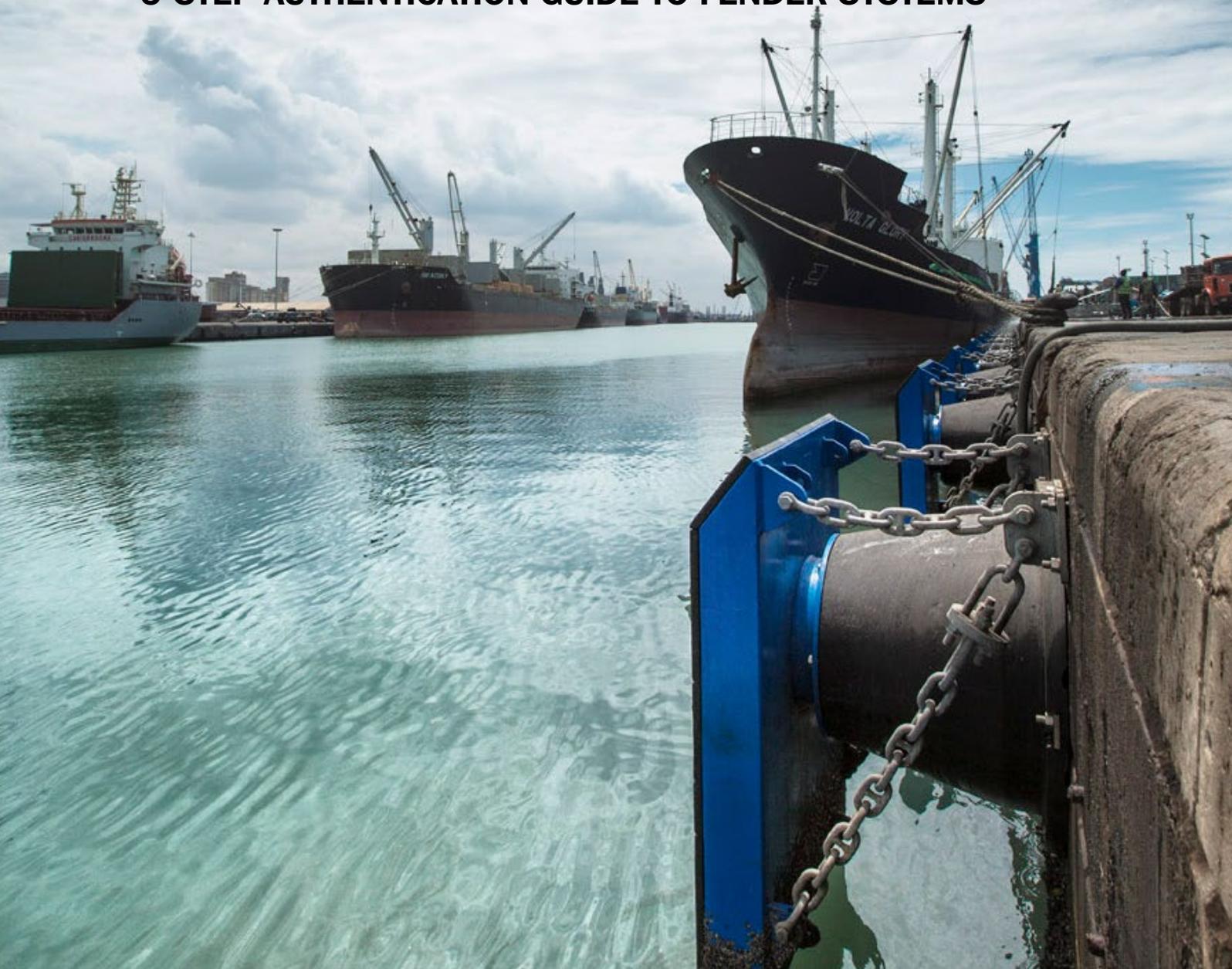


# Future-proofing Fenders

**5-STEP AUTHENTICATION GUIDE TO FENDER SYSTEMS**



# The Genuine Article

**Effective and reliable fender systems are mission critical equipment. They have a direct impact on the safe and efficient operation of our ports, helping improve berthing management procedures and increase vessel throughput.**

However, not all fenders are created equal. Rubber compounds are changing. New manufacturing bases are emerging. Testing procedures need to keep pace to ensure fender performance standards are maintained. Regulations and guidelines do exist, but how can you be sure that the product you buy is genuine? Is the test certificate enough to guarantee performance? Can you really trust catalog claims? In light of these developments, Trelleborg has developed a 5-step guide to authenticating fenders to help designers, operators and owners of port infrastructure procure these systems confidently, safe in the knowledge that they are investing cost-effectively in equipment that guarantees quality and reliable performance over the long-term.



