THE IMPORTANCE OF PNEUMATIC FENDERS FOR SHIP-TO-SHIP TRANSFERS:

A SERVICE PROVIDER'S PERSPECTIVE

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1/ EXECUTIVE SUMMARY

As will be explained in this paper, when conclusions are being drawn up on the use, management, and maintenance of this equipment, it is critical that the correct fender experts with appropriate operational experience are properly consulted. Ignoring the organisations that use and maintain this equipment through its entire life span, risks a lowering of standards that creates a significant safety risk in the sector.

2/ BACKGROUND

Increasingly the Maritime sector is coming under scrutiny in terms of safety and the Ship-to-Ship Transfer Industry is no different. STS operations are very specialised and there is a need to ensure that the equipment provided is as good as it possibly can be to eliminate the risk of failures and give maximum peace of mind to clients, the hosting IMO member state and operators alike.

Ship-to-Ship transfer, like many marine operations, carries with it an inherent operational risk. It is essential that all the equipment used is wholly appropriate, of the highest standard and correctly deployed to ensure the safety of the STS operation.

One of the most important components is obviously the fender system, so it is important that there is a clear understanding of who is best placed to give guidance on all aspects of their use.

3/ THE IMPORTANCE OF MAINTENANCE

Once the fenders leave the factory they are rarely seen again by the manufacturer. Due to this there needs to be, and is, a close co-operation between the STS service companies

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and the principal manufacturers. This close co-operation manages the changing requirements of the industry while maintaining the exceptional safety record of industry-standard compliant equipment.

Pneumatic fenders were introduced in the late 50's and right from the start were used in ship-to-ship operations in challenging conditions for the whaling industry. Today the greatest numbers are used in ports and harbours, particularly where the conditions are challenging and tidal ranges are large, along with large numbers deployed in other offshore sectors. However, STS operators remain major users, and typically also maintainers, of pneumatic fenders across all sectors I have mentioned above. The STS service companies are therefore extremely well placed to make informed expert judgements, in consultation with the manufacturer when appropriate.

4/ STS INDUSTRY SELF-REGULATION

Standards for equipment including ISO 17357 represent the minimum standards. The requirement and implications of reverse lightering, fender performance, and fender retirement have been developed by, or at the request of, the STS industry. This is a continuously evolving process by the companies in the industry, for the companies in the industry.

Self-regulation is typical of the STS sector historically and this has maintained the industry's safety performance at an extremely high level for many years. This is supported by the expertise and guidance of OCIMF Ports and Terminals Committee, and multiple meetings are held on an annual basis to monitor and action items of concern raised by the STS Service Providers at the meetings.

The OCIMF Ports and Terminals Committee interface with:

- Industry Task Force on Lightering ITOL
- European Middle East and Africa STS Forum
- Singapore Nautical Institute Best Practice Forum.

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Pneumatic Fender issues addressed at these forums include reverse lightering, performance and retirement age of fenders, use of foam fenders and many other aspects including the construction of the chain and tyre nets and regulation of fender standards.

Reverse Lightering

A slow change in Industry requirements, with the practice of reverse lightering (loaded vessel discharging into an empty or partially loaded vessel) becoming more common, began to highlight a problem. The traditional understanding of fender performance requirements was challenged by Industry and studies identified that a higher-performance pneumatic fender was required for reverse lightering.

The "Considerations for Reverse Lightering" study was adopted by OCIMF, initially as an information paper and then embedded into subsequent publications of the ICS/ OCIMF STS guide. and led to the "Performance Standards for Ship-to-Ship Transfer in Swell" being published in manufacturers handbooks.

The reverse lightering issue was identified by two separate indicators, one being a vessel contact in the bow area on landing and the second was deformation of the steel bead ring on the fenders which is an integral part of the ISO 17357 standard of construction.

Hence when this standard was revised in 2014 the main revision was to the ratio between the diameter of the fender and the steelwork of the bead ring. This was updated to ensure that at the maximum allowable deflection there would be no contact resulting in internal damage to the fender and the potential for failure.

Retirement Age of fenders

The age of the equipment being used, and its retirement criteria, have long been topics of discussion in the Industry. It is not unusual to see fenders of well over 20 years old still in service for activities other than STS, but the question of when to retire is critical.

The accepted norm of 15 years for fenders used on ship-to-ship operations was based on analysis of retired fenders subject to high usage in the US Gulf.

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The study conducted by an STS service provider, burst several fenders and the results provided factual evidence as to the residual strength of older fenders and their deterioration with age.

