PROJECT DELIVERABLE REPORT

Introducing advanced ICT and Mass Evacuation Vessel design to ship evacuation and rescue systems

PALAEMON MASS EVACUATION VESSEL

D4.6 Design of inflatables structures

A holistic passenger ship evacuation and rescue ecosystem

MG-2-2-2018

Marine Accident Response

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Abbreviations

MEV	Mass Evacualtion Vessel

1 Summary

In this deliverable the design of the inflatables for the MEV-I, as well as the downscaled MEV-I demo which will be tested at the premises of ASTADNER shipyard, will be accomplished. The design of the MEV-I as well as the inlfatables was accomplished using a test case the HELLENIC SPIRIT ship of ANEK lines. The MEV-I demo as well as the related inflatables, are a scaled prototype of the MEV-I, which is used for testing, a) the access of the people in the MEV, b) launching operation and c) sea trials.

2 Introduction

The premise in the PALAEMON project is the design of Mass Evacuation Vessels (MEVs) that can accommodate significantly more people than conventional Life boats, using the same area and volume as the life boats, on particular ship, as well as showcasing the ability of the MEVs to accommodate people from all demographics and mobility difficulties. A key ingredient for the design of MEVs, is the inflatables which offer improved stability and seakeeping characteristics to these vehicles. In this sense, the inflatables take minimal space when stored, before launching of the MEV and then when inflated, after MEV launch, can offer improved stability for seakeeping after an emergency. The inflatables proposed in PALAEMON, are a fail safe design, i.e. by adopting a multiple chamber design and construction, which entails that even if one chamber is punctured and deflated then the other chambers will not be compromised.

The inflatables when stored are a part of the MEV and do not take any more room on the deck of the ship.

3 MEV-I characteristics

3.1 MEV-I

3.1.1 Design

The inflatable buoyancy elements for MEV-I are made up of a set of buoyancy elements consisting of two mirror-image structures which are attached to the two long sides of the MEV-I base body. Each of the two structures in turn consists of different structurally separate groups of individual chambers, which are connected via overflow valves with non-return device. The main chambers are made of coated dropstitch material. Pressure relief valves in the chamber segments prevent overfilling but they are designed in such a way that no pressure losses occur due to wave impact. Filling of the buoyancy chambers is done by using interconnected pressure vessels which are filled with compressed air. The filling process can be activated either automatically on contact with water or manually by the boat operator. For both buoyancy elements, independent but jointly activatable filling systems are provided, each consisting of a set of pressure vessels, associated valves, and filling hoses, which are integrated into the base body of MEV-I.

The inflatable buoyancy elements for MEV-I are dimensioned considering the dimensions of the MEV-I main body specified in D4.2. The MEV-I base body has corresponding installation spaces along the two longitudinal sides to accommodate the packed buoyancy bodies.

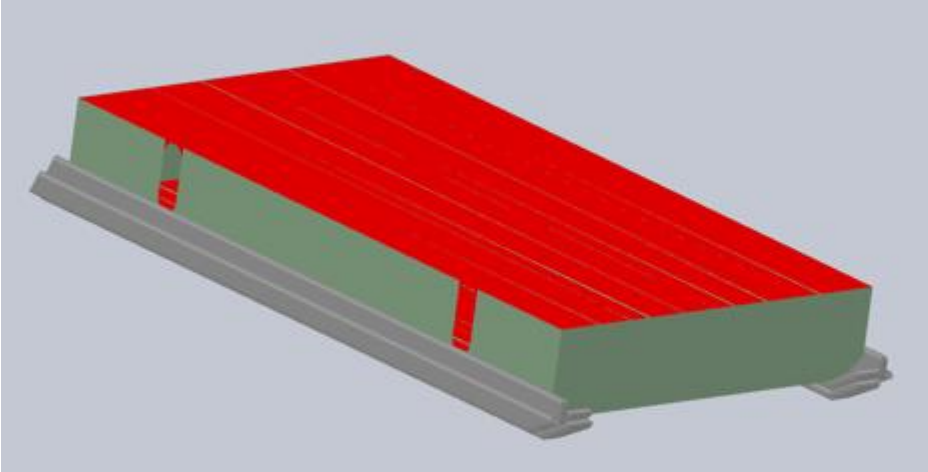

Figure 1 – General Arrangement MEV-I

The buoyancy chambers enclose parts of the bottom and the side wall after inflation. This provides additional support and stabilisation to the buoyancy bodies after they are fully formed in these areas. The bow is designed to run upwards to reduce resistance when the MEV-I cruises.

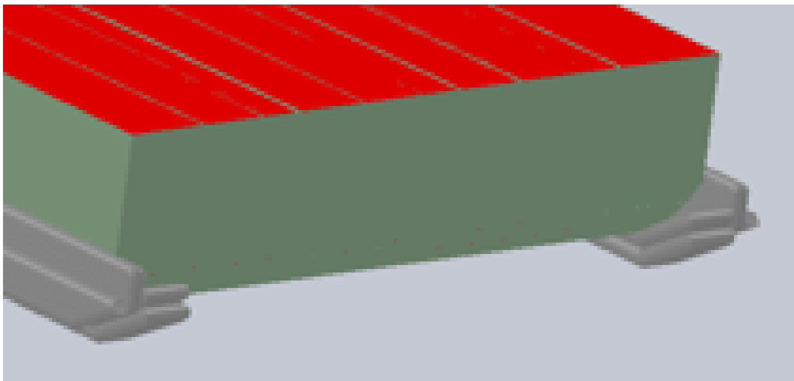

Figure 2 –Stern Section Inflatable MEV-I

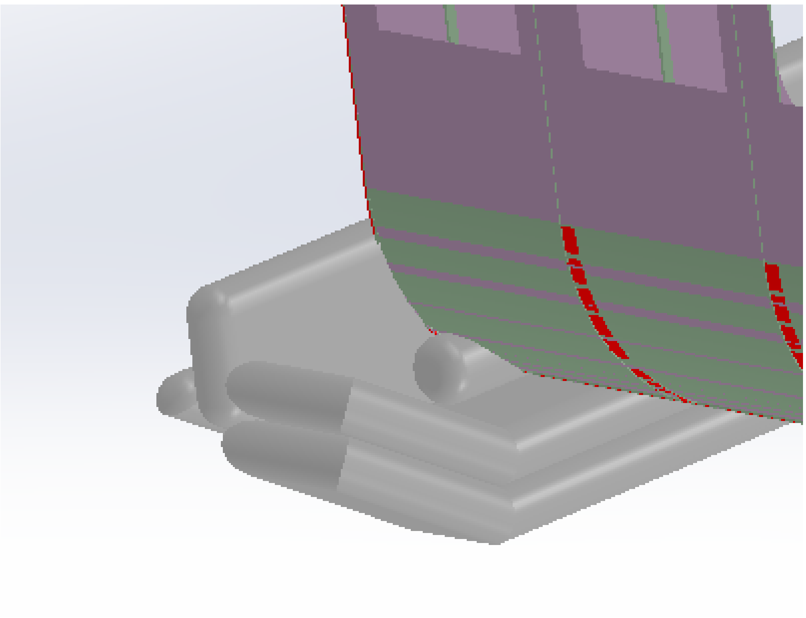

Figure 3 – Detail Stern Section Inflatable MEV-I

The inflatable buoyancy bodies are connected to the structure of the MEV-I basic hull by means of non-positive and positive-locking elements in the area of the frames. Loads occurring during use are thus transferred directly into the structure. This also ensures that the required movement distances of the buoyancy chamber during inflation are kept as short as possible, thus ensuring that they can develop unhindered until the operating pressure is reached.