## WHY IT MATTERS TO YOU

PIANC's announcement at its 2018 congress of a new Working Group (MarCom Working Group 211) to look at updating its 2002 Guidelines for the Design of Fender Systems is a welcome development. Advances in the design of fender systems, as well as evolutions in vessel design and industry applications now have the opportunity to be fully reviewed and incorporated into the fender guidelines to ensure they reflect improving performance capability and rising standards.

Trelleborg supports the need to update these guidelines to ensure they include the latest best practice in design, manufacture, materials and full-scale testing of fender systems. Our representatives will be contributing to the group and sharing Trelleborg's ongoing research into all of these areas.

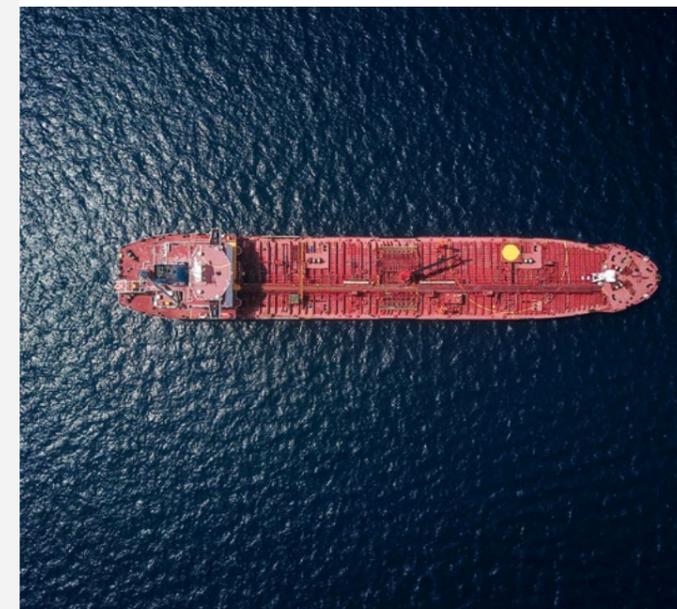
MarCom Working Group 211 may have been formed recently, but changes are on the horizon, and future-proofing is required. Organizations need to factor this into their procurement processes, exploring advanced compliance through criteria such as specifying fender systems that both meet and exceed the current guidelines.



## Contents

### CHAPTERS

AUTHENTICATION STEP 1: BERTHING VELOCITY	4
AUTHENTICATION STEP 2: TEMPERATURE	6
AUTHENTICATION STEP 3: ANGLE	8
AUTHENTICATION STEP 4: INDEPENDENT TESTING	10
AUTHENTICATION STEP 5: INDSUTRY WIDE BEST PRACTICE	12
SAFE AND SECURE	14



# Authentication Step 1: Berthing Velocity

**Berthing velocity has a significant impact on fender performance. Understanding the factors that affect velocity factor (strain rate and rubber compound) will ensure that the highest quality of fender system, and one that is truly fit for purpose, is secured.**

## VELOCITY FACTOR (VF)

Awareness of fender compression at different velocities is critical to understanding how it will perform once in situ. While it is impossible to replicate the actual berthing velocity of vessels in testing, as this is normally anywhere between 20mm/sec and 500 mm/sec, it is possible to carry out rigorous testing that simulates these berthing conditions.

For testing to meet the relevant Active Standard ASTM F2192 and PIANC 2002 guidelines, rated performance data (RPD) must show fender performance with an initial deflection (berthing) velocity of 0.15 m/s, decreasing to no more than 0.005 m/s at the test end. In addition to this, catalogs should also clearly indicate VF for other berthing velocities. VF calculations should be generated by testing real or model fenders at different speeds i.e. 0.001, 0.05, 0.10, 0.20, 0.25 and 0.30m/s. Data from some manufacturers can be ambiguous and may not clearly state if the performance is based on a berthing velocity of 0.15m/s or 0.001m/s. Manufacturers may try to make up any shortfall with velocity factors, which do not provide a proper indication of actual fender performance within the port environment.

Despite a general industry-wide understanding as to what VF is by definition, there has been little done to educate designers, operators and owners of port infrastructure as to how VF figures are calculated and so vary between manufacturers.

Investment must be undertaken in research and development to underpin claims or apply sufficient factors to products. Manufacturers and designers must understand the factors that affect VF and provide competent commentary in relation to the application of VF in their rubber compounds and fender designs.

They must incorporate guidance on the effects of VF on their fenders to ensure that strain rate and material grade is properly considered. This will ensure that when comparing catalog figures from different manufacturers, consultants can make fair and accurate comparisons.

