14: Position of the thermocouples

Two thermocouples were located inside the pipe, with the purpose of monitoring the internal temperature and controlling the inlet valve of the liquid nitrogen at the supply line. Two more thermocouples were installed under the ceiling of the climate chamber at different heights to monitor the ambient temperature.

The control and recording system of the climatic chamber and the thermocouples were performed using National Instruments modules and software: NI Chasis, LabView and DIAdem. The humidity inside of the climatic chamber was recorded by means of the software CIDPro by CTS.

The physical magnitudes were recorded in function of the time and could be displayed life as diagram and/or number. All measurements are available as TDM-file.

Two humidity sensors were installed on the test specimen. The sensors were placed horizontally along the length of the pipe, one at the top and the other at the bottom of the pipe. Both are located under the TEMBUTIL sheet layer, see Figure 15 (see Table 1, under 7.1).

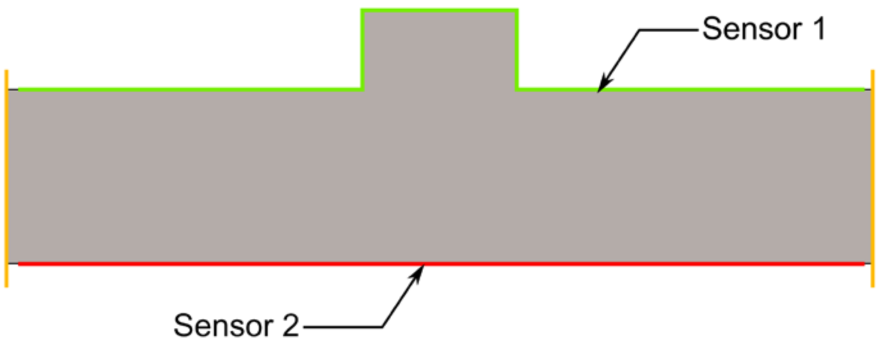


Figure 15: Location of the humidity sensors

12

5.4. CLIMATE SIMULATION

The objective of the climate simulation was to investigate the influence of tropical conditions within the LNG insulation system.

Cold insulation systems, under tropical conditions, could have condensed water on the surface and in worst case, the moisture could penetrate the insulation, especially in complex geometries like fittings and supports, because of the difficulty to get an absolute tight fit of the insulation in these areas. This phenomenon must be carefully investigated.

The tropical conditions were simulated inside the KAEFER climate chamber and the LNG temperatures to achieve steady state conditions were simulated with the controlled injection of liquid nitrogen inside the pipe. The evaporation temperature of Nitrogen was -196 °C, so it could be used to cool down the system. Keeping a controlled temperature level of -164 °C stable, it was possible to evaluate the behavior of the temperatures between the layers, the heat losses, and the material behavior within the system.

5.4.1. Ambient conditions

The test specimen was closed into the KAEFER climate chamber in Bremen / Germany, under the following ambient conditions:

Air Temperature	32 ° C ± 3 ° C
Humidity	88 % r. H. ± 5 %
Location	Climate laboratory, KAEFER Bremen

Table 2: Ambient conditions for the test

These conditions were kept constant during the test. The door of the climate chamber was opened daily to carry out visual inspections. This inevitably led to a decrease of temperature and humidity, but the decrease was always between the acceptable limits. The nitrogen tank was loaded several times a week, which led to an increment of the internal temperature of the pipe, the set value was stabilized after max. 2 hours

5.4.2. Cool down period

During the cool down period, the temperature inside the pipe decreased from 32 °C to -164 °C ± 3 °C. Based on our experience we estimated a cool down period of approximately 100 hours until the steady state conditions were reached, see Figure 16.

The cool down period started on October 13 and took approximately 7 days.