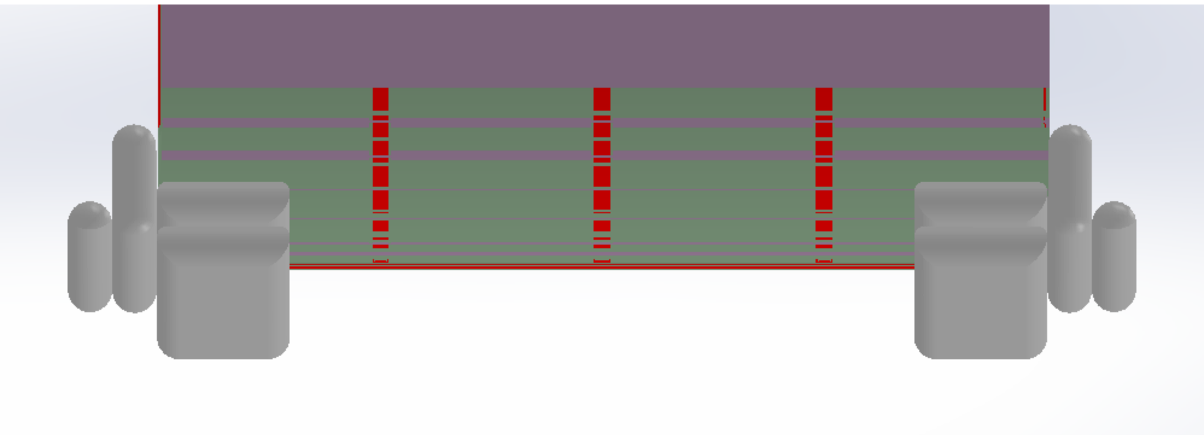

Figure 4 – Front Shape Stern Section Inflatable MEV-I

3.1.2 Volume Inflatables

The fully inflated and formed buoyancy bodies have subsequent volumes.

Table 1: Volume calculation Inflatables MEV-I

Chamber volumes (m3)				
Side	**Main**	**Side small**	**Total per side**	**Total**
2.016	5.320	1.484	8.820	17.640

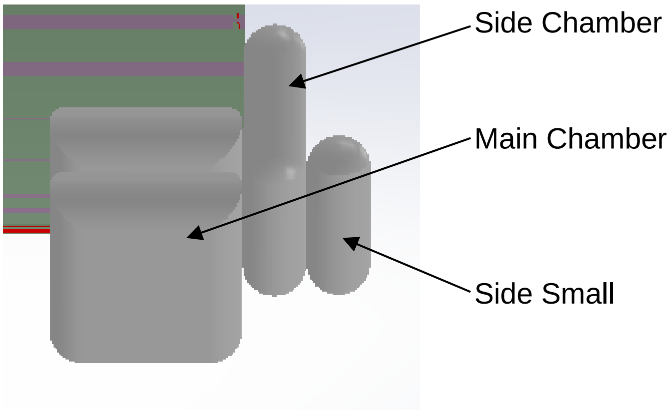

Figure 5 – Chamber Definition Volume Calculation Inflatables MEV-I

3.1.3 Weight groups Inflatables

The weight groups have been identified as

- Inflatable chamber material
- Air supply system
- Clamping/Fitting System
- Filling system (compressed air cylinders)
- Accessories

The weight calculation states the actual figures based on the latest design. The weight calculation considers minimum, nominal, and maximum weight of the system per side.

Table 2: Weight Calculation Inflatables MEV-I.

	Weight Callculation per side (Kg)		
	Min	**Nominal**	**Max**
Coated Fabric	223	249	276
Air Supply System	21	27	30
Clamping System	54	62	66
Compressed Gas	115	122	132
Accesories	32	42	45
Total	**445**	**502**	**549**

3.1.4 Fitting of the Inflatables

The buoyancy elements are attached by means of adapter plates mounted in the MEV-I base body with corresponding counterparts in the form of metal plates. This enables a secure and permanent fastening, but also one that can be detached again for e.g. maintenance. The fastening is dimensioned in such a way that after the chambers have been fully inflated, the buoyancy chamber rests against the outside of the MEV and thus obtains additional stability.

3.2 MEV-I demo

3.2.1 Design

The inflatable buoyancy elements of MEV-I Demo are downscaled models as designed for MEV-I.

The inflatable buoyancy elements for MEV-I Demo are made up of a set of buoyancy elements consisting of two mirror-image structures which are attached to the two long sides of the MEV-I Demo base body. Each of the two structures in turn consists of different structurally separate groups of individual chambers, which are connected via overflow valves with non-return device. The main chambers are made of coated dropstitch material. Pressure relief valves in the chamber segments prevent overfilling but are designed in such a way that no pressure losses occur due to wave impact. Filling of the buoyancy chambers is done by using interconnected pressure vessels which are filled with compressed air. The filling process can be activated either automatically on contact with water or manually by the boat operator. For both buoyancy elements, independent but jointly activatable filling systems are provided, each consisting of a set of pressure vessels, associated valves, and filling hoses, which are integrated into the base body of MEV-I.

The inflatable buoyancy elements for MEV-I Demo are dimensioned considering the dimensions of the MEV-I main body specified in D4.2.5.1, but downscaled tom meet the MEV-I demo size. The MEV-I Demo base body has corresponding installation spaces along the two longitudinal sides to accommodate the packed buoyancy bodies.

