TECHNICAL REPORT

MIKO MARINE A.S

QUALIFICATION OF MIKOPLASTER

REPORT NO. 530 10221/98

REVISION NO. 01

DET NORSKE VERITAS

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TECHNICAL REPORT

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Summary:

MikoPlaster is a magnetic tarpaulin intended for providing a temporary watertight seal over openings in ships hull sides such as sea chests, water inlets and outlets, etc. The purpose of the tarpaulin is:

- To facilitate maintenance and repair in such areas without the necessity for docking or use of other heavy-duty equipment.
- To serve as a fast method of stopping or reducing leakage's in emergency situations.

A program was carried out with the aim of qualifying MikoPlaster for this use under realistic assumption of operational conditions.

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Work carried out by: Stefan Palm		
Work verified by: Stig Wästberg (for)		
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1 BACKGROUND

MikoPlaster is a magnetic tarpaulin intended for providing a temporary watertight seal over openings in ships hull sides such as sea chests, water inlets and outlets, etc. The purpose of the tarpaulin is:

- To facilitate maintenance and repair in such areas without the necessity for docking or use of other heavy-duty equipment.
- To serve as a fast method of stopping or reducing leakages in emergency situations.

The tarpaulin is secured to the hull by the normal force exerted by the water head, the magnetic force between hull plate and tarpaulin and additional magnetic blocks placed on the tarpaulin after it is placed on location.

The tarpaulin is a layered construction based on an inner nitril rubber sheeting containing ferritic magnets which is bonded to an outer fabric consisting of a polyester weave covered with PVC film. The tarpaulin is flexible and will deform when subjected to the external water head. Hence, structural arrangements that can carry the resulting load in order to support the tarpaulin have to be provided in large openings.

The tarpaulin is restricted to use on mainly single curvature surfaces. A minor curvature perpendicular to the main curvature, e.g. due to fabrication tolerances, can be accepted provided it is possible to attach the tarpaulin such that it fits snugly to the steel plate.

The tarpaulin is restricted to use on CMn-steel plates. The maximum water head for which the tarpaulin is to be used is at present specified to 20 m.

2 SCOPE OF WORK

DNV's scope of work included the following activities:

- Development of a preliminary Qualification Program (QP)
- Witnessing or execution of tests and analysis as specified in the QP.
- Revision of the QP based on the experienced gained during the tests and analyses and on in-house discussions and discussions with the manufacturer and a prospective operator regarding the use and handling of the tarpaulin and operational hazards.
- Evaluation of the results from tests and analyses with respect to the requirements in the QP.
- Compilation of conclusions and recommendations to methods of operation of the tarpaulin.
- Review of the manufacturer's user's manual.

3 DESCRIPTION OF MikoPlaster

The MikoPlaster tarpaulin is a layered construction with an inner nitril rubber sheeting containing ferritic magnets which is bonded to an outer fabric consisting of a polyester weave covered with PVC film. The rubber sheet side of the tarpaulin shall be placed against the hull plating. Only the fabric carries any significant load. The rubber sheet is relatively brittle and has low strength such that it fails at loads that are significantly lower than the failure load of the fabric.

The materials and adhesive used is confidential with the manufacturer. Details about the materials and adhesives are filed in the corresponding project file with DNV. The qualification is valid for these materials only.

4 QUALIFICATION PROGRAM

Prior to commencement of the qualification process a preliminary QP was developed by DNV in August 1998 in co-operation with the client. The QP formed the basis for the tests and analysis that were to be carried out. Based on in-house discussions of the experience gained during the qualification process and discussions with the manufacturer and a potential end user of the tarpaulin the QP was then revised. The final revision of the QP is included in Appendix A.

5 QUALIFICATION PROCESS – TESTS AND ANALYSES

5.1 Summary

The following testing activities were witnessed or carried out by DNV (it is referred to the QP as regards the types of tests):

- Full scale testing in the Trondheim harbour 99.01.20: testing of leak tightness, structural strength and peeling resistance.
- Full scale testing in the Trondheim harbour 99.02.15: testing of leak tightness and holding by friction.
- Exposure to hydrocarbons: diesel oil and white spirit.
- Small scale creep tests.
- Testing of resilience.

The various tests are described in the following sections. The full scale tests were carried out by the client and witnessed by DNV.

In addition the client carried out full scale tests without the presence of DNV in November 1998.

5.2 Full scale test equipment

For the full scale tests a steel test structure was manufactured, Figs. 1 - 3. The structure consisted of steel plating representing a flat hull side and a single curvature (e.g. a bilge) with a radius of curvature of 1 m. On the flat side a circular opening was provided with a diameter of 500 mm. On the curved side an opening simulating a sea chest was provided with dimensions 800 x 1 700 mm. The "sea chest" opening had an aluminium grating fitted (similar to gratings normally fitted in sea chests) which supported the tarpaulin and carried the load from the hydrostatic head. The circular opening was tested with a support for the same purpose consisting of a steel profile fitted in the centreline.

Behind each opening water tight containers were fitted with see-through openings in order to collect and to observe any leaking water.

The curved side contained one butt weld with an approximately 3 mm high reinforcement that went form the edge of the opening to the edge of the plate.

5.3 Full scale testing

In the full scale tests the following items in the QP were covered:

- 5.1 Water tight seal.
- 5.2 Structural strength.
- 5.3 Holding by friction.
- 5.4 Resistance to peeling.

Photographs of the steel structure with tarpaulins mounted over the two openings and prepared for testing are shown in Figs. 4 and 5. The tarpaulins were mounted by lifting them on place by hand. For testing of the first two items the structure was brought out to sea on a tug and lowered into the water by means of the on-board crane.