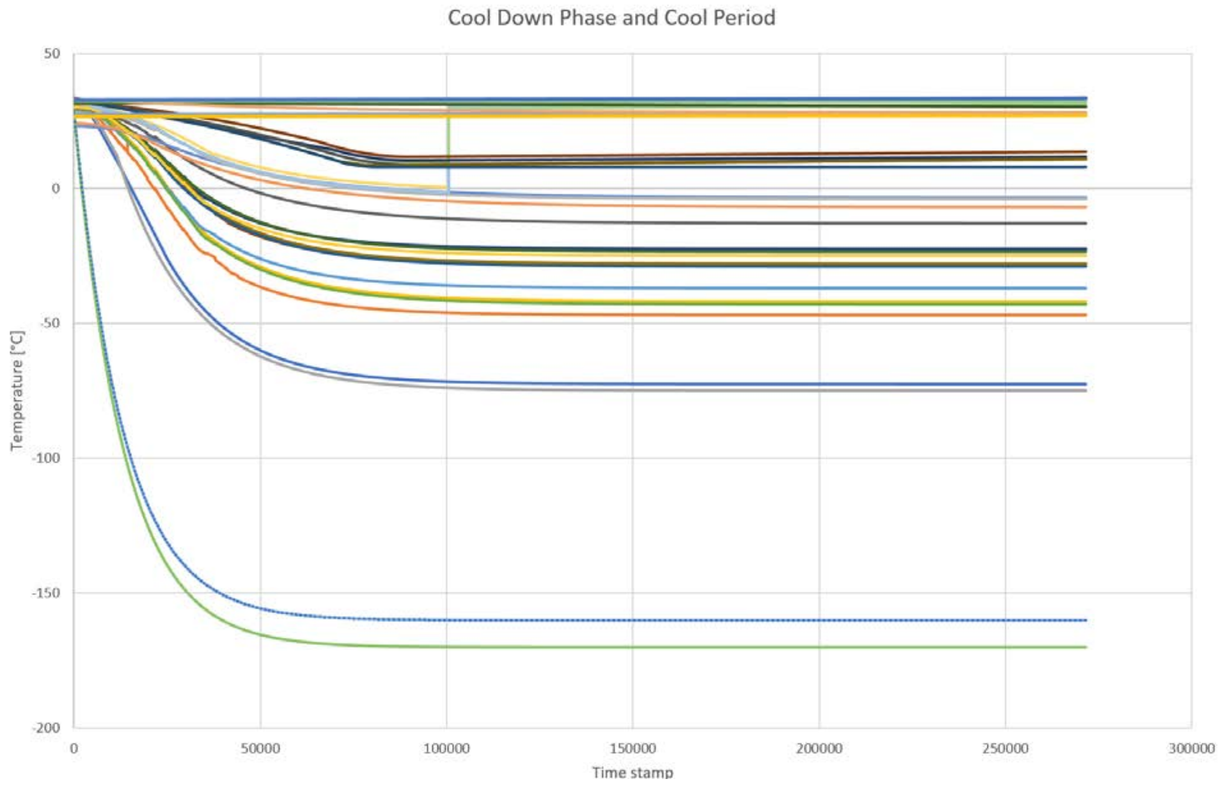


Figure 16: Cool down period

5.4.3. Steady state and end of the test

Steady state

After the cooling down period, the insulation system reached the steady state. This state was maintained for 3 weeks, from October 20 to November 5.

The steady state was verified with the readings of the sensors and the thermal calculations performed with the KAEFER Software WTB, see Table 3.

Layer	Calculated Temp. in [°C]	Measured Temp. in [°C]	Deviation
Pipe	-164,0	-161,7	2,3
1	-112,4	-114,5	-2,1
2	-73,6	-72,7	0,9
3	-42,2	-40,4	1,8
4	-28,3	-27,1	1,2
5	-3,0	-2,1	0,9
6	8,7	8,1	0,6
7	30,1	31,2	-1,1

Table 3: Calculation vs. Measured temperature values. Spot measurements taken on October 20, 16:52.

End of the test

The climate simulation was completed on November 5 and the inlet valve was turned off to allow the pipe to warm up. The tropical conditions in the test chamber were kept during the warm-up period.