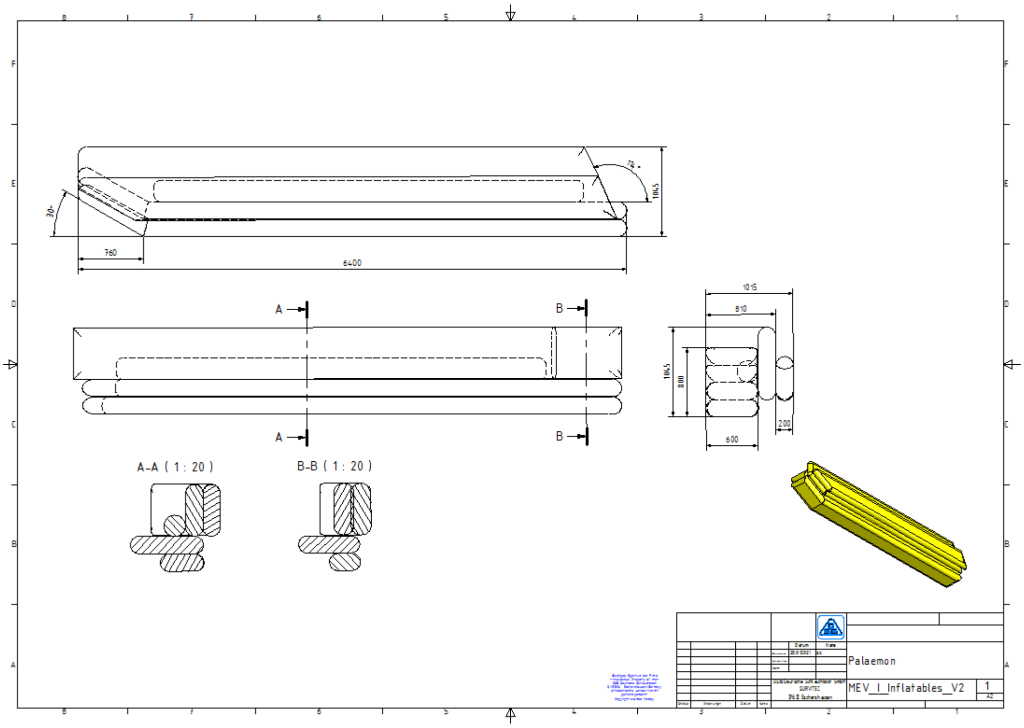

Figure 6 – GA Drawing Inflatables MEV-I Demo

3.2.2 Weight groups Inflatables

The weight groups have been identified as shown bellow:

- Inflatable chamber material
- Air supply system
- Clamping/Fitting System
- Filling system (compressed air cylinders)
- Accessories

The weight calculation states the actual figures based on the latest design MEV-I Demo. The weight calculation considers minimum, nominal, and maximum weight of the system per side.

Table 3: Weight Calculation Inflatables MEV-I.

	Weight Callculation per side (Kg)		
	Min	nominal	max
Coated Fabric	74	83	92
Air Supply System	7	9	10
Clamping System	18	21	22
Compressed Gas cylinder	134	36	37
Accesories	11	14	15
Total	**144**	**163**	**176**

3.2.3 Fitting of the Inflatables

The buoyancy elements are attached by means of adapter plates mounted in the MEV-I Demo base body with corresponding counterparts in the form of metal plates. This enables a secure and permanent fastening, but also one that can be detached again for e.g. maintenance. The fastening is dimensioned in such a way that after the chambers have been fully inflated, the buoyancy chamber rests against the outside of the MEV-I Demo and thus obtains additional stability.

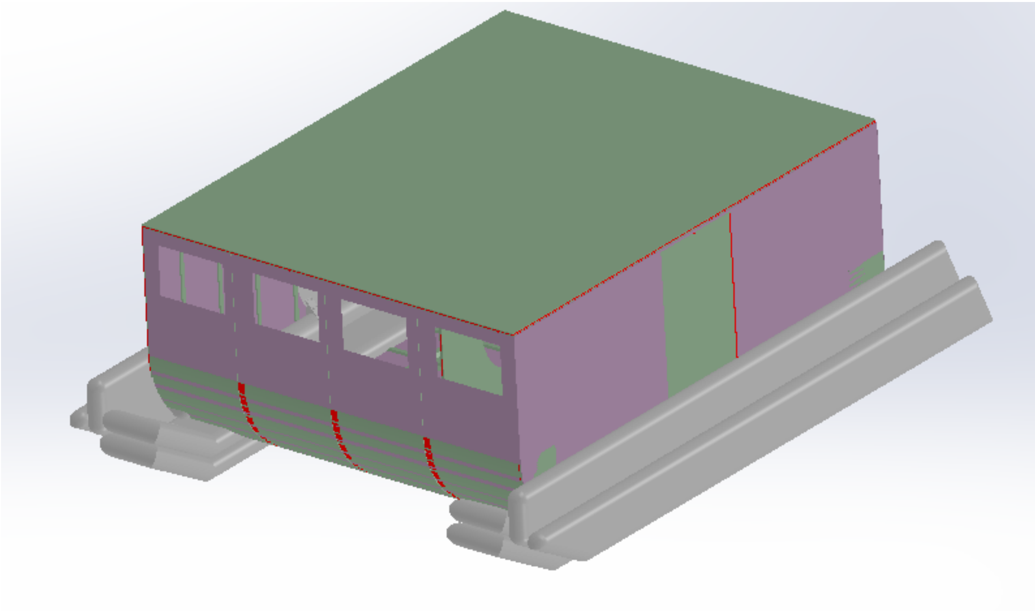

Figure 7 - MEV-I Demo – General Arrangement of the Inflatable

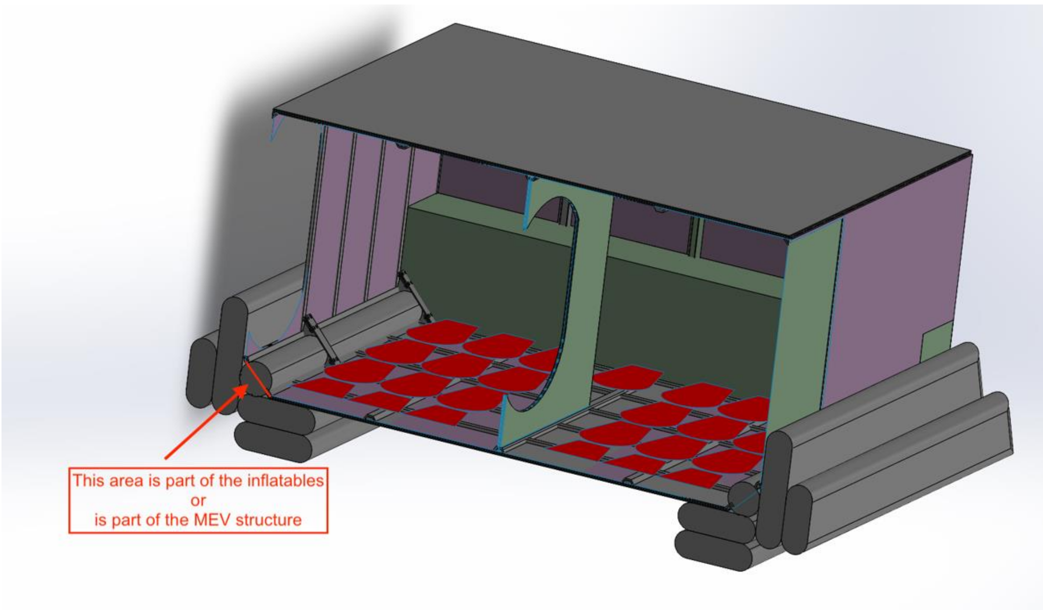

Figure 8 - MEV-I Demo – Fitting of the Inflatable

The updated design of the inflatables was accomplished, considering the opening of the doors on the MEV-I. The same design has been sued but a cut has been introduced in the middle of the inflatable assembly in order to accommodate the opening of the doors on the MEV-I (Figure 12).