The minimum distance between the edge of the tarpaulin and the edge of the sea-chest was 25 - 30 cm. The size of the tarpaulins were 2250 x 2500 mm.

<u>Water tight seal – Structural strength</u>

At the first test occasion the structure was lowered consecutively to 1 m, 5 m, 20 m and 30 m water depth and held at each depth for a period of at least one hour. Thereafter the structure was lifted up on deck and the tarpaulin and structure inspected. The following findings were made after the structure had been lifted out of the water:

- No damages to the polyester/PVC fabric could be observed.
- The rubber sheet exhibited extensive cracking inside the perimeter of the openings, particularly at edges of the openings and the supporting grating and steel profile.
- Water had penetrated into both containers. The leakage behind the circular opening was small, of the order of 2 – 3 litres of water had penetrated. By estimating the volume of water in the container behind the sea chest the leakage rate was estimated to 25 – 50 litres pr hour.

At the second test occasion an additional leakage test on the sea chest opening was carried out at 5 m water depth. This test confirmed the estimate given above regarding the leakage rate.

Holding by friction

The holding power by friction was tested by mounting a 900 x 1 250 mm sample of the tarpaulin on vertical steel surfaces. The steel surfaces included a wetted unprotected, rusty surface and a wetted painted surface. Wetting was ensured by a heavy rain during the tests. Force was applied to the tarpaulin by a rope attached to one of its fastening lugs. The rope was pulled by a crane or fork lift truck in the same vertical plane as the steel plate while the force was measured by means of a load cell. Various application points of the rope was tested.

The lowest force at onset of sliding of the tarpaulin was measured to 1 470 N corresponding to 1 450 N/m^2. (During this test the tarpaulin was lifted slightly from the steel plate at the point were the rope was secured to it.) The largest measured force at onset of sliding corresponded to 2 800 N/m^2.

Resistance to peeling

A 900 x 1 250 mm sample of the tarpaulin was mounted 1 m under water approximately midships on the hull of the tug. In addition the sample was secured by using six of the separate magnetic blocks supplied by MikoMarine.

The speed of the tug was increased during a period of 15 minutes up to approximately 8.5 knots at which speed the tarpaulin came loose. Earlier tests carried out by the manufacturer had shown that without the extra magnetic blocks the tarpaulin came loose at approximately 3.5 knots.

5.4 Small scale testing

The small scale testing covered the following items:

- 5.2 Structural strength.
- 5.5 Resilience
- 5.6 Environmental resistance/Storage

Structural strength

The full scale tests with respect to structural strength had a duration of a few hours. It was evident from the observations made on the tarpaulin during these tests and simple hand calculations that the load on the tarpaulin, in terms of the membrane stress in the fabric, may be significant for large water heads when compared with the strength of the material. Knowing that the fabric material exhibits a significant creep behaviour under load it was considered necessary to carry out creep tests on samples from the tarpaulin to determine its long term behaviour. These tests were also combined with conventional tensile tests to verify the short term tensile strength of the tarpaulin.

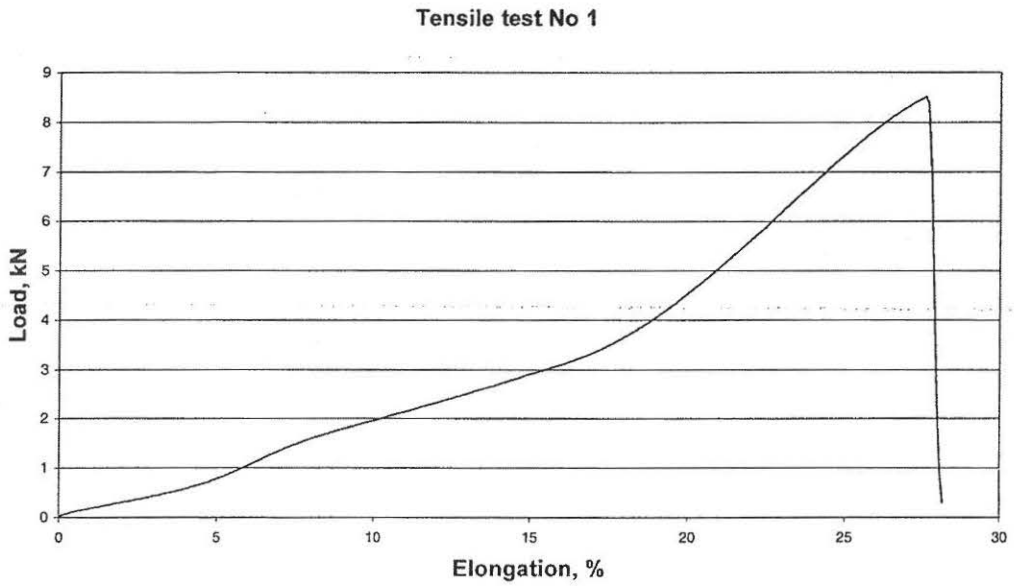
The small scale tests were carried out on 40 mm wide strips cut from the tarpaulin parallel to the warp or weft direction. The strips were tested in a servo-hydraulic tensile testing machine at room temperature. The free length of the specimens was 350 mm.