5.5. DISMANTLING OF THE MATERIALS

Armacell and KAEFER performed the dismantling of the materials together on November 11. The dismantling of the samples was carried out at tropical conditions to avoid the change of the humidity or water content in the materials.

During the dismantling of the insulation, a few water drops were found underneath the acoustic barrier. The water drops were located on the top of the pipe near the base of the T-piece, distributed on a surface of approximately 5 cm^2,. A similar amount of water was found on the bottom of the pipe near the support, section B.

It is important to note that the acoustic barrier had no thermal function and was not installed with vapour-tight seams, since the acoustic barrier was not part of the test objective. The acoustic barrier offered no weather protection and acted as a cladding of the specimen. Therefore, it was considered that the water found under it would be equivalent to condensation on the surface of the cladding and was not a sign of a system failure.

The droplets were only found on the top near the T-piece and at the bottom near the supports. Most importantly: all insulation layers underneath the outer Tembutil were found to be dry and without traces of water or ice: The aim of a cold insulation is to avoid condensation in the insulation layers, this had been fulfilled even for this deep cold insulation system.

Considering that the critical points susceptible to water ingress were located at the top of the pipe and that water tends to settle at the bottom because of gravity, specimens were taken on both sides of the T-piece at 0° and 180°, as well as two specimens at 90 ° just below the T-piece.

The cut specimens were weighted and packed in plastic bags to avoid moisture loss. The specimens were taken to the materials testing laboratory for the following tests:

- Moisture content acc. to DIN EN ISO 12570
- Thermal conductivity acc. to DIN EN 12667

6. FINDINGS AND CONCLUSIONS

THERMAL PERFORMANCE

The thermal performance of the ArmaGel was very good and stable even during the high stress conditions:

- The thermal conductivity of the ArmaGel without thermal load and after the test was the same, this verifies the robustness of the tested system, see Annex A and B*.
- The taken specimens for the moisture test were dry, see Annex C.
- No condensation or ice was found in any layer of the insulation or in the joints between the blankets and the supports: the system is watertight.
- The thermal performance of the system was very good even under critical conditions like the extremal temperatures (due to the valve issue) and the constant wind speed in the climate chamber.

HANDLING

Aerogel-based insulation materials are well known for offering a high thermal performance coupled with hydrophobic properties. This makes them attractive for use in extreme high air humidity and varying ambient temperatures. However, care and attention are needed during fabrication and installation, and the use of correct PPE is necessary for improved worker safety and comfort. One key benefit of ArmaGel is that the blanket is very flexible and perfectly follows the shape of the pipe and complex geometries.
As best practice, the use of spray adhesive was considered extremely helpful at creating a reliable fixing of the adhesive tape.
When working with aerogel insulation, it is considered necessary to keep all workspaces and environments clean and tidy at all times.

SUMMARY

1. Target of the test: performance of the cold insulation under tropical conditions → fulfilled
2. With the right practices and procedures, the insulation procedure is acceptable: PPE, special procedures → spray glue on the joints
3. Glue used as best practice: critical to quality for application on LNG equipment in tropical conditions.

*Thermal conductivity is measured in-house acc. DIN EN 12667 not under the same conditions (e.g. load) as the independent Guarded Hot Plate (GHP). This is likely to explain the slight difference in the measured values using the HFM compared with the declared thermal conductivity values measured with the GHP.