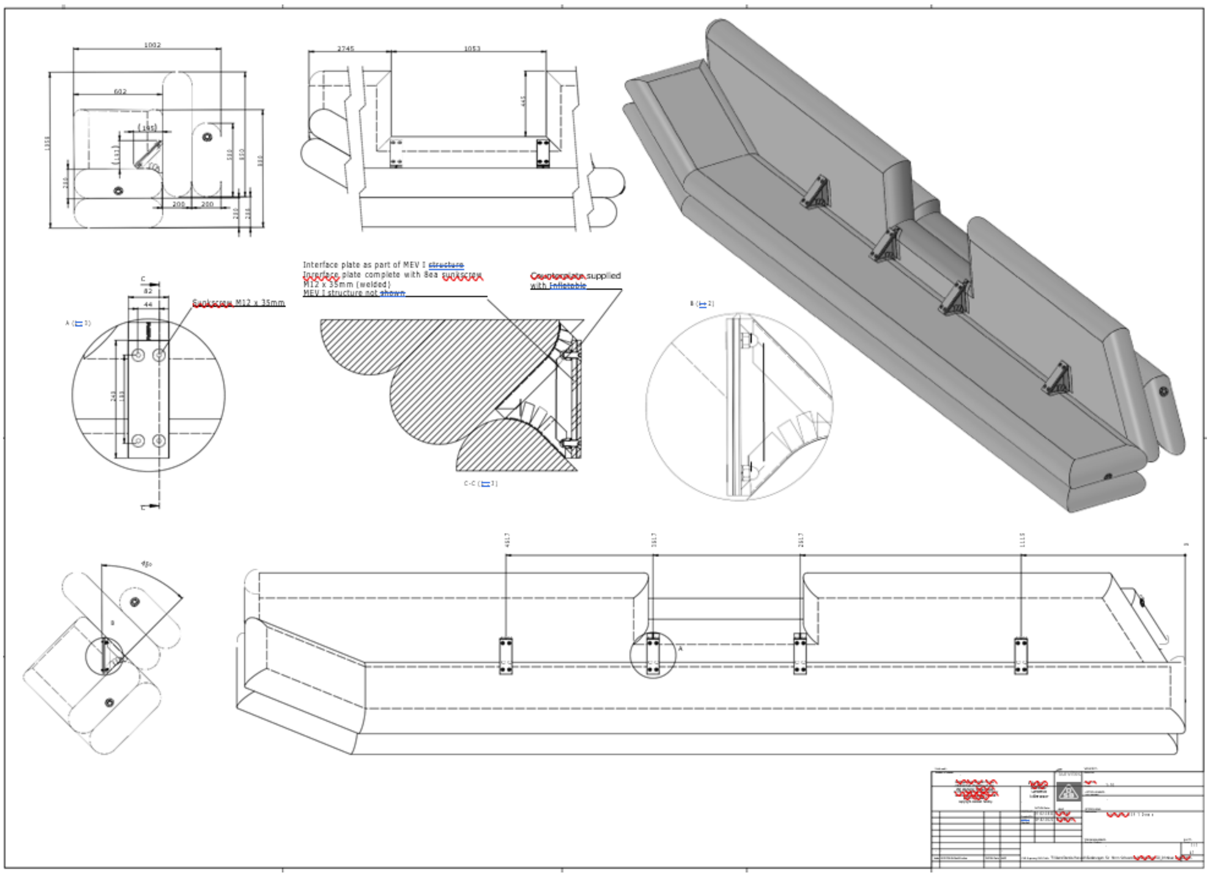

Figure 9 - MEV-I Demo - GA Drawing Fitting of the Inflatable (revised)