In the short term tests the strips were pulled to failure at a strain rate of approximately 0.5 %/s. The following results were recorded:

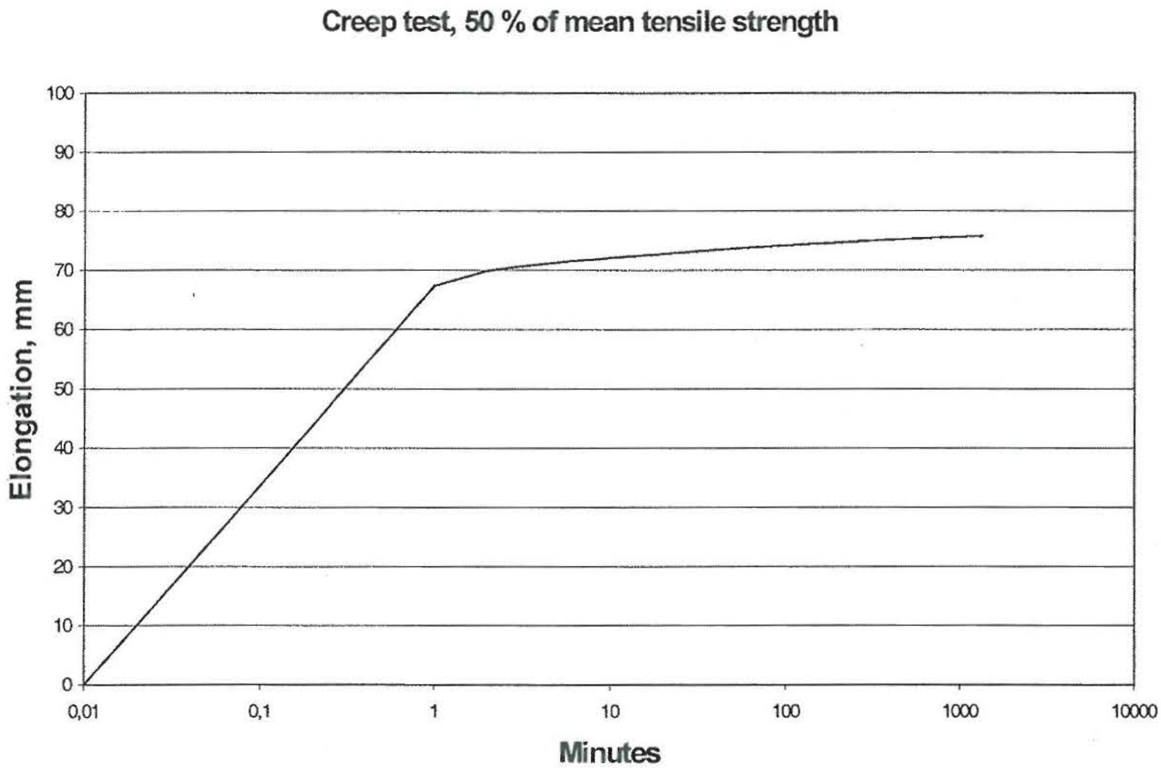
Tensile strength	mean[1]:	212	N/mm[2]
"	standard deviation[1]:	8	N/mm[2]
Elongation at failure	mean[1]:	27	%
Elongation at fracture of rubber sheet:		≈ 14	% (estimate)

1) Of three parallel specimens.
2) Force pr. mm of specimen width.

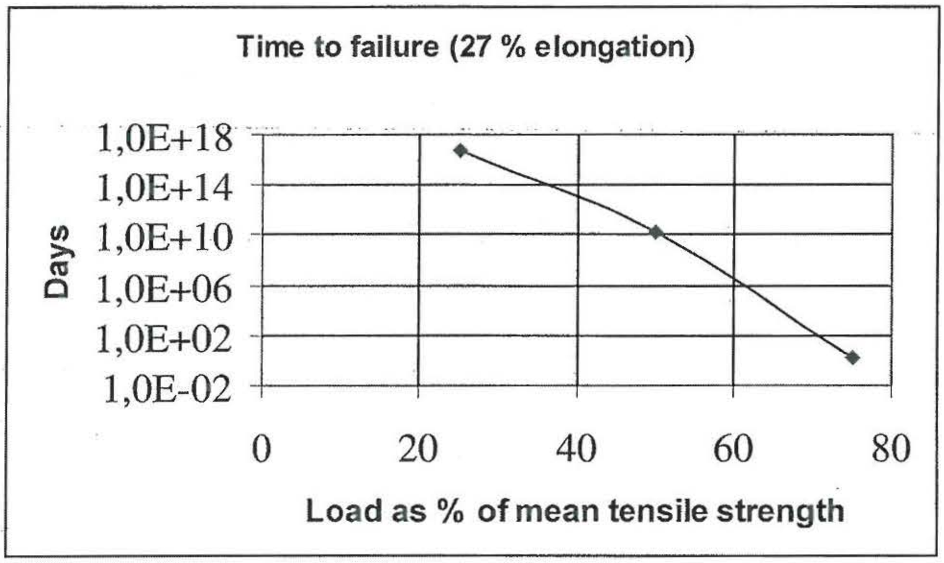
A typical graph showing load versus elongation is shown below.



The creep test were carried out on the same type of specimens. Three specimens were tested. The specimens were loaded by a constant load equal to 25 %, 50 % and 75 % of the mean tensile strength respectively, until failure or for a period of 24 hours, whichever occurred first. The elongation of the specimens were logged at regular intervals such that a graph of elongation versus the logarithm of time could be produced. A copy of such a graph is given below. All specimens exhibited a similar behaviour, i.e. a relative rapid elongation during the first minute until a slow more or less steady rate of creep was established.



For each specimen a straight line was fitted by hand to the upper slow rate part of the curve. This line was extrapolated to an elongation of 27 %, which was defined as failure of the specimens, thus giving time to failure. These times to failure were plotted versus the load on the specimen as shown in the following graph.



