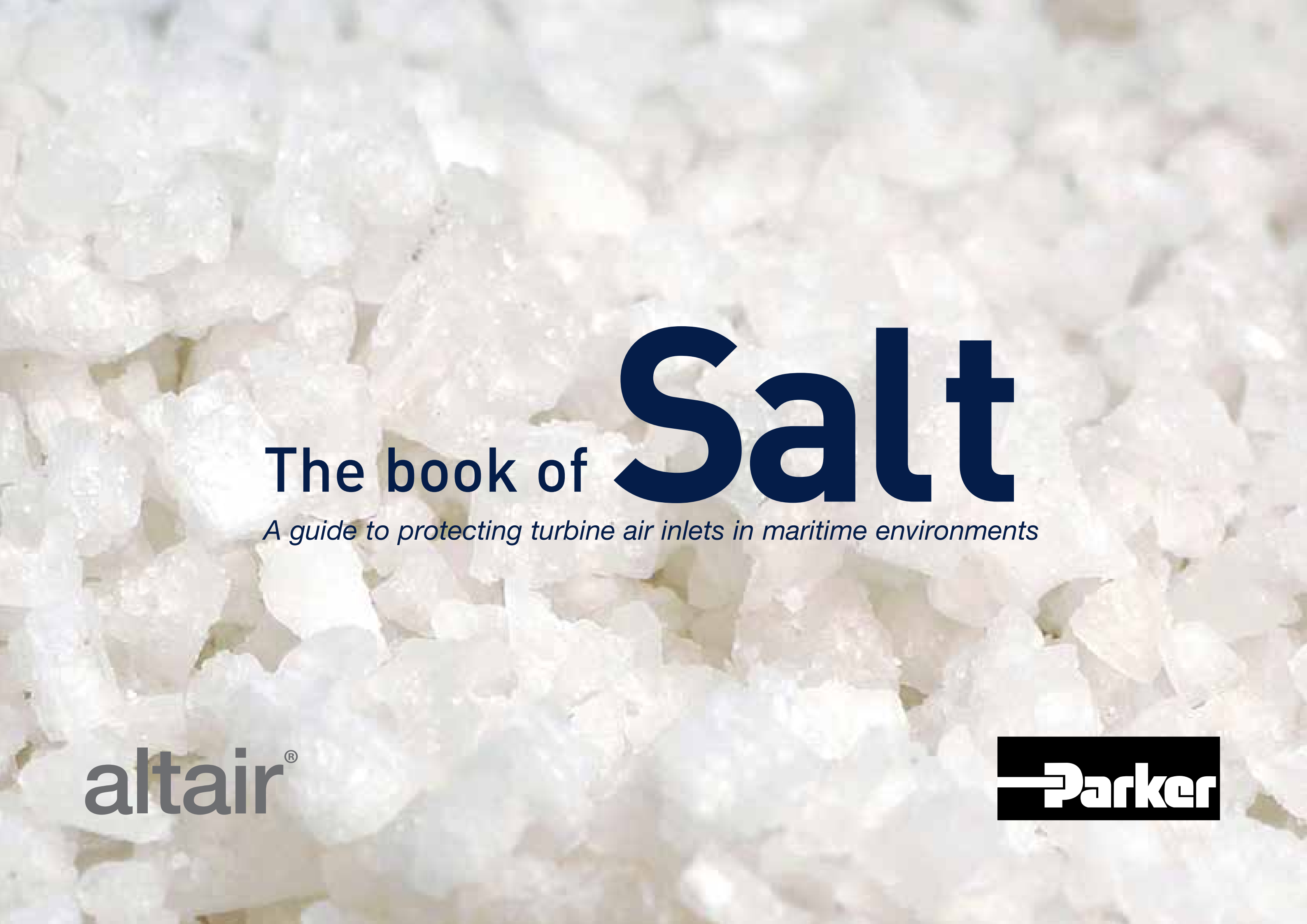


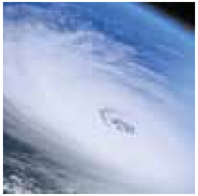
The book of Salt

A guide to protecting turbine air inlets in maritime environments

altair®

Parker

The Marine Environment



The maritime environment can be an unforgiving place when it comes to operating and maintaining complex rotating equipment such as gas turbines. Yet equipment failure can lead to substantial downtime, lost revenues and expensive repair bills.

Whether located on a ship, an offshore platform, FPSO or in a coastal region, turbines are required to operate in some of the most severe weather conditions on the planet. Hurricanes in the Gulf of Mexico, savage storms in the North Sea, and cyclones in the South China Sea are just a few examples of what can be expected.