7. ANNEXES

ANNEX A Thermal conductivity sample 1

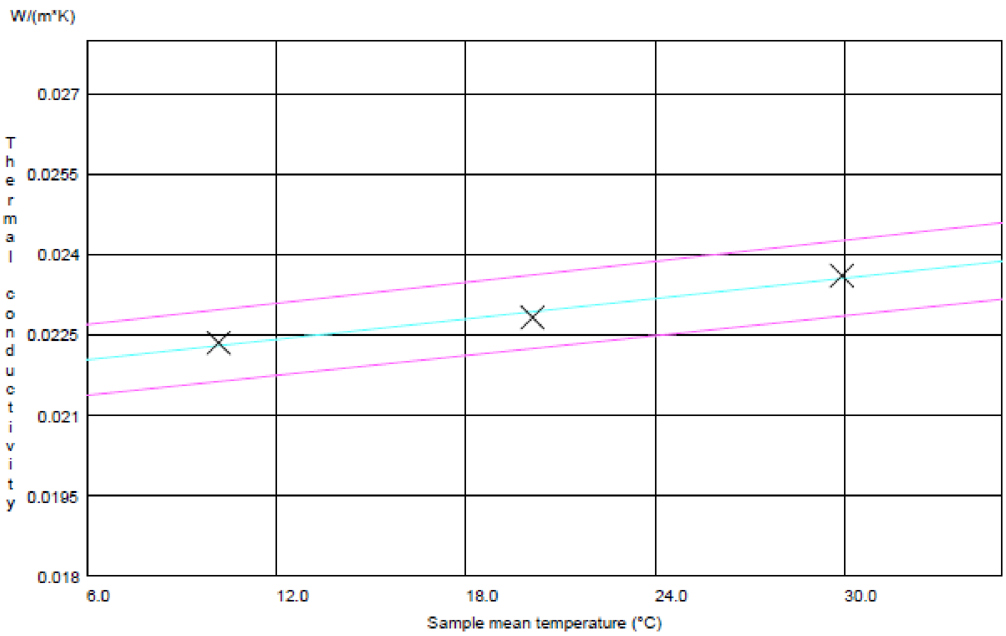
KAEFER

MEASURING THERMAL CONDUCTIVITY

Report No.: **2021-12391-GG**

Sample Thickness :	18.07 mm
Sample	Sample 1
Material	ArmaGel 20 mm
Dimensions	(300,0 x 300,0 x 10) mm
Test date	24.11.2021
Testing with	TLP 300 - DTX, Single-plate-process
Remarks	sample No 28 from Layer 1 in the middle Weight 341,9 g
Software-Version	Lambda V.2012, Single-plate

Measuring No.	Heating power (W)	Temperature cold sample surface (°C)	Temperature warm sample surface (°C)	Temperature-difference on sample (K)	Sample mean temperature (°C)	Thermal conductivity (W/m*K)
1	0.127	5.0	15.3	10.3	10.2	0.02237
2	0.130	15.0	25.3	10.3	20.1	0.02284
3	0.132	24.9	35.0	10.1	29.9	0.02362



Lambda (10°C) = (0.0223 +/-0.0007) W/(m*K)   Lambda = 0.02167 + 0.000064 * MT W/(m*K)

Result +/- expanded uncertainty (factor 2)