## STRAIN RATE AND RUBBER COMPOUND

There are two factors that significantly influence VF and are critical to simulating fender performance at a given velocity, and correctly identifying operational capability on the wharf or quayside: Strain Rate (inverse of compression time) and the type of rubber used.

Strain rate can be expressed by the number which is inverse of the compression time. The higher the compression time, the lower the strain rate. If all other parameters are constant, strain rate has a significant impact on VF. For a given velocity, large fenders need more time to be compressed than smaller fenders. This means the strain rate on a large fender, and the magnitude of VF, will be lower than on a smaller fender.



This should be factored in during testing and clearly indicated in all fender performance data.

The type of raw rubber used in compound formulation significantly influences VF. Testing shows VF is highly dependent on the blend and ratio of natural rubber (NR) and synthetic based rubber (SBR) used in the overall rubber compound formulation. Fender manufacturers should always provide commentary in relation to the application of VF in their rubber compounds and fender designs. By performing this kind of research and making the data available, fender suppliers and manufacturers can increase understanding and improve standards across the industry.

Robust chemical and physical material testing is also required to ensure that reclaimed rubber and nonreinforcing fillers are not used in fender production. These substitutions may not always be declared in supplier documentation, but will negatively impact the fender's ability to absorb designated berthing energy of a vessel and the VF as well as longevity of a fender. This is also one of the reasons why recycled rubber compound should not be used. Its behavior is unpredictable at different temperatures and could cause fender failure. Using recycled compound means that the velocity tables published in the fender supplier's catalog are not reliable.

## VELOCITY TESTING: KEY CONSIDERATIONS

- Have Active Standard ASTM F2192 and PIANC 2002 guidelines requirements been fully met?
- Does fender testing include simulations at 0.05, 0.10, 0.20, 0.25 and 0.30m/s?
- Does fender performance data adequately include advice on the effects of VF?
- How is strain rate factored in?
- Have both chemical and analytical testing been applied to verify type, quality and composition?
- Is it clear that Constant Velocity (CV) or Decreasing Velocity (DV) has been used in the performance calculations and fender selection process?
- Has the same compound been used for your fender as was used by the supplier to determine the VF?



**“Applying velocity factor is critical to understanding how a fender will perform in situ.”**

# Authentication Step 2: Temperature

**Changes in temperature have a tremendous effect on fender performance. It is therefore essential that manufacturer testing procedures comprehensively accommodate any variations in temperature that fenders will be exposed to under actual operating conditions. This ensures that the optimum fender system is acquired.**

## TEMPERATURE FACTOR (TF)

Temperature factor is vital in understanding changes to reaction force and energy absorption of fenders in normal operating conditions. This is because the stiffness (modulus) of the rubber compound changes dramatically with temperature which, in turn, impacts how the fender performs in situ. Ideally, rubber elements for fender systems should be tested on a case-by-case basis in accordance with the temperatures they will be subjected to in the field.

For fenders to meet Active Standard ASTM F2192 and PIANC 2002 guidelines requirements, rated performance data (RPD) must include the testing of fenders stabilized at  $23^{\circ}\text{C} \pm 5^{\circ}\text{C}$ . For any other application, TF must be applied to adjust the fender performance. TF should be created and indicated in the catalog by testing fenders at various temperatures, i.e.  $+50^{\circ}\text{C}$ ,  $+40^{\circ}\text{C}$ ,  $+30^{\circ}\text{C}$ ,  $+10^{\circ}\text{C}$ ,  $0^{\circ}\text{C}$ ,  $-10^{\circ}\text{C}$ ,  $-20^{\circ}\text{C}$  and  $-30^{\circ}\text{C}$ . It is important to ensure that tables have not been copied from elsewhere. As well as verifying that the full range of temperature factors have been applied during testing, it is also necessary to check that all data relates specifically to the fenders in question.

## TEMPERATURE AND RUBBER COMPOUND

Similar to VF, TF is highly sensitive to the type of rubber used – natural rubber or synthetic rubber, or a blend of the two, as well as the inclusion of recycled rubber. Temperature factor therefore varies with the rubber compound and from manufacturer to manufacturer, meaning factors are unique to each individual fender. It becomes important for a designer to know the type of rubber used during manufacturing process and to ensure TF published in the catalog corresponds to the type of rubber. Recycled rubber compound should not be used as its behavior is unpredictable at different temperatures and can lead to fender failure. Using recycled compound would result in the temperature tables published in the fender supplier’s catalog being unreliable.

At high temperatures, the fender is effectively softer with a lower energy absorption capacity and at low temperatures the opposite occurs. Design and selection of fender systems must take into account both energy absorption and reaction force. The most suitable fender is one that does not exceed the reaction force limits under normal operating conditions, while at the same time providing more than the minimum energy requirement. The converse situation applies to low temperature application.