In the QP it is specified that the tarpaulin shall sustain a water head at least 1,5 times higher than the water head at which it is operated. This means that the load on the tarpaulin shall as a maximum be equal to 1/1,5 = 0,67 of the tensile strength. The fact that no damages to the fabric were observed at the full scale tests indicates that load is even lower. From the curve above and this latter observation it is evident that at such a load a creep failure will not occur until some 100 days have passed.

Resilience

The tarpaulin may be damaged during storage, handling and installation. It is a requirement that the tarpaulin shall be inspected for damages after it has been installed, but prior to the water being evacuated from the opening on the inside. However, it may be the case that minor damages like e.g. small punctures may go undetected. If such a puncture is located in the part covering the opening water will penetrate the puncture with a pressure of the water corresponding to up to 20 m water head. It was therefore considered possible that such a water jet could damage the tarpaulin further. An erosion test was therefor carried out by DNV to verify whether this high pressure water "jet" would have any detrimental effect on the tarpaulin.

A small sample of the tarpaulin was punctured using a nail and hammer. The sample was placed on a steel flange which was then mounted on a pressure vessel with the test sample facing the inside of the vessel. A hole in the flange was located over the puncture such that the water could escape freely. The vessel was pressurised and the water left free to escape from the inside of the vessel through the puncture such that a forceful jet was produced. The pressure in the vessel was maintained at 2,8 +/- 0,4 bar for a duration of six hours. No significant change in the jet or any significant damages to the tarpaulin, when inspected in a light optical microscope, could be observed

Environmental resistance

Prior to the full scale testing carried out by the client in November 1998 one of the tarpaulins was exposed to diesel oil for five days. In addition samples of the tarpaulin was exposed to diesel oil and to white spirit. These tests demonstrated that the adhesive used between the rubber sheet and the fabric has a limited resistance to aromatic hydrocarbons. Hence, the tarpaulin shall not be stored or used for a prolonged period of time under heavy exposure to such liquids. However, no swelling of the rubber sheet or other detrimental effects to rubber sheet of fabric could be observed.

Handling

The general experience from testing and handling of the tarpaulin is that it can resist normal handling provided normal care is taken to protect it against impacts and/or sharp objects.

The rubber sheet is fairly brittle. It is therefore necessary that the tarpaulin is not bent over a sharp radius. The rubber sheet start to fracture at a bending diameter smaller than approximately 200 mm. During storage the tarpaulin shall be rolled on a mandrel with a diameter of at least 300 mm. The rubber sheet shall be towards the inside of the roll.

Failure mode effect analysis.

The QP specifies that a failure mode effect analysis (FMEA) shall be carried out. This was carried out as a continuous process from the compilation of the first draft for the QP in August 1998 and throughout the whole qualification process. During this process several discussions regarding possible failure modes were held in-house and with the client and a potential operator. These discussions included failure scenarios and the findings from the tests. The discussions led to the final revision of the QP included in the Appendix.

6 CONLUSIONS

General conclusion

It is DNV's general conclusion that MikoPlaster is suitable for the intended use with the limitations stated further below. These limitations shall be clearly stated in a user manual to be worked out by MikoMarine. The user manual shall be accepted by DNV.

Below are given DNV's detailed conclusions with respect to each item in the Qualification Program. The numbering refers to the sections in the Qualification Program.

Detailed conclusions

5.1 Water tight seal.

It is DNV's conclusion that one can not expect that MikoPlaster will provide a leak-proof seal over hull side openings under all conditions. The user/operator of MikoPlaster must be prepared to handle a certain leakage and take the necessary precautions to be able to remove the amount of water that enters. The user manual must make the user/operator aware of this fact and on the necessity to use working procedures that enables him to estimate the rate of leakage before he opens up to the void covered with MikoPlaster. In this way he can ensure that e.g. enough pumping capacity is available.

The minimum distance between the edge of the tarpaulin and the edge of the opening shall be 400 mm. This shall be reflected in the user manual.

(During the qualification tests a leakage rate in the range 25 - 50 l/hour was recorded. However, leakage rates in other situations may deviate significantly from this range depending on the water depth and/or the characteristics of the hull plate surface.)

5.2 Structural strength

It is DNV's conclusion that MikoPlaster has sufficient structural strength when used as during the tests that has been carried out. The tarpaulin shall be supported for each 100 mm at 20 m water head. This shall be reflected in the user manual.

5.3 Holding by friction

It is DNV's conclusion that the friction force between MikoPlaster and the hull side plating will be sufficient for the intended use.

5.4 Resistance to peeling

It is DNV's conclusion that MikoPlaster can be used in wave heights up to 1 m when MikoPlaster is mounted on a depth smaller than 5 m. On larger water depths MikoPlaster can be used in wave heights up to 2 m. These wave heights apply when the sea current velocity is smaller than 2 m/s. If the current velocity is smaller than 0,5 m/s these wave heights can be increased by 1 m.

These acceptable wave heights only apply if MikoPlaster is secured to the hull side plating with additional permanent magnets of the same type as used during the qualification testing. A minimum of two magnets shall be used pr metre of circumference of MikoPlaster. The magnets shall be placed within 5 cm from the outer edge of the MikoPlaster. This shall be reflected in the user manual.

During a tow the rate of flow past the MikoPlaster shall not be larger than 2 m/s (corresponding to approximately 4 knots). It is a requirement that MikoPlaster is mounted on depth of at least 5 m.

5.5 Resilience

The tarpaulin has an adequate resilience with respect to minor damages like e.g. small punctures.