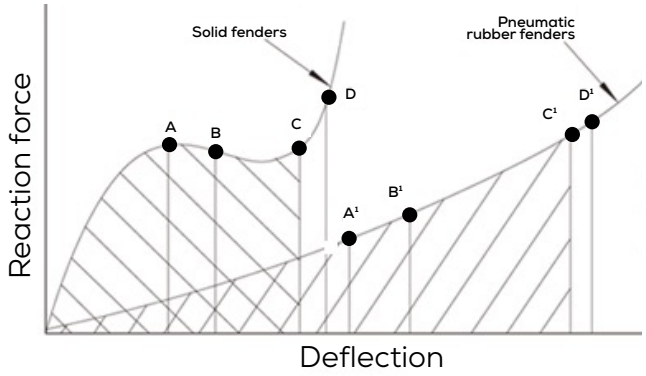
This again was an Industry-led initiative and the results fed through to the OCIMF working groups as best practice. Self-regulation again, on this most critical piece of equipment, was to the benefit of the whole Industry not just the participants in the tests. 15 years became the standard for the retirement of pneumatic fenders based on hard verifiable facts.

Care needs to be taken to ensure that the retirement criteria for pneumatic fenders used in the ship-to-ship sector are not based on the use of equipment not specifically constructed for the purpose. A reduced service life will also not protect from incidents arising from sub-standard equipment sold as being manufactured in accordance with ISO 17357.

5/ DIFFERENT TYPES OF FENDER

Pneumatic Fenders

Since the inception of commercial Ship-to-Ship transfer operations in the 1970's, pneumatic fenders have been the protective system of choice. Pneumatic fenders have significantly different properties to solid (fixed) dock fenders and can be used in a variety of applications.



Compression stages
A, A¹ : First buckling point of solid fender
B, B¹ : Normal deflection point during typical berthing
C, C¹ : Designed rated energy point
D, D¹ : abnormal berthing

Pneumatic fenders have the benefits of being relatively lightweight in relation to their size. They have high energy absorption with a low reaction force.

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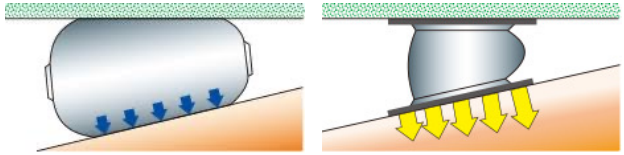
Coupled with this there is no reduction in performance even with berthing angles up to 15 degrees, provided the units are designed and produced correctly.

As can be seen in the diagram, the forces on the hull are evenly distributed in the pneumatic fender and high-pressure points are seen in the solid (fixed) fender.

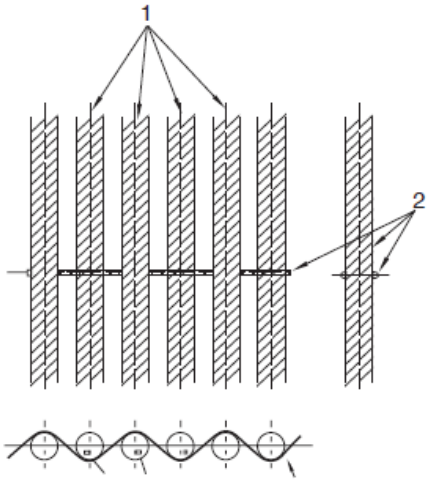


Pneumatic fender Solid fender

There are several manufacturers offering pneumatic fenders, and some are produced using methods employed for manufacturing ship-launching airbags. This will lead to lower and less consistent performance characteristics for STS application and the design may well reduce the operational life of the fenders or fail at a critical point in an operation. The reasons for this are described underneath.

ISO 17357

In 2002 the First Edition of ISO 17357 was produced. This new standard set out clear parameters for production, performance, inspection and testing of both high and low-pressure pneumatic fenders and specified the use of synthetic tyre cord (see below) as the reinforcement material. Prior to the standard, many manufacturers employed nylon mesh or canvas type material rather than individual strands and it was found that the abrasion between the warp and weft of the mesh led to the threads breaking. The weakened structure significantly increased the risk of catastrophic failure.



1 : Warp (tension member)
2 : Weft (no tension member)

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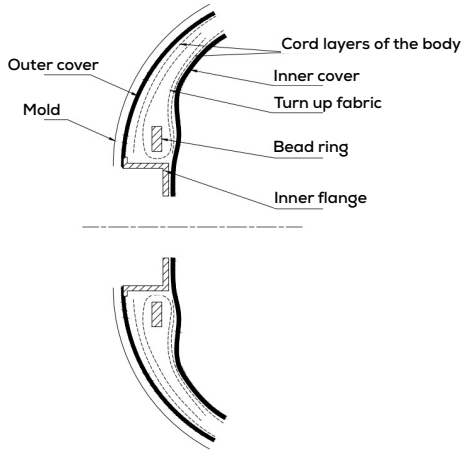
Synthetic tyre cord was specified in the standard as it is linear, with each strand being separated by rubber giving better resistance to fatigue.