## TEMPERATURE FACTOR: KEY CONSIDERATIONS

- Have Active Standard ASTM F2192 and PIANC 2002 guidelines requirements been fully met?
- Is performance data shown for temperature variables at  $+50^{\circ}\text{C}$ ,  $+40^{\circ}\text{C}$ ,  $+30^{\circ}\text{C}$ ,  $+10^{\circ}\text{C}$ ,  $0^{\circ}\text{C}$ ,  $-10^{\circ}\text{C}$ ,  $-20^{\circ}\text{C}$  and  $-30^{\circ}\text{C}$ ?
- Has the rubber type been chemically determined?
- Has TF been applied based on the fender’s individual rubber compound?
- Does TF performance data relate specifically to the manufacturer? How is this verified?
- Does the fender system optimize the balance between energy absorption and reaction force?
- Is bespoke fender testing that reflects temperature exposure in the field available?
- Has the same compound been used for your fender as was used by the supplier to determine the TF?



**“Rubber elements should be tested in accordance with the temperatures they will be subjected to in the field.”**

# Authentication Step 3: Angle

Differing port infrastructures and vessel sizes mean that the angle of impact during berthing will vary depending on circumstances. A fender system must be designed to have enough energy absorption capacity to accommodate the appropriate berthing patterns.

## ANGLE FACTOR (AF)

Fender performance will vary depending on the angle of contact that results from a vessel's berthing approach. Therefore the capacity requirements in a fender system designed to accommodate parallel berthing will differ significantly from one with an acute angle of approach. Understanding how well a fender is able to absorb energy at different angles is critical to its performance at the quayside.

For fenders to meet Active Standard ASTM F2192 and PIANC 2002 guidelines requirements, rated performance data (RPD) must include the testing of fenders at zero degree angle of approach. By zeroing the angle factor, this should allow for easier comparison of fender performance data using other testing parameters (temperature, velocity, deflection). However, this is just the first step. In addition, manufacturers must also provide adjustment factor information for contact angles at 3, 5, 8, 10, 15 and 20 degrees – for each fender type. This makes it possible to determine if there is a reduction in performance (energy absorption) at large berthing angles.

Manufacturers should show angle factor testing data in relation to both transverse and longitudinal angular berthing to illustrate performance under different berthing conditions.



## ANGULATION: KEY CONSIDERATIONS

- Have Active Standard ASTM F2192 and PIANC 2002 guideline requirements been fully met?
- Does RPD indicate testing of fenders at zero degree angle of approach?
- Is additional testing data available for contact angles at 3, 5, 8, 10, 15 and 20 degrees?
- Does testing give a like-for-like comparison of how AF affects fender performance?
- Are AFs applied for both transverse and longitudinal angular berthing for leg type of fenders?



**“Understanding how well a fender can absorb energy at different angles is critical to quayside performance.”**

# Authentication Step 4: Independent Testing

**With the critical role that fenders play in the operations of ports, it's essential that independent testing verifies the authenticity and performance of fenders. However, current testing of fenders lies with the suppliers themselves which may result in unreliable data and flawed practices.**

## FLAWED PRACTICES

Performance verification testing is usually performed in a large press or test frame with either load cells or pressure transducers. Outside of manufacturers' facilities, these test frames are extremely rare. As a result, performance testing usually occurs in manufacturers' own factories where there is the potential for data manipulation to occur.

During testing it is not uncommon for fenders to be specifically selected for the test rather than chosen at random. These fenders will be built to pass performance tests, but when it comes to creating the products that actually go to market, often lower cost, substandard materials are used in production. Similarly, test results may be manipulated, meaning the fenders that are sold are not fit for purpose in the port environment.

The industry's response to this has been to introduce independent witnessing to verify the authenticity of results. However, the implementation of this process has also been flawed.