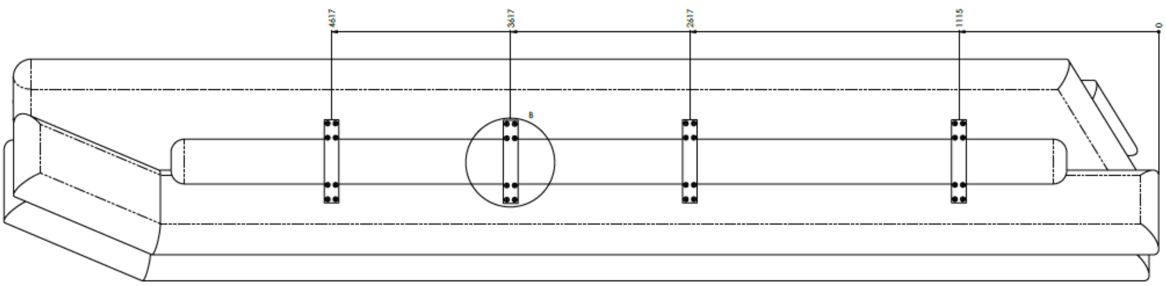

Figure 10 - MEV-I Demo - Fitting of the Inflatable DIM

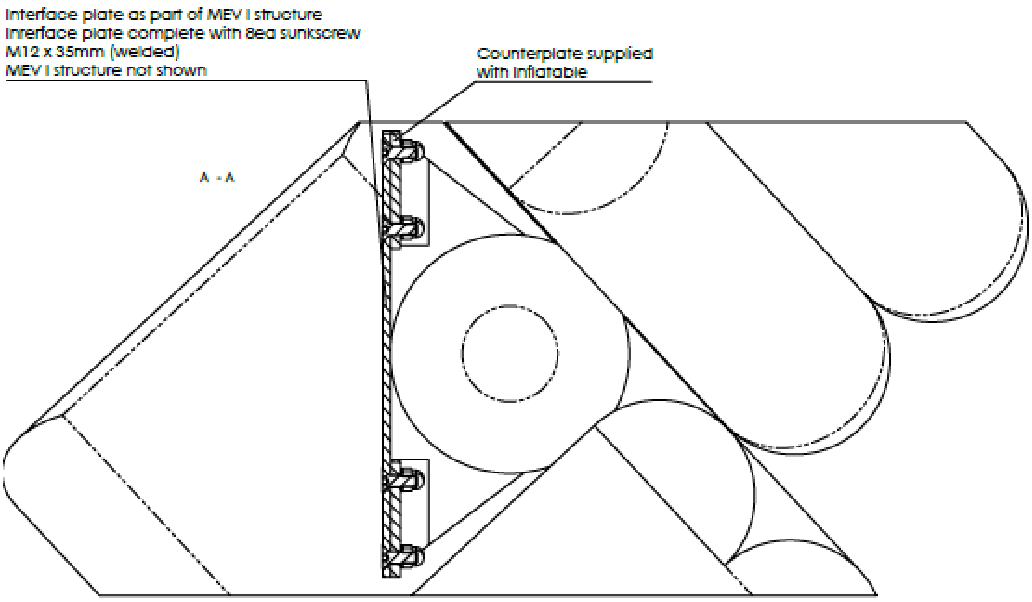

Figure 11 - MEV-I Demo - Fitting of the Inflatable Cross Section 1

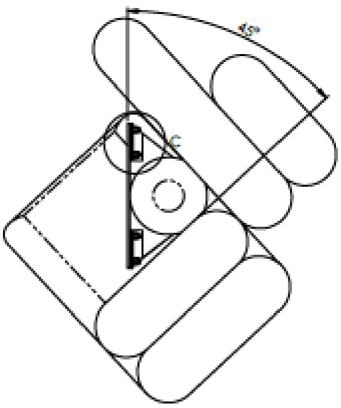

Figure 12 - MEV-I Demo - Fitting of the Inflatable Cross Section 2

4 Inflatable design

4.1 General characteristics

The MEV-I and MEV-I Demo inflatable buoyancy elements are composed of a set of buoyancy elements made up of two mirror-image structures that are fastened to the MEV port and stbd sides. Each of the two structures is made up of various architecturally distinct groupings of individual chambers that are connected by non-return overflow valves. Coated drop stitch material is used to construct the major chambers. While preventing overfilling, pressure relief valves in the chamber segments are constructed so that no pressure losses result from wave impact. Utilizing a network of connected pressure vessels that are filled with compressed air, the buoyancy chambers are filled. The filling procedure can be started manually by the boat operator or automatically upon contact with water. Both buoyancy elements have independent but cooperative filling systems that are built into the base body of the MEV-I. Each system consists of a set of pressure vessels, related valves, and filling hoses.

4.2 Volume and weight of the system

4.2.1 MEV-I Demo

Table 4: Volume calculation Inflatables MEV-I Demo

Chamber volumes (m3)				
Side	**Main**	**Side small**	**Total per side**	**Total**
0.720	1.900	0.530	3.150	6.300

Table 5: Weight Calculation Inflatables MEV-I Demo.

	Weight Callculation per side (Kg)		
	Min	**Nominal**	**Max**
Coated Fabric	74	83	92
Air Supply System	7	9	10
Clamping System	18	21	22
Compressed Gas	34	36	37
Accesories	11	14	15
Total	**144**	**163**	**176**

4.2.2 MEV-I

Chamber Volumes				
Side	Main	Side small	Total per side	Total
2,016 m³	5,320 m³	1,484 m³	8,820 m³	17,640 m³

Figure 13 – Volume calculation Inflatables MEV-I

Weight Calculation (per side)

	min	nominal	max
Coated Fabric	223 kg	249 kg	276 kg
Air Supply System	21 kg	27 kg	30 kg
Clamping System	54 kg	62 kg	66 kg
Compressed Gas cylinder	115 kg	122 kg	132 kg
Accesories	32 kg	42 kg	45 kg
Total	445 kg	502 kg	549 kg

Figure 14 - Weight Calculation Inflatables MEV-I

4.3 Materials Inflatables MEV-I Demo

4.3.1 General

The MEV-I Demo is made of different fabrics compared to the MEV-I. Core features of the fabric will stay the same as on the real MEV-I f.e. abrasion resistance, drop stitch properties, related working pressure, but properties like FR, colours and so on are not essential for the demo unit. Dedicated areas of the inflatable chmabers are additionally reinforced with an extra top layer.

4.3.2 Main and side chamber material

Main chamber and side wall chambers are made from drop stitch fabric 940dtex, black coated with the side wall made from neoprene coated PES fabric usually used for boat application. Attachment points are made from 1100dtex neoprene coated fabric.

Base fabric :	Polyester High tenacity **1100-1670 dtex – 990-1500 deniers**
	Threads Connections : Polyester
Double ply :	Polyamide **470 dtex - 425 deniers**
Coating :	Polychloroprene (CR)
Item code :	6223500

Specifications	Standard-Test	Direction	Result (Imperial)	Result (Metric)
Inflated Height			7,874 in	200 mm
Surfacic Mass	*ISO 2286-2* *FSTM 191/5041*		79 oz/yd² ± 7,96	2 680 g/m² ± 270
Tensile Strength	*ISO 1421* *ASTM D 751 / B*	*CH (W)* *TR (F)*	≥ 506 lbs/in ≥ 562 lbs/in	≥ 450 daN/5cm ≥ 500 daN/5cm
Elongation at break	*ISO 1421* *ASTM D 751 / B*	*CH (W)* *TR (F)*	≤ 30 % ≤ 30 %	≤ 30 % ≤ 30 %
Permeability (Helium) Zeppelin Test	*NFG 37 114*			< 3 l/m²/24H
Tear Resistance	*ISO 4674-1* *ASTM D 751 / B*	*CH (W)* *TR (F)*	≥ 56,2 lbs ≥ 33,7 lbs	≥ 25 daN ≥ 15 daN
Peeling Test Adhesion external side	*ISO 2411* *ASTM D 751*		≥ 16,85 lbs/in	≥ 15 daN/5cm
Peeling Test Adhesion between ply	*ISO 2411* *ASTM D 751*		≥ 22,47 lbs/in	≥ 20 daN/5cm
Low Temperature Resistance	*ISO 4675*		≤ - 31 °F	≤ - 35 °C
Flex Bending	*DIN 53351* *50000 cycles*		no crack	
Oil resistance ASTM n°1	*ISO 1817*		≤ 1,18 oz/yd²	≤ 40 g/m²
Heat Aging 7 day at 158 °F (70°C)	*NF EN 12280 - 1*		Mechanical prop. unchanged	

Figure 15 – Specification Drop Stitch Fabric MEV-I Demo

4.3.3 Reinforcement Material

Product Name **KK 200** **Part-No. 15146 00000**
Regulations **TL 8305-188/7 from 2010 Nov. 23.th**