Bremen, 25.11.2021

W.Dierksen-Wellbrock

ANNEX B Thermal conductivity reference sample

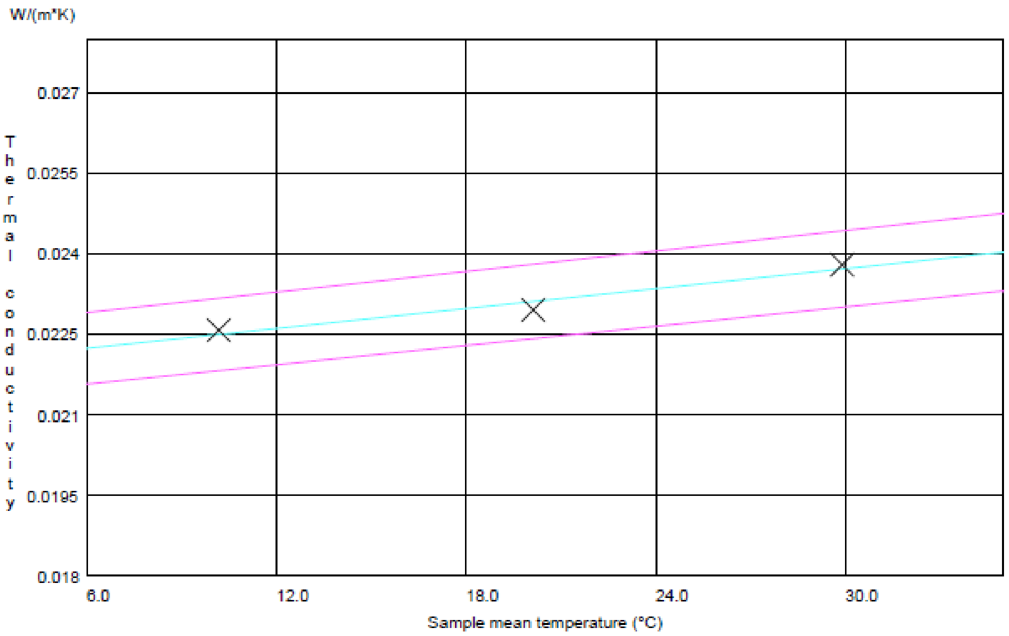
KAEFER

MEASURING THERMAL CONDUCTIVITY

Report No.: **2021-12391-GG**

Sample Thickness :	17.91 mm
Sample	Sample 2
Material	ArmaGel 20 mm
Dimensions	(300,0 x 300,0 x 10) mm
Test date	29.11.2021
Testing with	TLP 300 - DTX, Single-plate-process
Remarks	Referenzprobe 20 mm Weight 341,9 g
Software-Version	Lambda V.2012, Single-plate

Measuring No.	Heating power (W)	Temperature cold sample surface (°C)	Temperature warm sample surface (°C)	Temperature-difference on sample (K)	Sample mean temperature (°C)	Thermal conductivity (W/m*K)
1	0.129	5.1	15.3	10.3	10.2	0.02259
2	0.131	15.0	25.3	10.3	20.1	0.02296
3	0.135	24.8	35.0	10.2	29.9	0.02381



Lambda (10°C) = (0.0225 +/-0.0007) W/(m*K) Lambda = 0.02188 + 0.000062 * MT W/(m*K)

Result +/- expanded uncertainty (factor 2)

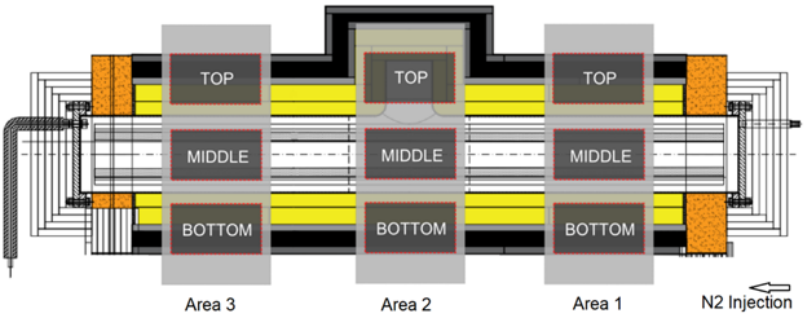
Bremen, 02.12.2021

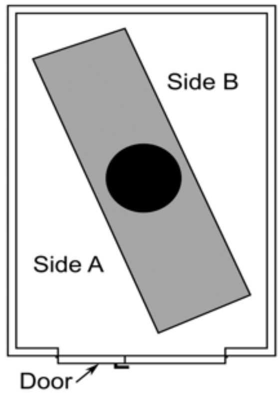
W.Dierksen-Wellbrock

ANNEX C Moisture content of the taken specimens

Water Content

Material	ArmaGel	Tester	Dolinka
Project	Mozambique RFQ	Test standard	DIN EN ISO 12570
Project-No.	2021-12391	Date	11. Nov 21