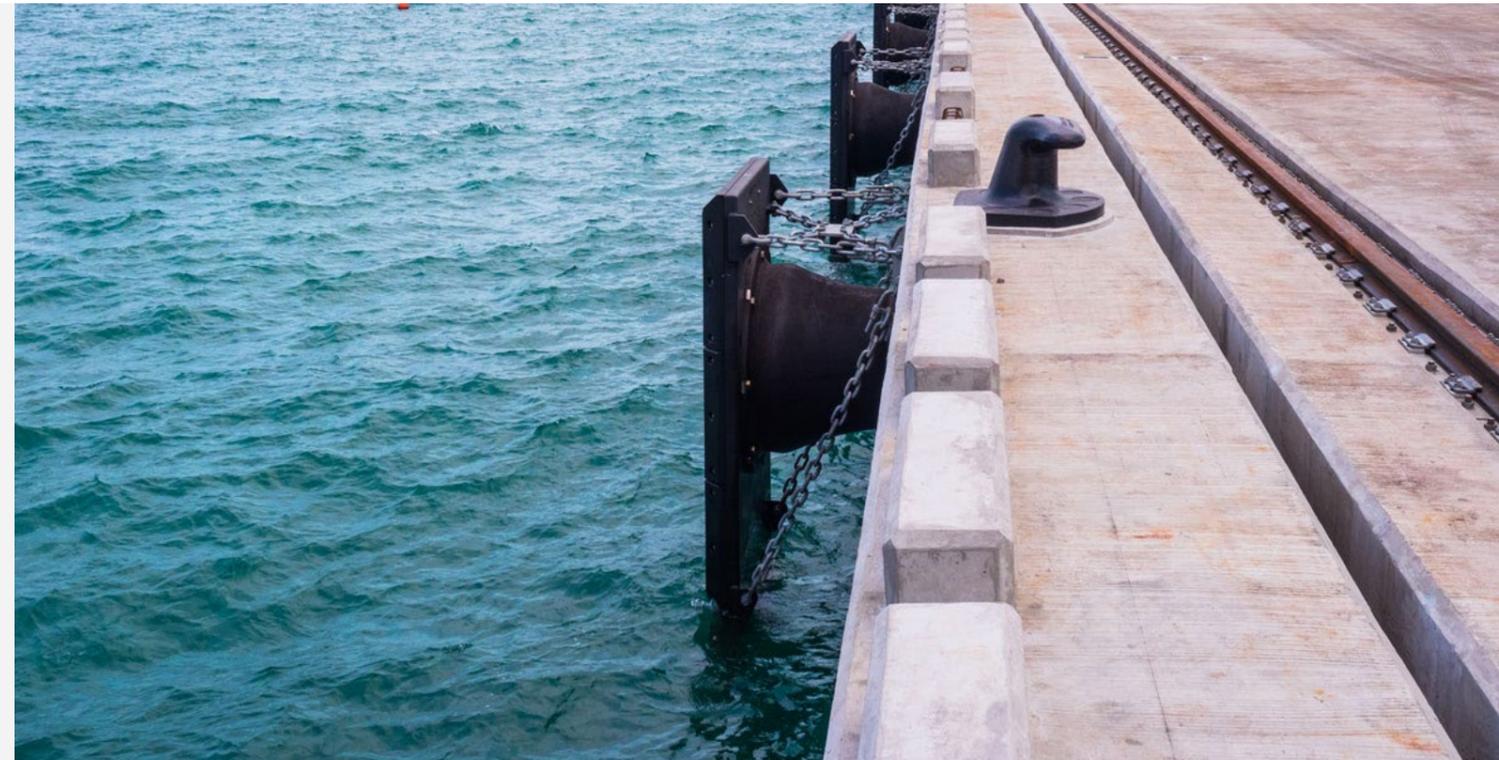
## UNRELIABLE WITNESSES

Common practice in the industry has relied on factory testing with witnessing by either a third party or a consultant. However, there is no easy way for witnesses to verify the results independently of what the manufacturer is reporting. Modern data acquisition methods rely on computers to interpret the data and produce a report. Witnesses do not always have an understanding of how the data acquisition system functions, which means data recorded in the computer is often manipulated without the witness knowing.

Many project specifications require a third party inspection agency to witness the test. The shortcoming here is that witnesses do not provide oversight on how the test data was acquired or if the report they are asked to endorse is even from the test they observed. The inspection agencies are not in any way guaranteeing the validity of the data they are endorsing - essentially rendering their endorsement useless.

## TRUE INDEPENDENT TESTING

The fender industry involves big contracts and vast sums of money and there is too much at stake to allow manufacturers to serve as their own regulators. The marine and fender industry must move towards true independent testing, rather than just witnessed testing, and the simplest way to get objective, trustworthy results is to conduct tests in an independent laboratory.



The long term goal for the industry is for manufacturers to have testing at their own facilities but with independently recorded results by an independently calibrated testing jig. This will remove any uncertainty from the results and enable end users to have confidence that the lifecycle and performance of fenders meet specification, and that fenders are therefore fit for purpose.



**“There is too much at stake to allow manufacturers to serve as their own regulators.”**

## INDEPENDENT TESTING: KEY CONSIDERATIONS

- Have the fenders been tested using an independent rig?
- Is the real-time testing data shown on an external display and are the results printed in real time so the witness has direct access to the data?
- Can the load cell and deflection measuring devices be calibrated on the spot or by an independent external party?
- Can the test data obtained from the rig be compared with the test data reported by the manufacturers using their measuring devices. Can manipulations of data by manufacturers be easily traced?
- Can witnesses consult with well-known third party inspection agencies to certify results?