5.6 Environmental resistance/storage

It is DNV's conclusion that the fabric and the magnetic elastomer are suited for the intended use. In order to ensure a satisfactory adhesion between the fabric and the elastomer it is important that MikoPlaster is not exposed to hydrocarbons or other harmful substances during storage. Further, heavy exposure to e.g. hydrocarbons for a prolonged period of time (days) during use may have a significant adverse effect on the adhesion between fabric and elastomer. This shall be clearly stated in the user manual.

During storage the tarpaulin shall be rolled up on a cylindrical mandrel, rubber sheet facing inwards, with a diameter not smaller than 300 mm.

5.7 Handling

It is DNV's conclusion that MikoPlaster will withstand normal handling. It is a requirement, however, that care is exercised, as it is relatively easy to inadvertently puncture MikoPlaster. Suitable requirements to handling shall be included in the user manual.

It is a pre-requisite that the tarpaulin is inspected visually after it has been mounted. Visible damages over or close to the opening are not acceptable. Minor damages like small cuts can be accepted at other locations. This must be clearly stated in the user manual.

APPENDIX

A

MIKROPLASTER MAGNETIC TARPAULIN

QUALIFICATION PROGRAM

MIKO MARINE A.S

Final revison: 99.02.23

MIKOPLASTER MAGNETIC TARPAULIN
QUALIFICATION PROGRAM

Project number: **530 10221**
Revision date: 99.02.23

1. DESCRIPTION OF MIKOPLASTER

MikoPlaster is a magnetic tarpaulin intended for providing a temporary watertight seal over openings in ships hull sides such as sea chests, water inlets and outlets etc. The purpose of the tarpaulin is to facilitate maintenance and repair in such areas without the necessity for docking or use of other heavy-duty equipment and to stop or reduce leakage's in an emergency situation. The tarpaulin is secured to the hull by the normal force exerted by the water head and the magnetic force between hull plate and tarpaulin, sometimes aided by additional magnetic blocks.

The basic design of the tarpaulin is a layered construction based on an inner nitril rubber sheeting containing ferritic magnets which is bonded to an outer layer of a polyester weave covered with PVC film.

The maximum water head for which the tarpaulin is to be used is specified to 20 m.

The tarpaulin is restricted to use on mainly single curvature surfaces. A minor curvature perpendicular to the main curvature, e.g. due to fabrication tolerances, can be accepted provided it is possible to attach the tarpaulin such that it fits snugly to the steel plate.

The tarpaulin is restricted to use on CMn-steel plates.

2. CONDITIONS OF OPERATION

The operational parameters within which the tarpaulin can safely fulfil its task shall be defined. As a minimum the following parameters shall be defined:

- The minimum radius of curvature of the hull plating.
- The maximum size of openings for which it can be used.
- The maximum and minimum water head. The maximum water head is specified to 20 m.
- The minimum overlap, i.e. the minimum distance between the edge of the opening and the edge of the tarpaulin.
- Requirements to the surface to which the tarpaulin shall be secured, such as surface roughness, cleanliness, marine growth, surface irregularities (e.g. weld reinforcements etc).
- Method of securing the tarpaulin to the hull plating additional to the magnetic layer in the tarpaulin itself.
- Weather conditions: calm weather without major waves or swells is assumed.

In addition an installation procedure shall be made available by the manufacturer. Verification of the installation procedure is part of the qualification. It is intended to do the installation without divers, sometimes aided by an ROV.

3. BASIS FOR QUALIFICATION

There are no rules, regulations or standards on which an approval or verification of the magnetic tarpaulin can be based. The present qualification program is therefor based on:

- the description of the product given in Section 1
- the operational conditions given in Section 2
- relevant functional requirements and failure modes defined based on DNV's best knowledge, judgement and evaluation of realistic conditions
- the assumption that the tarpaulin is used on the operator's own risk

Compliance with the qualification program does not lead to an automatic accept of the tarpaulin for use on ships classed by DNV or other class societies, or by authorities.

4. FUNCTIONAL REQUIREMENTS

The following functional requirements to the magnetic tarpaulin is identified for its intended service:

- **Water tight seal.** The tarpaulin shall provide a more or less leak tight seal between outside and inside of the tarpaulin, i.e. preventing water to enter between the tarpaulin and the hull plate and penetration of water through the tarpaulin itself.
- **Structural strength.** The tarpaulin shall have a sufficient strength to support the maximum external water head acting over the covered opening with an adequate safety margin.
- **Holding by friction.** There shall be sufficient frictional force established between tarpaulin and hull side so as to prevent the tarpaulin form being displaced from its original location over the opening in the hull, e.g. due to wave action, current or other external actions, natural or man-made.
- **Resistance to peeling.** The bond strength between the tarpaulin and the hull plate shall be strong enough such that peeling of the tarpaulin from the plate due to wave action, current or other external actions, natural or man-made, is prevented.
- **Environmental resistance.** The materials in the tarpaulin shall be resistant to freshwater, seawater, hydrocarbons to a degree commensurate with its intended use giving a sufficient lifetime of the product.
- **Storage.** The tarpaulin shall resist storage in ambient conditions, i.e. within a temperature range of -30 °C - + 40 °C and relative humidity in the range 30 % - 95 %. If stored unprotected outside, the material shall be resistant to UV light.
- **Handling.** The tarpaulin shall have a resistance to normal wear and tear commensurate to handling in a marine environment.
- **Resilience.** Minor damages like e.g. small punctures shall not lead to a sudden failure of the tarpaulin's functions.

5. QUALIFICATION TESTS AND ANALYTICAL EVALUATIONS

For each of the functional requirements identified in Section 3 requirements to test and/or analytical methods together with acceptance criteria are summarised below.

5.1 Water tight seal

The tarpaulin's ability to establish and to maintain a watertight seal shall be demonstrated through practical testing.