1. Fabric Layer:

1.1. Fabric Spec.	**661300**
1.2. Material	**PA 6.6**
1.3. Yarn	**940 dtex**
1.4. Quantity of threads/cm	**10 / 10**
1.5. Fabric bonding	**L 1/1**

2. Coating

2.1. - Material	**Polychloroprene (CR)**
2.2. - Production Meth.	**Calander**

3. : Construction	Material	Name of compound	Weight (g/m²)	Colour
3.1. Coating outside	CR	GAIQ 60900	455 ± 45	black RAL9005
3.2. Fabric Layer	PA		200 ± 10	raw-colour
3.3. Coat. betw. layers				
3.4. Fabric Layer				
3.5. Coating inside	CR	GAIQ 6090	455 ± 45	black RAL9005

4. Properties of the coated fabric:	Unit	Debit	Test Method	Remarks
4.1. Total weight	g/m²	1110 ±100	DIN EN ISO 2286-2	
4.2. Thickness	mm	appr. 0,9	DIN EN ISO 2286-3	
4.3. Tensile Strength				
- Warp	N/50mm	≥ 2750	ISO 1421	
- Weft	N/50mm	≥ 2500	ISO 1421	
4.4. Tear Resistance				
- Warp	N	≥ 90	DIN 53356	Trouser Tear
- Weft	N	≥ 90	DIN 53356	Trouser Tear/
4.5. Adhesion				
4.5.1 Adhesion at room temp.				
- outside	N/25mm	≥ 75	DIN 53530	GXGQ/GDBQ
- inside	N/25mm	≥ 75	DIN 53530	GXGQ/GDBQ
4.5.2 Adhesion at 90°C				GDBQ is test
- outside	N/50mm	≥ 30	DIN 53530	by DSB
- inside	N/50mm	≥ 30	DIN 53530	
4.5.3 Adhesion in water				
- outside	N/50mm	≥ 75	DIN 53530	Cefa
- inside	N/50mm	≥ 75	DIN 53530	requirement
4.6. Elongation at break warp	%	≤ 30	ISO 1421	
weft	%	≤ 30	ISO 1421	
4.7. Elongation warp at 500N	%	—		
weft at 500N	%	—		
4.8. Tightness rubber/weave	—	tight	According TL	
4.9. Crosstightness weave	Level 0-3	≤ -	AV 177 / 02	

Figure 16 – Specification Reinforcement Material MEV-I Demo

4.3.4 Side Wall Material

Base fabric :	Polyester High tenacity 1100 **dtex –990 deniers**
Coating :	Polychloroprene (CR) double side
Item code :	V261664 (ex 6322900 ORCA 861664 Noir GT)

Specifications	Standard-Test	Direction	Result (Imperial)	Result (Metric)
Surfacic Mass	*ISO 2286-2* *FSTM 191/5041*		≥ 18,29 oz/yd²	≥ 620 g/m²
Tensile Strength	*ISO 1421* *ASTM D 751 / B*	*CH (W)* *TR (F)*	≥ 337,08 lbs/in ≥ 337,08 lbs/in	≥ 300 daN/5cm ≥ 300 daN/5cm
Elongation at break	*ISO 1421* *ASTM D 751 / B*	*CH (W)* *TR (F)*	≥ 15 % ≥ 15 %	≥ 15 % ≥ 15 %
Permeability (Helium) Zeppelin Test	*NFG 37 114*			< 3 l/m²/24H
Peeling Test Adhesion	*ISO 2411* *ASTM D 751*		≥ 16,85 lbs/in	≥ 15,0 daN/5cm

Figure 17 – Specification Side Wall Material MEV-I Demo

4.4 Inflation system

4.4.1 General

The filling system for the inflatable elements at MEV-I essentially consists of the following components:

- 20ltr compressed gas cylinder 300bar (qty depends on MEV-I configuration)
- Gas inflation system
- Transfer valves
- Gas inlet valves
- Pressure relief valves
- HP hoses

The main chambers of the inflatables are equipped with pressure relief valves. The individual chambers are connected via transfer valves. The center inflation tube chamber is equipped with inlet valves where the HP hoses running from the 20ltr gas cylinders are attached.

All valves f.e. pressure release valves, inlet valves, are certified by ISO 15738 respecitvely ISO9650.

The activation of the inflation process is possible in way of:

- Manually operated (by pulling support gas cylinder)
- Water activated by immersion.

4.4.2 Compressed Air Cylinder 20ltr 300bar

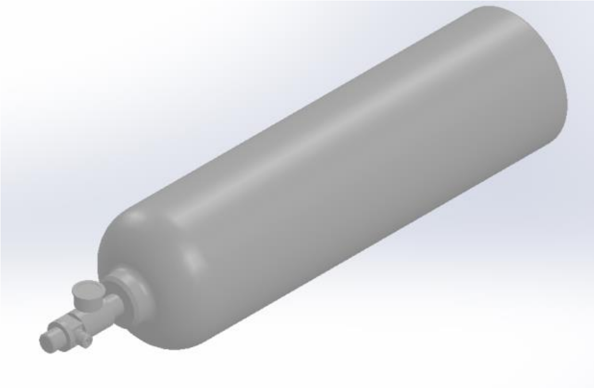

Figure 18 – Compressed air cylinder 20 ltr 300bar

4.4.3 Pressure Relief Valves

A6 PRESSURE RELIEF VALVE

- Very smooth low profile
- Rugged and reliable
- Materials used have high UV resistance
- Protects from over inflation and excess pressure build-up due to solar heat
- 100% tested for opening and closing pressures
- High flow for size
- Approved to ISO 9650 and ISO 15738 as a transfer valve
- Rapid installation with clamp fitting – no welding or adhesive required
- –30°C to +65 °C operating temperature

Figure 19 – Pressure Relief Valve

4.4.4 Gas Inflation System

The gas inflation system GIS can be configured to perform manually and/or water activated. Via transfer sensoring lines different inflation actuators can be combined to act simultaneously.

Actuator with GIS

GAS INFLATION SYSTEM (GIS TYPE)

- Extremely reliable and rugged.
- Fast consistent inflation times.
- ISO 15738 approved for SOLAS use on life-rafts.
- Approved to European Pressure Equipment Directive 2014/68/EU.
- CE standard safety Burst Disc fitted to prevent excessive pressure in cylinder.
- Operate using CO2, CO2/Nitrogen, air, and Nitrogen.
- Versions available for use on cylinders up to 450 bar test pressure.
- Activation load between 60 to 100 newtons.
- Full activation regardless of painter/lanyard pull speed.
- Available with internal or external over pressure venting.
- Available with pressure gauge.
- Water activated version available.