General Information

Temperature	65 °C																									
Dimensions [mm]	Test Sample																									
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	31	32
Sampling point	Layer 7 Area 3 Side B Middle	Layer 7 Area 1 Side B Top	Layer 7 Area 2 Side B Middle	Layer 7 Area 2 Side B Bottom	Layer 7 Area 1 Side B Middle	Layer 7 Area 2 Side B Top	Layer 7 Area 1 Side B Bottom	Layer 7 Area 3 Side B Top	Layer 7 Area 3 Side B Bottom	Layer 6 Area 3 Side B Top	Layer 6 Area 3 Side B Bottom	Layer 6 Area 1 Side B Top	Layer 6 Area 1 Side B Middle	Layer 6 Area 3 Side B Middle	Layer 6 Area 1 Side B Bottom	Layer 4 Area 3 Side B Top	Layer 4 Area 3 Side B Middle	Layer 4 Area 2 Side B Top	Layer 4 Area 2 Side B Bottom	Layer 4 Area 2 Side B Middle	Layer 4 Area 1 Side B Bottom	Layer 4 Area 1 Side B Middle	Layer 4 Area 1 Side B Top	Layer 4 Area 3 Side B Bottom	Control sample	Control sample
Length	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200
Wide	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200
High	20	20	20	20	20	20	20	20	20	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	20
Volume [cm³]	800	800	800	800	800	800	800	800	800	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	800