The tests shall be carried out on a single curvature steel surface simulating a ship's side including openings with the following minimum sizes:

1 200 x 600 mm	for reinforced opening or tarpaulin
Ø 500 mm	for un-reinforced opening

The tarpaulin shall be mounted according to the manufacturer's procedure. The condition of the surface shall be such that it is representative for a "well used" surface. A representative weld reinforcement that is continuous from the edge of the tarpaulin to the opening shall be included. The radius of curvature of the plate shall be 1 m.

A hydrostatic pressure equal to the minimum hydrostatic head, 1 m, shall be applied on the outside of the tarpaulin for a period of one hour and the leakage rate measured.

A hydrostatic pressure equal to the maximum hydrostatic head shall be applied on the outside of the tarpaulin for a period of one hour and the leakage rate measured.

Acceptance criteria: Water leakage due to the surface roughness of the hull side can be accepted, but no excessive leakage is acceptable.
No water shall penetrate through the tarpaulin itself.

5.2 Structural strength.

The tarpaulin's ability to carry the load resulting from the external water head shall be demonstrated through practical testing.

The tests shall be carried out on a single curvature steel surface simulating a ship's side including openings as prescribed under item 5.1. The tarpaulin shall be mounted according to the manufacturer's procedure.

A hydrostatic pressure shall be applied on the outside of the tarpaulin equal to the maximum head during operation multiplied by a factor of 1,5 for a period of one hour.

The creep properties of the material under static load shall be documented.

Acceptance criteria: The tarpaulin shall withstand the pressure without any failure of its structural arrangements or other parts.
The creep properties shall be adequate for the period of time for which the tarpaulin is exposed to the water head.

5.3 Holding by friction.

The tarpaulin's ability to stay in place based only on the magnetic force and friction between tarpaulin and hull side shall be demonstrated by testing. The tests shall be carried out with plate and tarpaulin soaked in water. The surface of the hull side shall be representative for a situation were a low level of friction is expected: e.g. a newly painted surface with some marine growth.

Acceptance criteria: The frictional force shall not be smaller than 1 000 N/m^2 at zero water head.

5.4 Resistance to peeling.

The tarpaulin's ability to stay in place when exposed to a flow of water along the hull side (i.e. resisting peeling) shall be demonstrated by a practical test. The tarpaulin shall be exposed to a flow of minimum 2 m/s.

Acceptance criteria: The tarpaulin shall not show any peeling effects or be displaced.

5.5 Resilience.

The tarpaulin shall have a sufficient resilience such that small damages like minor punctures etc. inflicted to the tarpaulin during handling or installation do not lead to a catastrophic failure if they go undetected.

A sample of the tarpaulin shall be punctured and exposed continuously from one side by water under pressure corresponding to a water head of at least 20 m. The water shall be allowed to escape freely through the puncture for a duration of at least 6 hours.

Acceptance criteria; There shall be no significant increase of the damaged area around the puncture.

5.6 Environmental resistance/Storage.

The tarpaulin's ability to resist the normal marine environment in which it will be used and the storage conditions specified shall be demonstrated and/or verified.

The resistance of the tarpaulin and its constituent parts can be demonstrated through testing, service experience or other relevant experience with the materials and components.

Acceptance criteria: The mechanical properties listed below shall not deteriorate to any significant degree

- strength and toughness of fabrics
- strength and toughness of structural arrangements
- bond strength between fabrics
- bond strength between fabrics and structural arrangements

Resistance against hydrocarbons can be verified by soaking the tarpaulin in diesel oil at room temperature for a period of five days prior to carrying out the tests under items 5.1 to 5.3. After exposure and before and after testing the tarpaulin shall be examined visually for swelling, separation or other damages. The bond between the different layers shall be examined. The bonds shall not deteriorate significantly.

5.7 Handling.

The tarpaulin's ability to resist normal wear and tear commensurate with handling in a marine environment shall be demonstrated and/or verified.

The resistance of the tarpaulin and its constituent parts can be demonstrated through testing, service experience or other relevant experience with the materials and components.

Acceptance criteria: The mechanical properties listed below shall not deteriorate to any significant degree

- strength and toughness of fabrics
- strength and toughness of structural arrangements
- bond strength between fabrics
- bond strength between fabrics and structural arrangements

The handling shall not inflict any major damages to the tarpaulin.

6. FAILURE MODE EFFECT ANALYSIS

When installed the tarpaulin becomes a safety device as it will be the only barrier between the inside of the hull and the external water head. Therefore a Failure Mode Effect analysis (FMEA) shall be performed in order to verify that minor deviations from the normal operational procedures or minor damages to the tarpaulin do not render the installation unsafe. The FMEA shall include:

- Identification of failure modes of the tarpaulin
- Identification of their effect on the tarpaulins ability to act as a barrier
- Evaluation of the probability for the occurrence of the different failure modes