# Authentication step 5: Industry Wide Best Practice

**To guarantee the performance and durability of a fender over time, there are two crucial factors: the quality of the rubber compound and the manufacturing process. It's essential that proper testing takes place to bridge these gaps and set a consistent standard for fender quality.**

## RUBBER COMPOUND COMPOSITION

The chemical composition of the rubber compound in a fender has a severe impact on the velocity factor, temperature factor, energy absorption capacity, reaction force, lifespan and overall efficiency. Having a complete understanding of the chemical composition needed to ensure a high-quality fender is therefore critical. If poorly designed or made from low-grade materials, the performance and durability of a fender will suffer. Without suitable testing and specifications, however, there is no way to assure the chemical composition of a fender.

Specifying the minimum amount of vital ingredients for a fender, for example a specific percentage of rubber or ash, does not prevent manufacturers from creating new formulations. An infinite number of rubber compounds can be developed, even if the manufacturer adheres to a particular chemical composition with a specified percentage of ingredients. This is often the reason why fenders differ from supplier to supplier, with confusion over varying numbers.

## THERMO-GRAVIMETRIC ANALYSIS

Thermo-Gravimetric Analysis (TGA) testing is an important step in ensuring the quality of materials used in fender manufacturing. During TGA testing, the chemical composition of a rubber compound sample is compared with the final fender product, easily identifying any discrepancies. TGA is a useful test in rubber industry. It assists in:

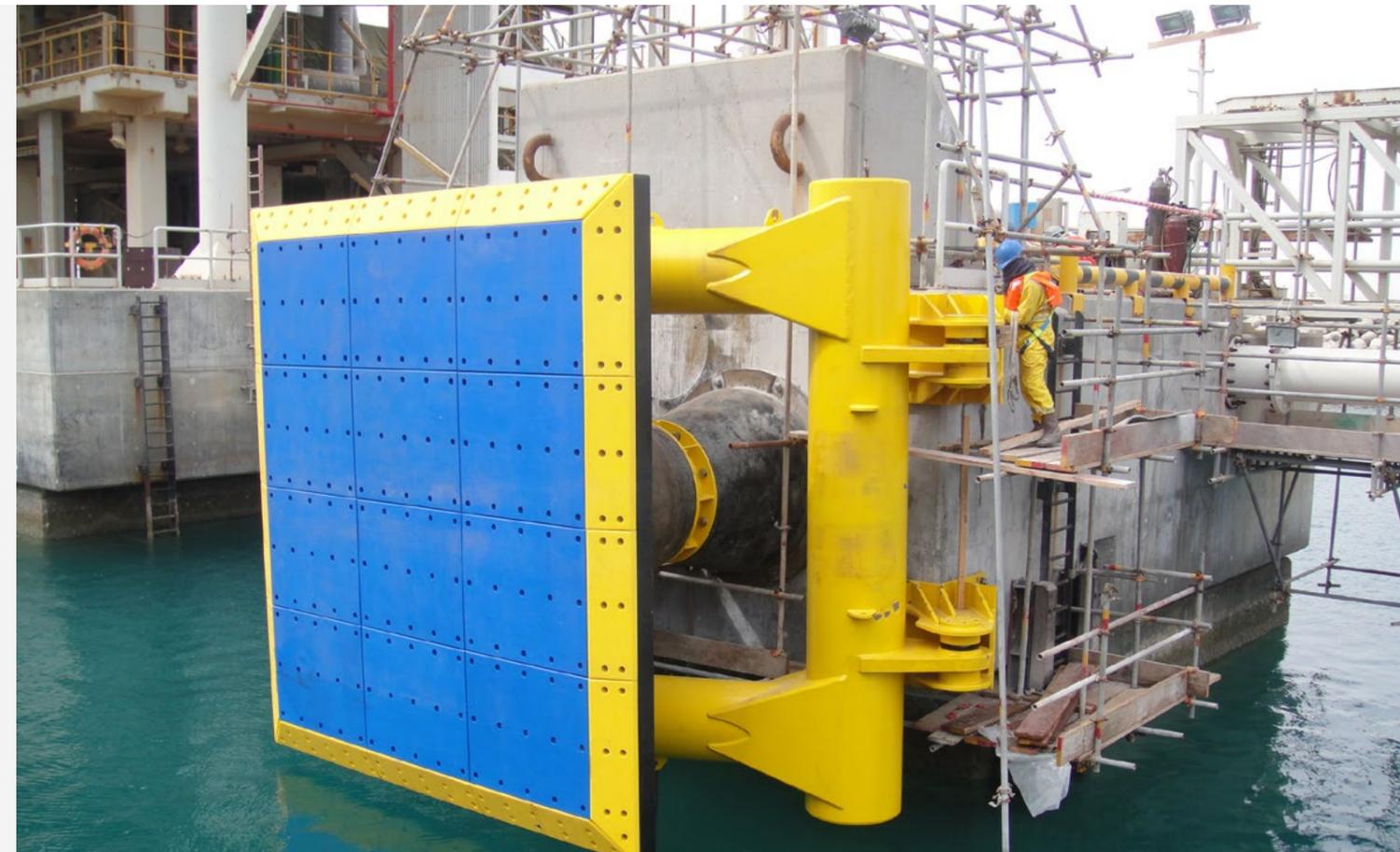
### Determining the chemical composition