Measurements

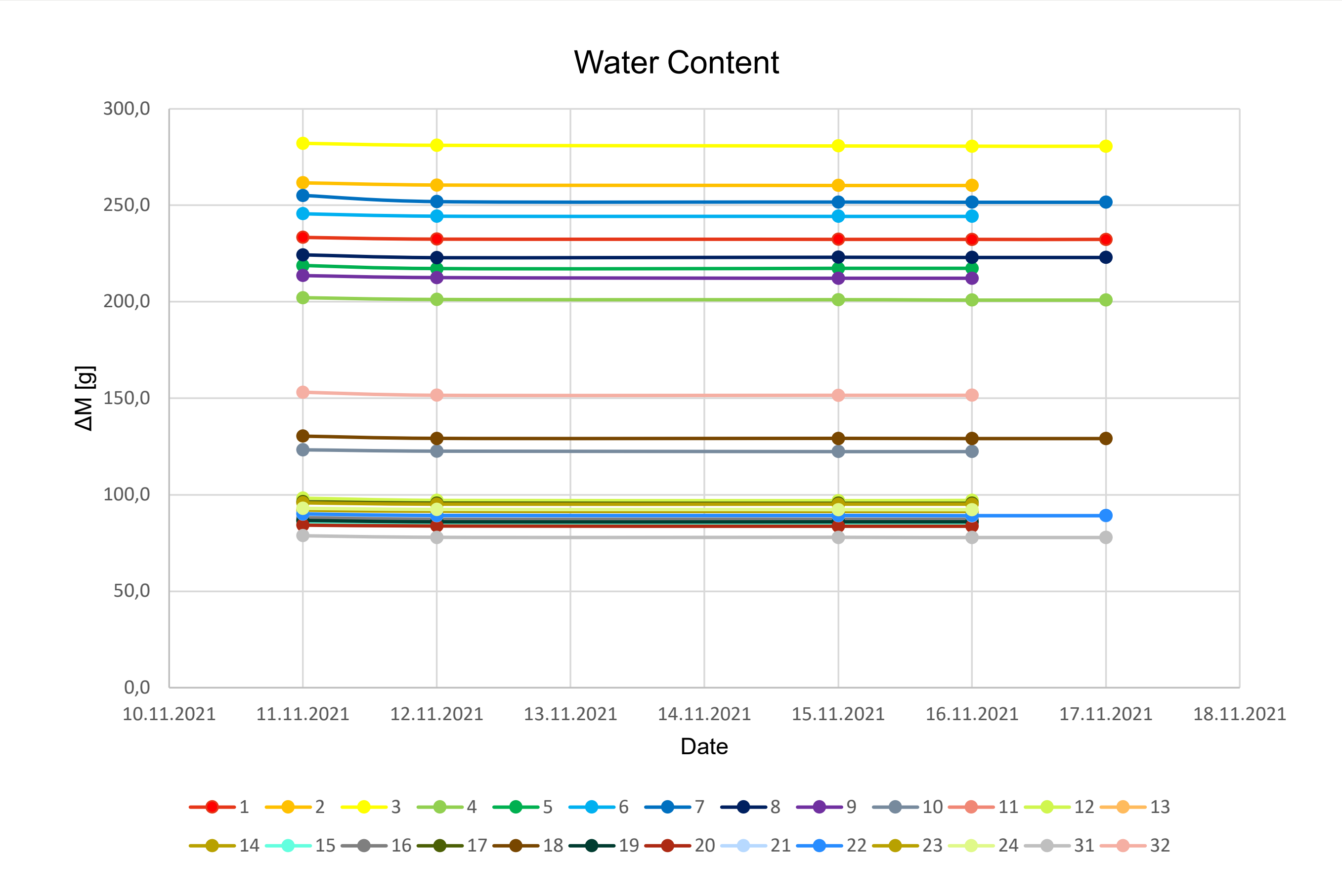
Date	Test Sample																									
	1		2		3		4		5		6		7		8		9		10		11		12		13	
	Weig. [g]	ΔM	Weig. [g]	ΔM	Weig. [g]	ΔM	Weig. [g]	ΔM	Weig. [g]	ΔM	Weig. [g]	ΔM	Weig. [g]	ΔM	Weig. [g]	ΔM	Weig. [g]	ΔM	Weig. [g]	ΔM	Weig. [g]	ΔM	Weig. [g]	ΔM	Weig. [g]	ΔM
11.11.2021	233,4	--	261,7	--	282,1	--	202,1	--	218,8	--	245,6	--	255,1	--	224,3	--	213,6	--	123,3	--	86,6	--	98,2	--	86,7	--
12.11.2021	232,5	0,9	260,5	1,2	281,1	1,0	201,2	0,9	217,2	1,6	244,4	1,2	251,9	3,2	222,9	1,4	212,5	1,1	122,6	0,7	85,9	0,7	97,1	1,1	85,8	0,9
15.11.2021	232,4	0,1	260,3	0,2	280,8	0,3	201,1	0,1	217,3	-0,1	244,3	0,1	251,7	0,2	223,1	-0,2	212,2	0,3	122,4	0,2	85,8	0,1	97,0	0,1	85,7	0,1
16.11.2021	232,3	0,1	260,3	0,0	280,6	0,2	200,9	0,2	217,3	0,0	244,3	0,0	251,6	0,1	223,0	0,1	212,2	0,0	122,4	0,0	85,9	-0,1	97,1	-0,1	85,7	0,0
17.11.2021	232,3	0,0			280,6	0,0	200,9	0,0					251,6	0,0	223,0	0,0										
Results Vol.-%	**0,14**		**0,17**		**0,19**		**0,15**		**0,19**		**0,16**		**0,44**		**0,16**		**0,18**		**0,22**		**0,17**		**0,28**		**0,25**	

Date	Test Sample																									
	14		15		16		17		18		19		20		21		22		23		24		31		32	
	Weig. [g]	ΔM	Weig. [g]	ΔM	Weig. [g]	ΔM	Weig. [g]	ΔM	Weig. [g]	ΔM	Weig. [g]	ΔM	Weig. [g]	ΔM	Weig. [g]	ΔM	Weig. [g]	ΔM	Weig. [g]	ΔM	Weig. [g]	ΔM	Weig. [g]	ΔM	Weig. [g]	ΔM
11.11.2021	92,0	--	85,7	--	88,3	--	96,4	--	130,4	--	86,7	--	84,3	--	89,9	--	90,1	--	95,8	--	93,0	--	78,8	--	153,1	--
12.11.2021	91,4	0,6	84,8	0,9	87,7	0,6	95,7	0,7	129,2	1,2	86,0	0,7	83,8	0,5	89,1	0,8	89,3	0,8	95,1	0,7	92,4	0,6	77,9	0,9	151,6	1,5
15.11.2021	91,3	0,1	84,7	0,1	87,6	0,1	95,6	0,1	129,2	0,0	86,0	0,0	83,7	0,1	89,1	0,0	89,3	0,0	95,1	0,0	92,3	0,1	77,9	0,0	151,5	0,1
16.11.2021	91,3	0,0	84,7	0,0	87,6	0,0	95,6	0,0	129,1	0,1	86,0	0,0	83,7	0,0	89,0	0,1	89,2	0,1	95,1	0,0	92,3	0,0	77,8	0,1	151,6	-0,1
17.11.2021									129,1	0,0					89,0	0,0	89,2	0,0					77,8	0,0		
Results Vol.-%	**0,18**		**0,25**		**0,18**		**0,20**		**0,33**		**0,18**		**0,15**		**0,23**		**0,22**		**0,18**		**0,18**		**0,25**		**0,19**	