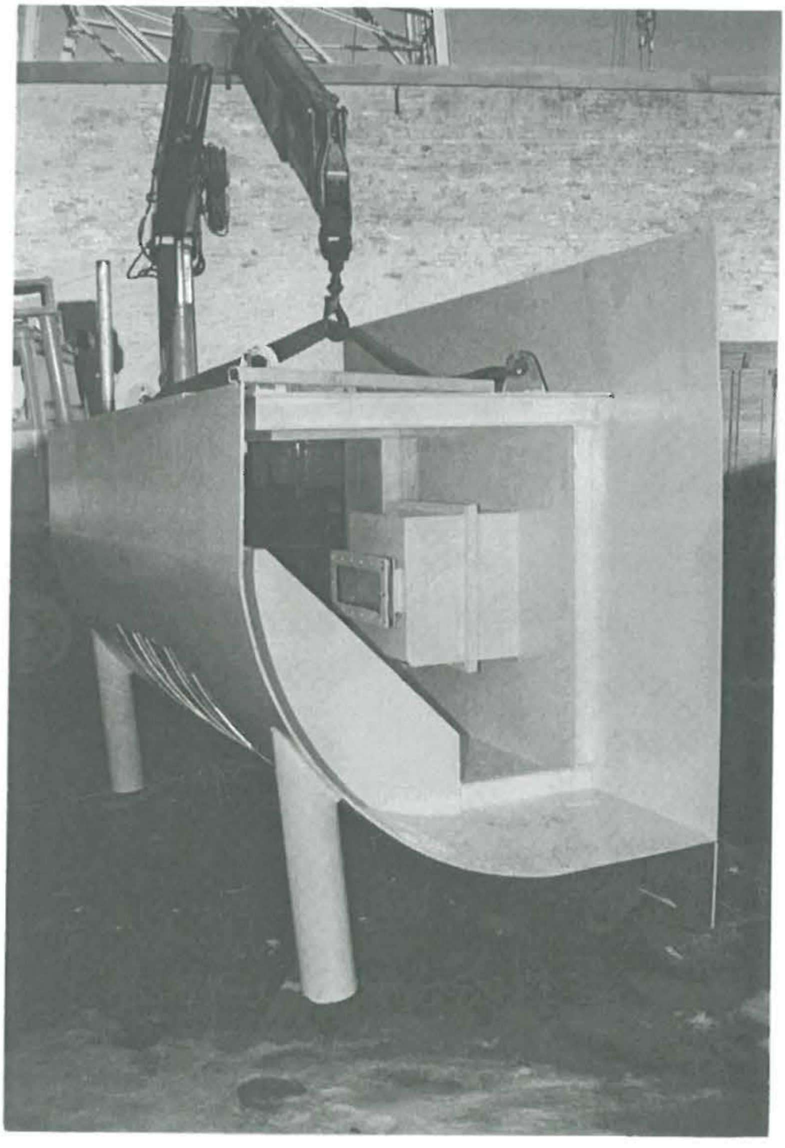


Fig. 1: Steel structure

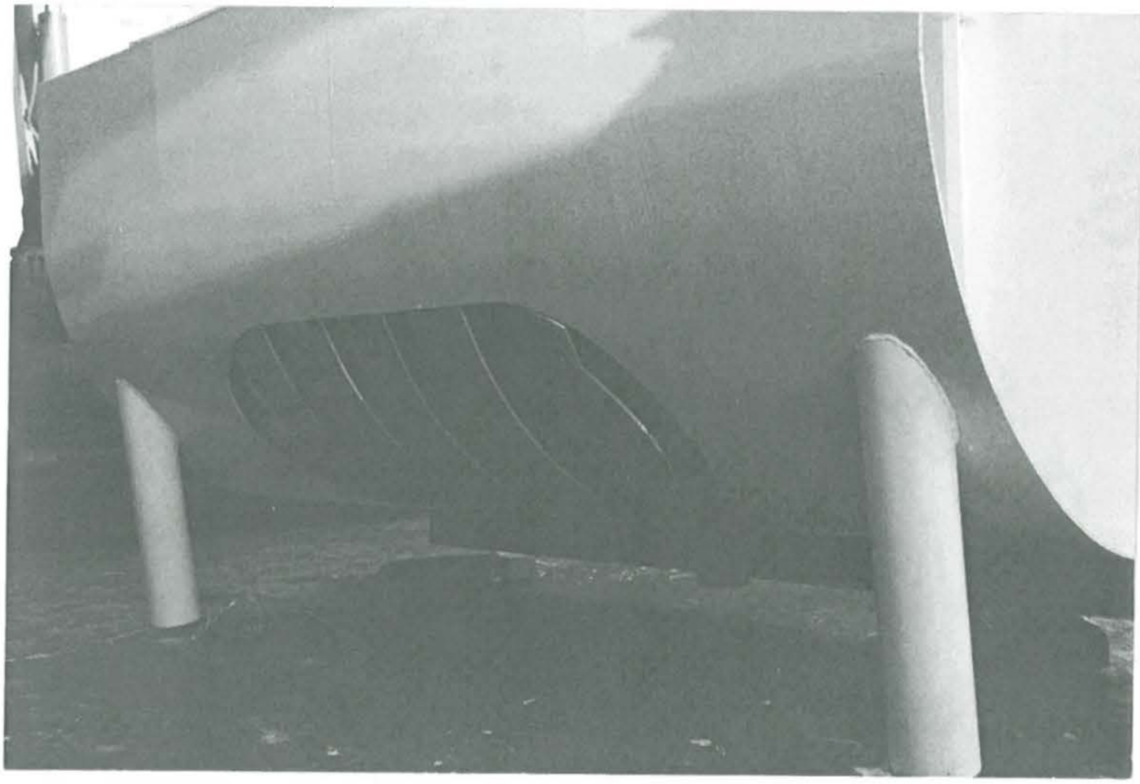


Fig. 2: Sea-chest opening

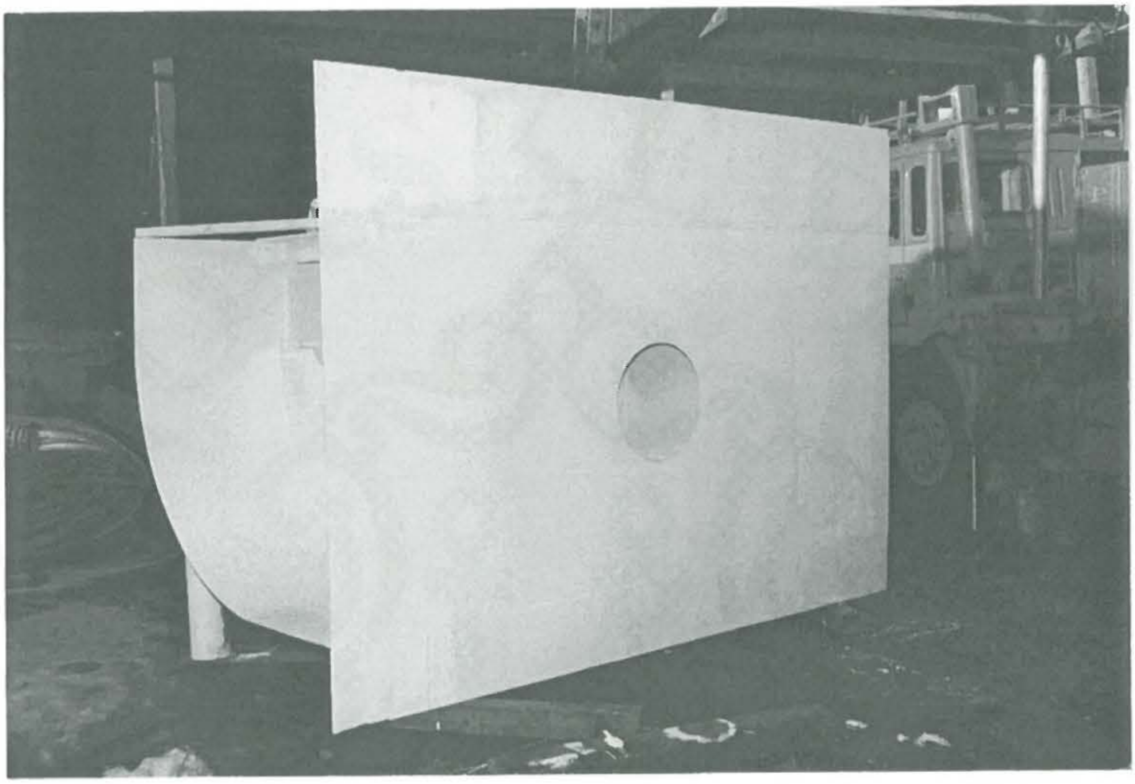


Fig. 3: Circular opening