Better quality pneumatic fenders use polyester tyre cord as it does not deteriorate in the presence of water. However, some manufacturers favour nylon (polyamide) as it offers greater elongation properties. The disadvantage is that this material degrades in the presence of water and there have been instances where water, condensed from the steam used to vulcanise the rubber, has become trapped in the cord layers. This trapped moisture has caused the nylon to degrade over time resulting in a significant reduction in strength of the fender and again leads, ultimately, to catastrophic failure.

The ISO 17357 Standard only specifies that "synthetic" tyre cord should be used but the leading manufacturers producing the premium fenders will be using polyester as opposed to nylon - and the buyer should check this particular detail extremely carefully before purchase because of the implications described above.

Fender Construction

Pneumatic fenders have been developed in two ways. One uses technology like that used in the manufacture of vehicle tyres, the other from that used in ship launching airbags. In the former the tyre-cord layers in fenders are laid in at precise angles so that the loads are distributed evenly through the structure and gives them the ability to accommodate both parallel and shear forces - such as when the vessels move longitudinally and vertically against each other. Likewise, using the correct method of incorporating the bead ring into the structure of the fender is vital to its longevity in service.



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The bead ring opening houses the safety valve and filling valve and without reinforcement would be a potential weak point in the structure.

The ISO standard specifies the way this structural strength should be achieved, with the rubber and cord wrapping around the ring for strength.

Airbag Technology

Fenders manufactured using Airbag processes will not conform to the ISO 17357 standard, as construction tends to be less exact and less well controlled.

Airbags work well in a ship launching situation. When deployed, there are usually many units in place and the failure of one is not likely to be a major problem.

The forces on the ship launching airbags are always applied in one direction, at 90 degrees to the longitudinal axis.

Airbags are built in two parts: an airbag and its protective casing. Manufacturing starts from the inside out with the inner airtight bag being constructed and vulcanised first, this is then inflated and whilst its rotating on rollers the reinforcement layers and outer cover is laid on using an adhesive. The disadvantage of this process is that the inflated airbag does not give a solid surface on which to apply the layers, and this can lead to a lack of adhesion leading to air bubbles forming between the layers. This in turn could be exacerbated by contamination picked up as the body rotates. Contamination will either come from the air or directly from the layers being applied if the preparation area is not scrupulously clean. From our observations, unless the build is very well controlled there can

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be issues ensuring the two parts are completely bonded, and if this process is not rigorously controlled the integrity of the fender will be compromised.

In an STS situation there will be only 4 to 6 fenders deployed, so individual structural integrity is clearly much more important than for ship launching.

Foam fenders

The rewrite of the OCIMF STS Guide in 2013 allowed for the use of alternative fenders in more benign environments. Some operators favoured the use of foam filled fenders, but their use now is exceedingly rare, or they are used only as secondary fenders. These fenders usually consist of a closed-cell polyethylene foam material which is wrapped on to a mandrel to give a finished diameter.

Better quality units use thinner foam which is supplied on reels and the sheets are bonded together either using heat or a contact adhesive to create an armature. Another method favoured by those manufacturers who use EVA foam is to cut discs of the required diameter from sheets, these are bonded together using a contact adhesive.

The ends are then shaped, and the armature is then spray-coated with polyurethane: this part of the process is common to most type of foam fenders.

Some manufacturers use a fibre reinforcement layer of nylon or Kevlar to aid abrasion resistance, and to prevent splitting in the PU coating. However, it can have the effect, if not done well, to act like cheese wire and cut the polyurethane.

In some cases, a mesh has been used with the thinking being that the polyurethane will go through

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the mesh and create a better bond. There is some evidence to show that this is not the case and the mesh can increase the risk of layer separation. If the polyurethane coating is pierced, water will get between the skin and the foam and cause the two parts to separate. In the worst-case scenario, the hydraulic effect of the water between the foam and the skin can then cause the foam to disintegrate.

After external damage allows water ingress, the water adds extra weight

to the fender effectively ballasting it down and reducing its performance. This clearly from an STS perspective, even in a benign environment, has the danger that the performance cannot be judged by the physical appearance. It has also been found that foam fenders tend to lose shape over time, an effect known as "compression set" and thus both standoff and performance can be reduced. In a ship-to-ship application, there is an argument that foam fenders as secondary fenders are better, but after a heavy landing, or a series of moderate landings, they will likely be deformed and need to be replaced.

It should also be noted that the STS market is generally spot and the need for us to transport fenders at time and cost critical notice. Foam fenders cannot be deflated and packed into a container resulting in extremely high mobilisation costs.