The TGA test can be used to ensure undesirable materials are not used in rubber formulations during the fender manufacturing process. This test is valuable to determine the percentage of the vital ingredients in an uncured or cured rubber compound.

### Assures the quality of rubber compounds in samples versus final products

The TGA test, which is increasingly being built into specifications by consultants, acts as a proof point for consultants in helping to establish the consistency of rubber samples taken from the rubber compounds (intended to use for manufacturing a fender) and the commercial fender supplied to project sites.

It also enables consultants to examine and compare the chemical composition of a rubber compound sample (used for manufacturing and testing of physical properties) and model (sample) fenders (used for durability testing), against that of a commercial fender. This means consultants can guarantee the chemical composition of the rubber compound they have specified, tested and supplied



to their clients.

## TYPE APPROVAL TESTING

As our vessels become larger, so does the kinetic energy they exert. Having fenders that can absorb this kinetic energy is crucial to ensuring the safety of operations and preventing damage to the vessels themselves. Many manufacturers provide fenders that are Type Approved, courtesy of different certification bodies across the country. It is not clear to consultants, however, how manufacturers have gained such approval and what data needs to be provided in the process. Often, the reality is that while Type Approval is awarded for single fenders by testing using the protocol identified in the PIANC guidelines, the certification is provided for the complete product line and in some cases, manufacturing facilities.

Unsurprisingly, one small sample is not sufficient to guarantee the performance of the entire fender range and grades. Each and every model, size and grade

of fender in a range should be thoroughly tested – a process which should take between 12-24 months to complete, as suggested by PIANC's guidelines. Likewise, once the performance of a particular grade and size of fender is published, any future adjustment in performance or the compounds within the fender requires another set of type approval testing.

## INDUSTRY-WIDE BEST PRACTICE CONSIDERATIONS

- Has the chemical composition of the fender been tested?
- Are there any discrepancies between the final product and the sample?
- Has the Type Approved test certification been applied to a whole product range or one fender?
- Has the performance data been independently verified?