Figure 20 – Gas Inflation System Actuator basic

Figure 21 – Gas Inflation System Actuator pneumatic activated

Figure 22 – Gas Inflation System Actuator with sensor line

Figure 23 – Gas Inflation System Activaiton Water

Transfer Valve

A8 TRANSFER VALVE

- Compact size and smooth exterior design.
- Rugged and reliable construction.
- Good flow rate due to low opening pressure.
- Smooth contoured product.
- Rapid installation with clamp fitting into a wide range of fabrics.
- Approved for SOLAS life-rafts to ISO 15738.

Figure 24 – Transfer Valve

Gas Inlet Valve GIST type

GAS INLET VALVE (GIVT TYPE)

- Compact and rugged design.
- Built in swivel joint to allow movement of the hose during inflation.
- Wide range of jet sizes available to allow flow to be matched to the size of the structures being inflated.
- For use with up to 450 bar test pressure cylinder.
- Designed to minimise ice formation in the system when used with the GIST Cylinder Valve.
- Incorporates a non-return valve to prevent potential loss of pressure from the structure after inflation.
- Snap fit high pressure hose for fast assembly without the need for tools.
- Simple alignment of the jets from outside of the tube.

Certificate of type approval:
SAS S150044/M4

- Incorporates a non-return valve to prevent loss of pressure after inflation.
- Snap fit hose connections for fast assembly without tools.
- Simple alignment of the jets from outside of the structure.
- Body available in a Nickel plated or un-plated Brass versions. Connector nut is available in either Plated Steel or Stainless Steel.

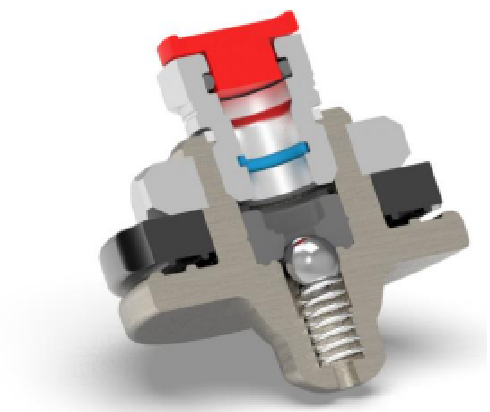

Figure 25 – Gas Inlet Valve

4.4.5 Inflatable attachment points on the MEV demo

The inflatlable assembly will be attached on the MEV-I using bolted plates. The bolted plates will be mounted on hard points on the MEV-I demo, where transversal stiffeners are present. In this sense the attachment points of the inflatable assembly are shown in Figure 31. The mounting plates which connect the inflatable assembly with the MEV-I are shown in Fgure 32. Lastly, the attachment of the assembly is done on hard points of the MEV-I (Figure 33), locations where the transveral stiffeners are present.