Regulation of Fender Standards

Currently there are no international standards, like those for pneumatic fenders, that can be applied to foam fenders, although we are aware that PIANC working group 211 is currently

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engaged in reviewing and updating the work published in 2002 by PIANC working group 33, which has become a standard reference document, and is likely to include recommendations for foam fender evaluation.

In addition to the introduction of these standards, when the report of WG 211 is published it is highly likely that there will be a requirement for full size fender testing to cover all fender types including pneumatics, rather than the extrapolation of results that is currently allowed for in both PIANC 2002 and ISO 17357-2014.

6/ THE IMPORTANCE OF FENDER CERTIFICATION

Once a fender has been built it is difficult, if not impossible, to determine whether it conforms to the ISO standard and the client is reliant on the manufacturer's certificates. The inspection criteria for any third-party inspections on quality will be defined by the contracting party (which is typically the manufacturer) so even these inspection certificates cannot be completely relied upon as their definition by some manufacturer's may be designed exactly to mask deficiencies in how their products have been designed or manufactured.

From experience, third-party witnessed certificates are not much of an insurance, even though some manufacturers have been keen to hold them up as guarantors of quality as all such visual and dimensional inspections will usually verify is the conformity of the finished product with the manufacturer's own drawings. There are specialist companies who can provide that build-quality assurance, typically under the instruction of the buyer not the seller, which gives a more independent verification of the build quality of the fender.

From an assurance perspective, there are certificates in circulation that at first sight seem to show full compliance with the standard, but closer inspection and comparison with the standards reveal many have at least one of the criteria missed.

In theory, all fenders manufactured that "declare they are manufactured in accordance with the standard" should

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be equal, however it is well known that this is not the case - and this is very much due to ISO standards largely being a self-certification process. Care needs to be taken to ensure that the fender is genuinely 100% ISO compliant and meets all aspects of that standard, experience has shown that not many do.

7/ CHAIN/TYRE NETS AND MAINTENANCE

Whilst the STS fenders will come with a chain and tyre net, this is often not supplied by the manufacturers of the fenders, and are instead manufactured and fitted by a third party. Ongoing through-life maintenance and repair is usually carried out by companies such as the STS companies who have the skills internally to manage these tasks and specialist third party contractors who buy sell and rent these units.

Because of this lack of experience on their practical use, the manufacturer is typically not best placed to advise on anything other than basic recommendations as to maintenance, repair, and servicing.

Clear understanding of the intended purpose is required to properly cover these aspects in through-life care of pneumatic fenders.

The same as a tyre protects the inner tube on a motor vehicle, the chain and tyre nets protect the fender body. It tends to be forgotten that the pneumatic fender body is typically only the bladder and the chain and tyre netting provides a safe means to protect the bladder from damage and give structural strength to deploy these fenders in rough operating environments.

There are many designs of chain and tyre net and it is not untypical that fenders supplied direct from a manufacturer with these factories' fitted nets are not fit to go directly into STS service. This is not necessarily a reflection on the manufacturer, as different nets and towing rings are required for different applications and the operators will generally be more aware of those field needs than the manufacturers.

Well-manufactured and maintained chain and tyre nets are critical to safe through-life protection of the fenders. When considering the chain and tyre net, the safe working loads of all the materials

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should be considered, alignment of shackles to take the expected loads and the number and placement of tyres to protect the body from damage.

It is just as critical to the ship-to-ship industry, that the chain and tyre netting is properly assembled, as it is that the fender is properly constructed to ISO standard. There is not a certificate for the chain and tyre nets as these are consumable items that require ongoing repair. Nets not constructed for STS service and poor chain and tyre net maintenance will reduce the expected working life of a pneumatic fender.

8/ CONCLUSION

Quality STS providers undertake due diligence on their critical equipment such as fenders which extends well beyond the tick-box exercise of checking a manufacturer's certificate. To undertake meaningful due diligence, there must be a full understanding of the operational use and purpose for the fenders, or the basic safety principle of ALARP will not be met.

None of the fender manufacturers, as far as I am aware, offer a maintenance service, so this aspect is firmly in the hands of the STS Service providers and third-party contractors.

Thank you for taking the time to read this paper, please feel free to contact myself or any of the Safe STS team regarding any advice you may require.

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Capt Bob sailed up to the rank as Master on oil tankers and spent 21 years at sea, before training as an STS Mooring Master and conducting STS operations and salvage operations in many parts of the world.

Utilising his practical hands-on experience with a progressive and innovative approach Bob was a co-founder of SafeSTS Ltd. With extensive experience of the practical and management of STS operations, Bob also advises clients and governments on STS matters and acts as an expert witness in the case of disputes and incidents.

Through his commitment to the STS Industry Capt Bob currently serves as Co-Chair of the European Middle East and Africa (EMEA) STS focus group supporting safety and development in the STS Industry.

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