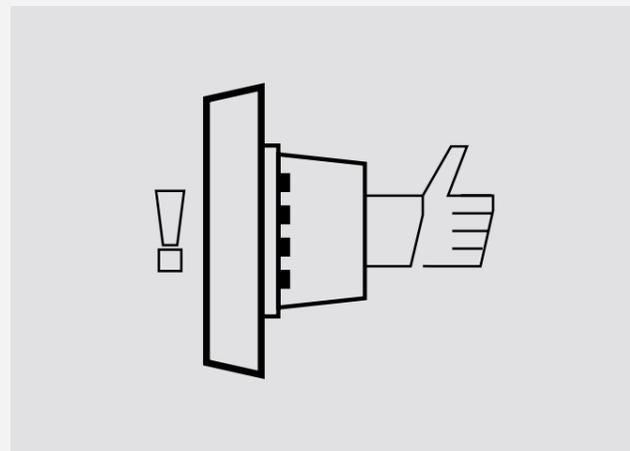
## CHAPTER 6

# Safe and Secure



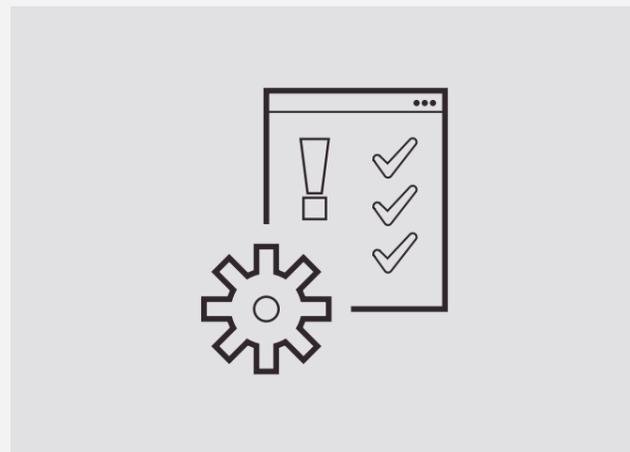
### 1. DON'T JUDGE A BOOK BY ITS COVER

Tables showing the impact of temperature factor and velocity factor can look impressive in a product catalog, but these tables are easily copied and may not necessarily correlate with the specified product and should not be accepted verbatim. It's important to interrogate the information shown and to check that the correction factors and equations really do add up and have been properly applied. This will ensure that the fender being sourced will deliver the expected performance once installed.



### 2. THE RIGHT MIX

With the availability of new raw materials, rubber compounding is changing and this has a significant impact on fender performance and lifecycle. Understanding the role of the type of rubber used – natural or synthetic, virgin or recycled – and within that, the compound composition of the rubber, is essential to avoid procuring underperforming fenders and the subsequent effect on port infrastructure. Care should be taken to note the different types of rubber compound when comparing products from different manufacturers and material testing should include comprehensive chemical and physical analysis.



### Counter-measures to protect your port and fender investments

Procuring and installing an effective, safe fender system that will deliver high quality performance over the long-term represents a sound investment. To achieve this, buyers need to be confident that the fenders they select based on available performance testing data are genuinely the ones that are installed on-site. The stakes are high and therefore greater understanding of authentication procedures is essential.

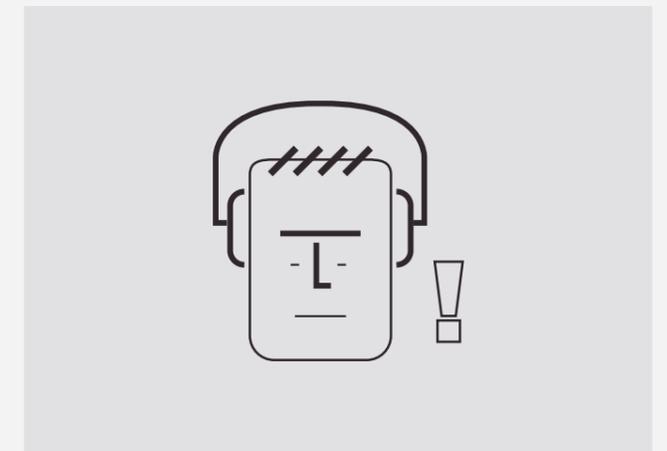
### 3. WHOLE-LIFE MATTERS

There is now a movement away from a culture of procurement that is focused on up-front costs to one that is based on whole-life costs that takes into consideration rubber grade and compound formulation. The longevity of fender performance is a key factor in delivering best value on this mission critical equipment, supporting safe and efficient port operations over the long-term.



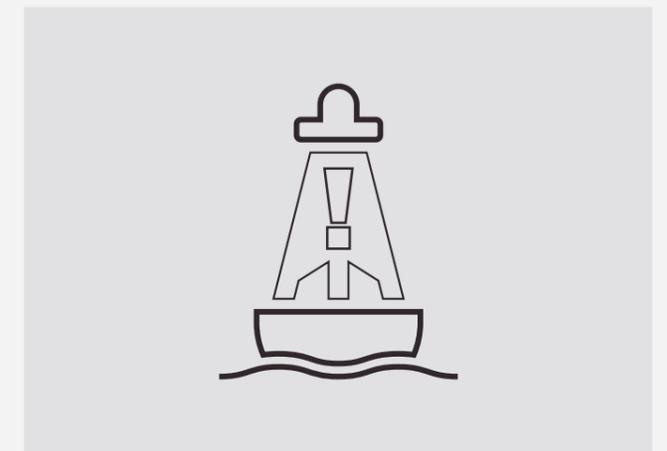
### 4. A CREDIBLE WITNESS

The phrase 'third party witness' is not enough to reassure buyers that the complete fender testing procedure has been validated. It should be understood that third party witnessing does not verify the validity of the testing and the subsequent results could mean the difference between a sound investment and an expensive mistake. Be familiar with the different fender testing available and interrogate any data that is presented. Third party independent testing that is performed away from the manufacturing premises and that independently records the results, rather than simply witnessing the procedure, is recommended.



### 5. A GUIDING HAND

It is important to recognize that PIANC is an industry body whose "Guidelines for the design of fender systems, 2002" represent best practice and should, as a minimum, be adhered to. At the same time, PIANC is not a regulatory body and it does not enforce the guidelines or certify products in any way. Fenders that claim PIANC certification are misrepresenting themselves.





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