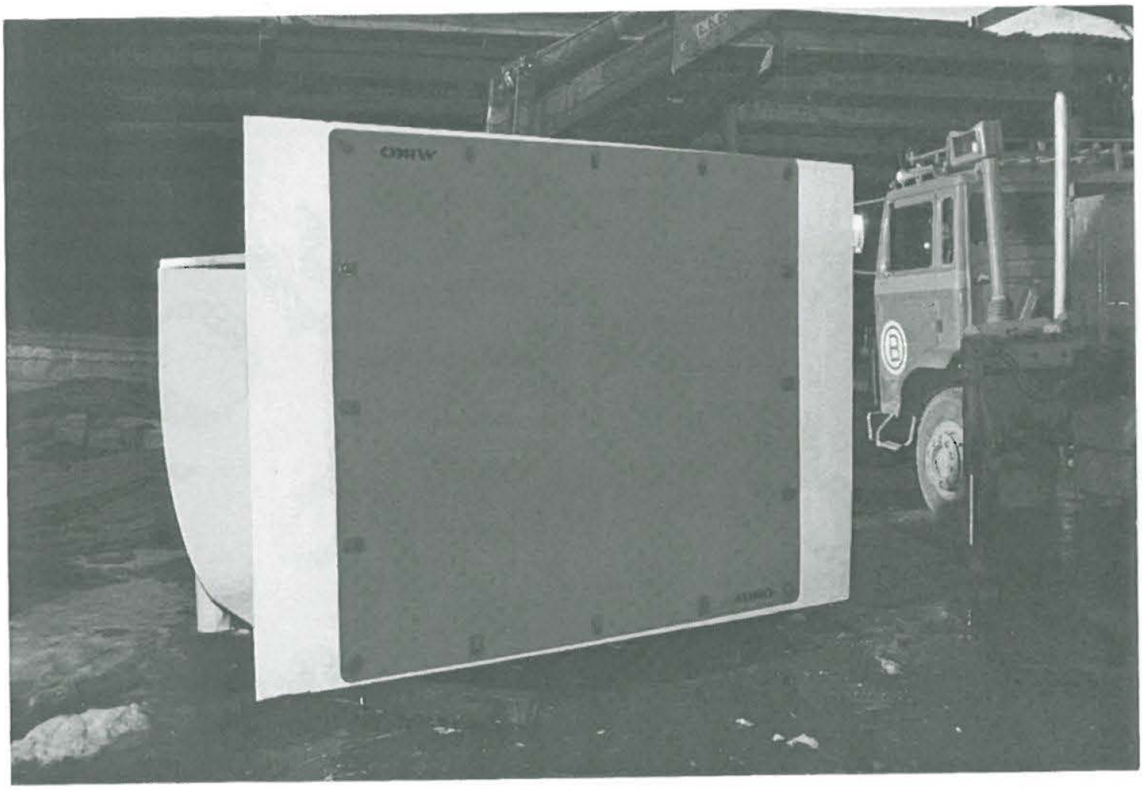


Fig. 4: Tarpauling mounted over circular opening

Fig. 5: Tarpauling mounted over sea-chest opening

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