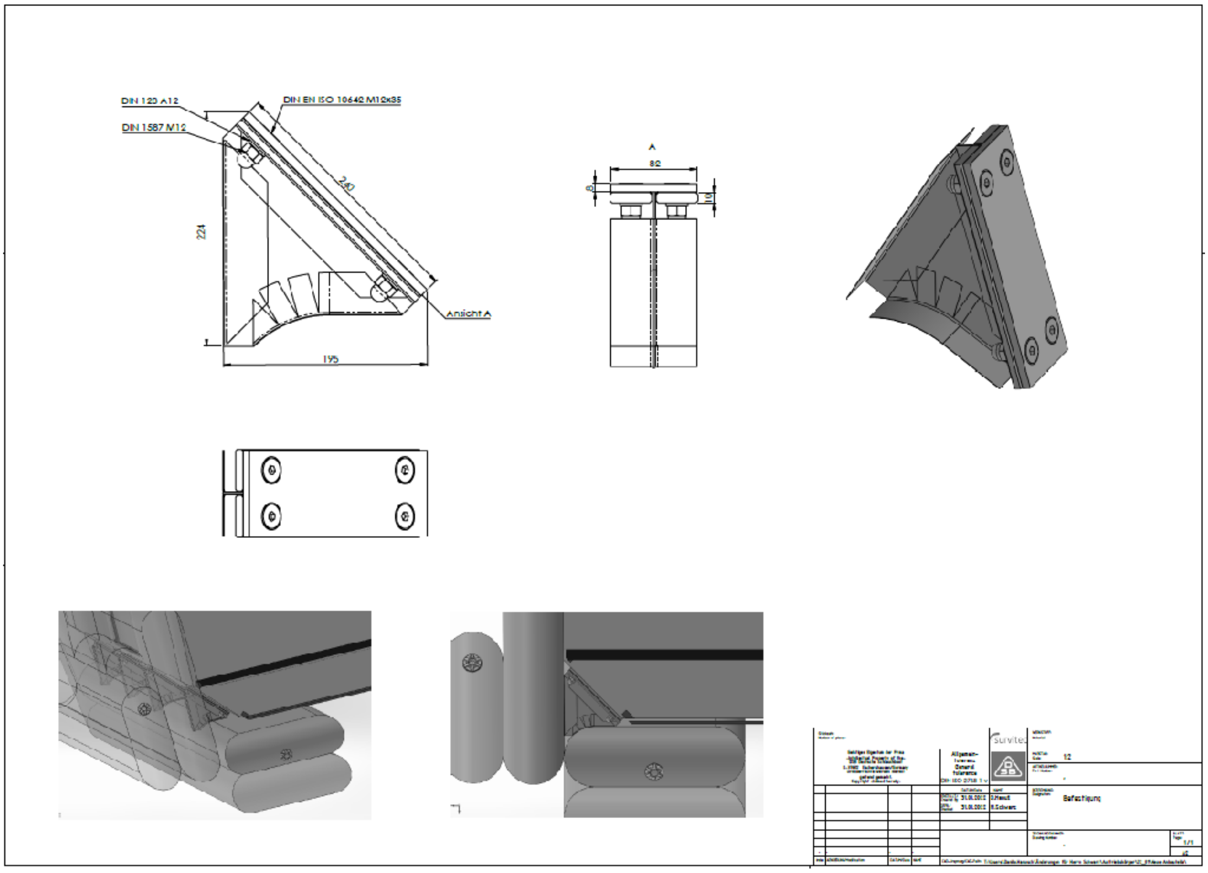

Figure 26 – Attachment points of the inflatable structure

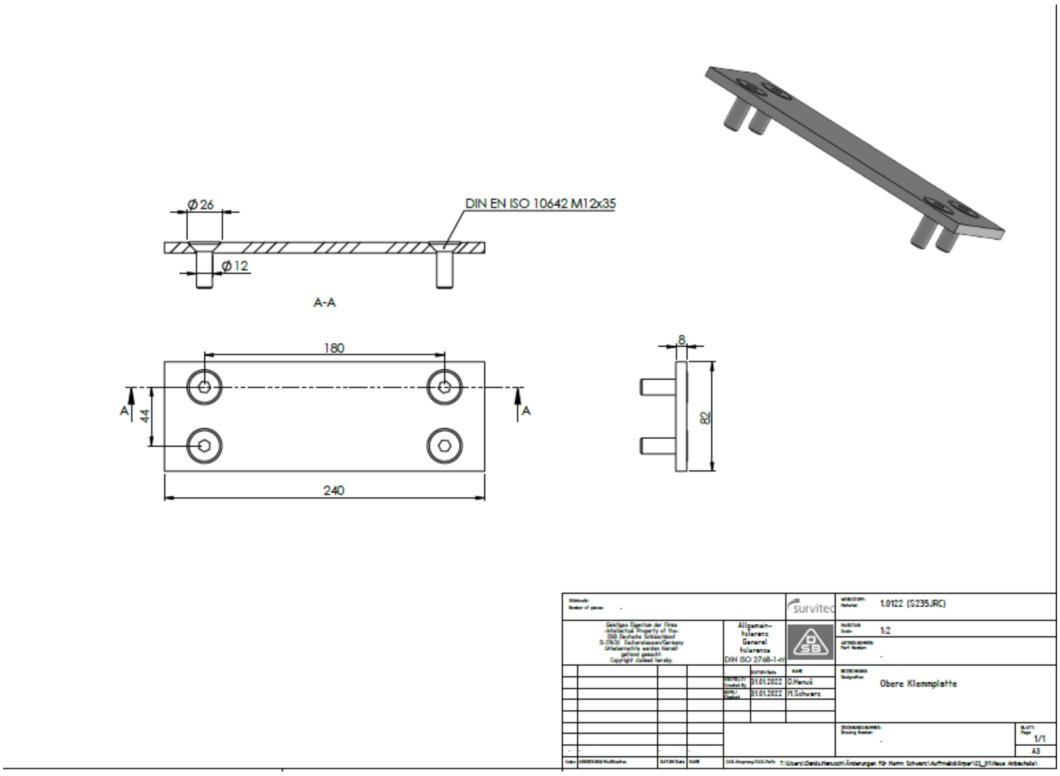

Figure 27 – Mounting plates that connect the inflatable assembly to the MEV-I

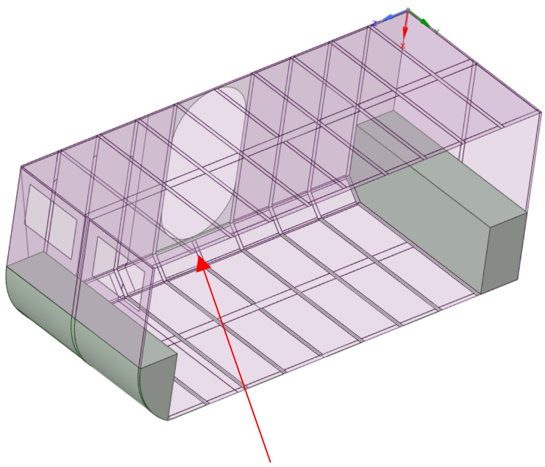

Figure 28 –Locations of transversal stiffeners on the MEV-I where the inlfatables are attached.

4.5 Maintenance, Inspection

The MEV-I is considered a hybrid structure, in the sense that there is a Life boat (the rigid structure which houses the accommodation of the people, navigation, power plant, etc.) and the inflatables which follow the guidelines that are in place for lifer rafts.

Inflatable structures require periodic servicing and maintenance. The reasons for inflatable maintenance can be enumerated as follows:

- Constant usage during drills or previous emergencies can render the inflatable assemblies, weather worn which could cause problems at the time of emergencies.
- The inflation system of the inflatable assembly could have problems and the lack of the same could pose problems during exigency situations. Furthermore, the lack of workability of the respective equipment necessitates inflatable assembly servicing.

Services for inflatable assembly involve adequate upfront inspection and monitoring done by qualified professionals. In general, it is advised to carry out an annual inspection of the inflatable assembly for any issues or damage. The inflatable assembly is regularly inspected each year to ensure that it will last for a long period of time. But in order to be qualified to carry out the necessary maintenance work, the technicians in charge of the inflatable assembly maintenance operations must meet a few requirements. To perform the maintenance operation, the technicians must be certified. However, the validity of the aforementioned certificate is only valid for three years. As a result, it becomes essential to confirm that a technician's accreditation for maintenance inflatable assemblies is still valid.

The inflatable assembly maintnenance involves the following aspects:

- The inflatable assembly is thoroughly inspected after which the external case of the inflatable assembly is also thoroughly inspected.
- The instruments and devices stored in the inflatable assembly are checked for their expiration dates.
- The inflation of the inflatable assembly with respect to pressure, its maximum inflation capacity, the toughness of the inflatable assembly material, and the stitches are carefully monitored and recorded.
- The cylinders where the pressurized gas is stored, which is used to inflate the inflatable assemblies are a very significant device that requires careful and diligent management.
- When the monitoring is finished, the technicians must refold the inflatable assembly according to the established methodology. According to the specifications of the manufacturers of the inflatable assembly, different procedures must be followed, and the refolding requirement must be strictly followed.
- According to SOLAS guidelines, owners of inflatable assemblies are required to conduct a ten-yearly servicing inspection and to abide by a few specified requirements. The owners of SOLAS standard inflatable assemblies must also do a five-yearly servicing check of the inflatable assembly's entire gas inflation system in addition to these servicing requirements.
- After the maintnenance work on the inflatable assembly is finished, the owners are given the necessary certifications, and the monitoring work is properly documented. These procedures provide total transparency throughout the process, which helps prevent complications.

5 Conclusions

For the purpose of the PALAEMON project and in particular for the MEV-I concept, inlfatables were designed and analyzed, considering the specifications provided in D4.1 and D4.2. The inlfatables were designed to provide additional stability and improved seakeeping of the MEV-I. The inflatable assembly for the real scale MEV-I, was designed to be used with MEV-I design used in the test case ship “HELLENIC SPIRIT”, provided by ANEK. Following the calculations in D4.2 regarding stability of MEV-I, the inflatable assembly design was accomplished and satisfies all the requirements and specifications in D4.2 but also in this deliverable (fail safe, minimum storage when folded).

The second inflatable assembly was designed to be used with the scaled down MEV-I demo, which will be tested at the premises of ASTANDER shipyard. This inflatable structure was designed using the same philosophy as the real scale MEV-I case, regaridng material, assembly structure, different compartments for fail safe, etc. The attachment points where also designed. The inflatable has different attachment points which are then bolded on hard points of the MEV-I demo (transversal stiffeners), using metallic plates which bonfd the MEV I demo structure with the inflatable assembly. Lastly the inflation system was also presented considering, volume and inflation characteristics of the assembly.