Results

	1	2	3	4	5	6	7	8	9	10	11	12	13
Ma [g]	233,4	261,7	282,1	202,1	218,8	245,6	255,1	224,3	213,6	123,3	86,6	98,2	86,7
Me [g]	33,6	29,5	30,0	41,6	39,9	41,1	43,6	46,0	48,5	51,0	52,2	54,7	57,1
Weig. [g]	1,10	1,40	1,50	1,20	1,50	1,30	3,50	1,30	1,40	0,90	0,70	1,10	1,00
Weig. - %	0,47	0,54	0,53	0,60	0,69	0,53	1,39	0,58	0,66	0,74	0,81	1,13	1,17
Vol.-%	0,14	0,17	0,19	0,15	0,19	0,16	0,44	0,16	0,18	0,22	0,17	0,28	0,25

	14	15	16	17	18	19	20	21	22	23	24	31	32
Ma [g]	92,0	85,7	88,3	96,4	130,4	86,7	84,3	89,9	90,1	95,8	93,0	78,8	153,1
Me [g]	59,6	62,1	63,3	65,8	68,2	70,7	73,2	74,4	76,9	79,3	81,8	84,3	85,5
Weig. [g]	0,70	1,00	0,70	0,80	1,30	0,70	0,60	0,90	0,90	0,70	0,70	1,00	1,50
Weig. - %	0,77	1,18	0,80	0,84	1,01	0,81	0,72	1,01	1,01	0,74	0,76	1,29	0,99
Vol.-%	0,18	0,25	0,18	0,20	0,33	0,18	0,15	0,23	0,22	0,18	0,18	0,25	0,19


Water Content
300,0
250,0
200,0
150,0
100,0
50,0
0,0
ΔM [g]
10.11.2021
11.11.2021
12.11.2021
13.11.2021
14.11.2021
15.11.2021
16.11.2021
17.11.2021
18.11.2021
Date
1 2 3 4 5 6 7 8 9 10 11 12 13
14 15 16 17 18 19 20 21 22 23 24 31 32

00758 I ArmaGel DT Kaefer I WhitePaper I 012024 I GBL I EN Master

ABOUT KAEFER

KAEFER is a global leader in insulation, access technology, surface protection, passive fire protection and interior outfitting. The company actively works with clients every day to reduce their emissions, increase the energy efficiency of their sites and extend the life of their industrial facilities. KAEFER's teams provide reliable and efficient technical industrial services to clients in the Industry, Marine & Offshore and Construction sectors.

We pride ourselves on doing things the KAEFER way. This sets us apart and is clearly evident in our high safety record, our cutting-edge technical expertise and our strong ethical values that guide us in everything we do. We are driven by our efficient and innovative approach to overcoming challenges and providing customised services and solutions. We also ensure quality, safety, cost efficiency and continuous improvement through our extensive in-house expertise and fully integrated services. With an annual turnover of around 2 billion euros, the company employs more than 30,000 qualified employees worldwide. Further information can be found on www.kaefer.com.

KAEFER

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. 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

armacell®
MAKING A DIFFERENCE AROUND THE WORLD