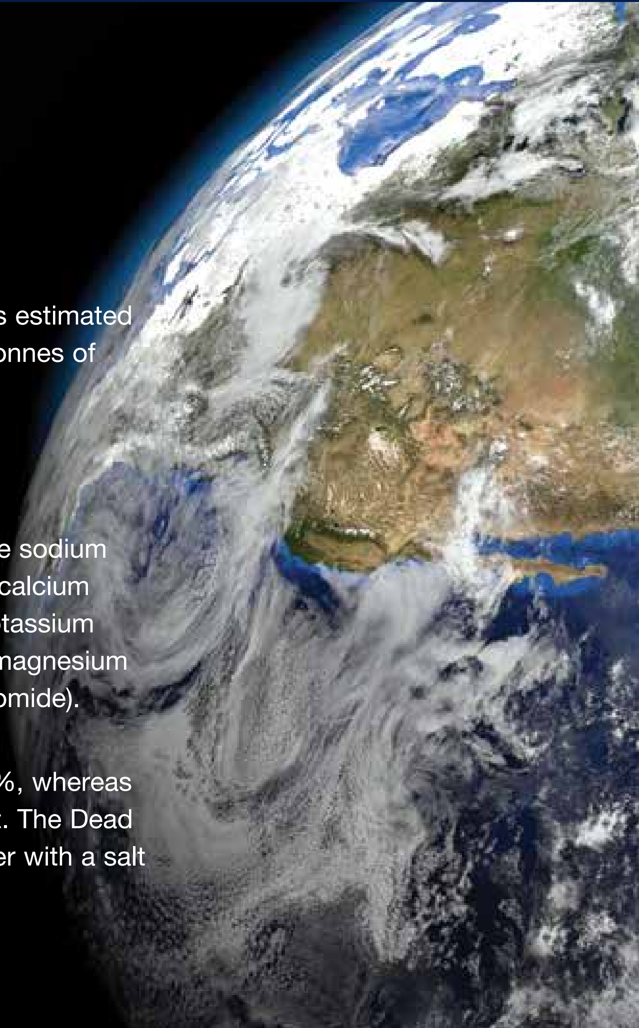
In order to operate in such harsh conditions a turbine must have a superior air inlet protection system. And this system must be of a design proven to cope not only with extreme weather, but also with the maritime atmosphere's other potent weapon - Salt!

Salt & Salinity

97% of all the water on earth is saline, and this is estimated to add up to a total of 50,000,000,000,000,000 tonnes of dissolved salts in the world's oceans, seas and saltwater lakes.

The ocean's principal (~85%) dissolved solids are sodium chloride or common salt. Other constituents are calcium salts (calcium carbonate and calcium sulfate), potassium salts (potassium sulfate), and magnesium salts (magnesium chloride, magnesium sulfate, and magnesium bromide).

The average salinity of the oceans is around 3.5%, whereas fresh water typically contains less than 0.1% salt. The Dead Sea is the world's most saline large body of water with a salt content of over 30%.



Salt Aerosols

The majority of airborne salt aerosols are formed when wave action causes air to become trapped within the sea water. This air then rises to the surface as bubbles. When these bubbles burst, small sea water droplets are expelled into the atmosphere.

The amount and make-up of the aerosols is a function of wind and sea state, i.e. strong winds lead to more droplets of a larger size being ejected into the atmosphere.

During high winds it is also possible for sea spray to become directly entrained in a gust of wind, but generally the aerosol droplets formed during this process are very large and remain airborne for only a matter of seconds.

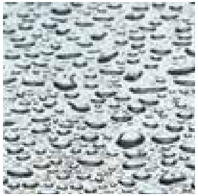
The Marine Boundary Layer

The Marine Boundary Layer (MBL) is the portion of the atmosphere directly above and affected by the sea surface. The MBL extends for many thousands of metres in height, but it is normally the first 50 metres that is of main relevance when considering the impact of salt aerosols.

Extensive studies have been conducted into the salt aerosol concentration in the lower MBL. Although there is wide variation in the absolute figures, almost all studies concur on the fact that concentration is a function of wind speed.

Parker Hannifin has adopted the MMBL Salt Concentration Standard as it provides a conservative, yet realistic figure for the year-round average salt levels in the lower MBL throughout the world.

Wet or Dry



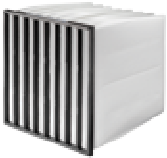
Depending on the ambient relative humidity (RH), sea salt can exist as dry or wetted particles, or as solution droplets. At levels of humidity above 75%, sea salt aerosols are always in liquid form. As the RH falls below 75% and towards 40%, water from the droplets evaporates and they begin to take on a ‘sticky’, semi-solid form. Once below 40% the salt aerosol will essentially consist of solid salt particles.

However, reversing the process sees a different result - that is to say that as the RH increases above 40%, salt particles retain their basic solid characteristics. This remains the case until the humidity reaches around 65%, at which point the particles rapidly deliquesce back to liquid droplets.

During the change of phase from liquid to solid, the salt aerosol will undergo a substantial change in size. For example, a liquid salt droplet at 90% RH will contract to about 25% of its original size as it becomes a solid particle below 40% RH.

The Need for Salt Filtration

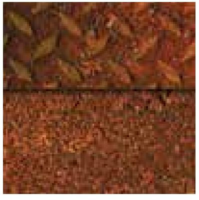
The ingestion of airborne salt has been proven to be a major contributing factor in both decreased turbine performance and reduced engine lifetime. This is easier to understand when considering the amount of inlet air consumed by gas turbines. For example, a 15 MW unit may require 110 lb/s (50 kg/s) of air. If this air contains 0.1 ppm of sea salt aerosol, then after only 2000 hours of operation the turbine will have ingested ~80lb (36 kg) of salt.



Salt aerosols, like any other contaminant, can damage a turbine through the following mechanisms: erosion, cooling-path blockage, fouling and corrosion. But, it is the latter two which are most often associated with salt.

Fouling of the compressor blades can be a particular problem. A poor filtration system can allow salt build-up to affect the compressor's aerodynamic efficiency. Although compressor washing at regular intervals can alleviate this, it also introduces the danger of washing salt into other parts of the turbine.

Hot Corrosion and Sulfidation



Ingested sea salt can cause corrosion problems throughout the turbine, but it is normally hot corrosion associated with post-combustion sections of the turbine that are of most concern. Hot corrosion is a complex process, but can be considered to be the accelerated attack of turbine materials by molten sulfates (primarily sodium sulfate). The process is often known as sulfidation.

Sodium sulfate (Na_2SO_4) is present in sea salt, but most often occurs when sodium chloride and sulfur react during combustion. The sulfur is almost always supplied by the fuel, while the sodium chloride can be the result of contaminated fuel or insufficient inlet air filtration.

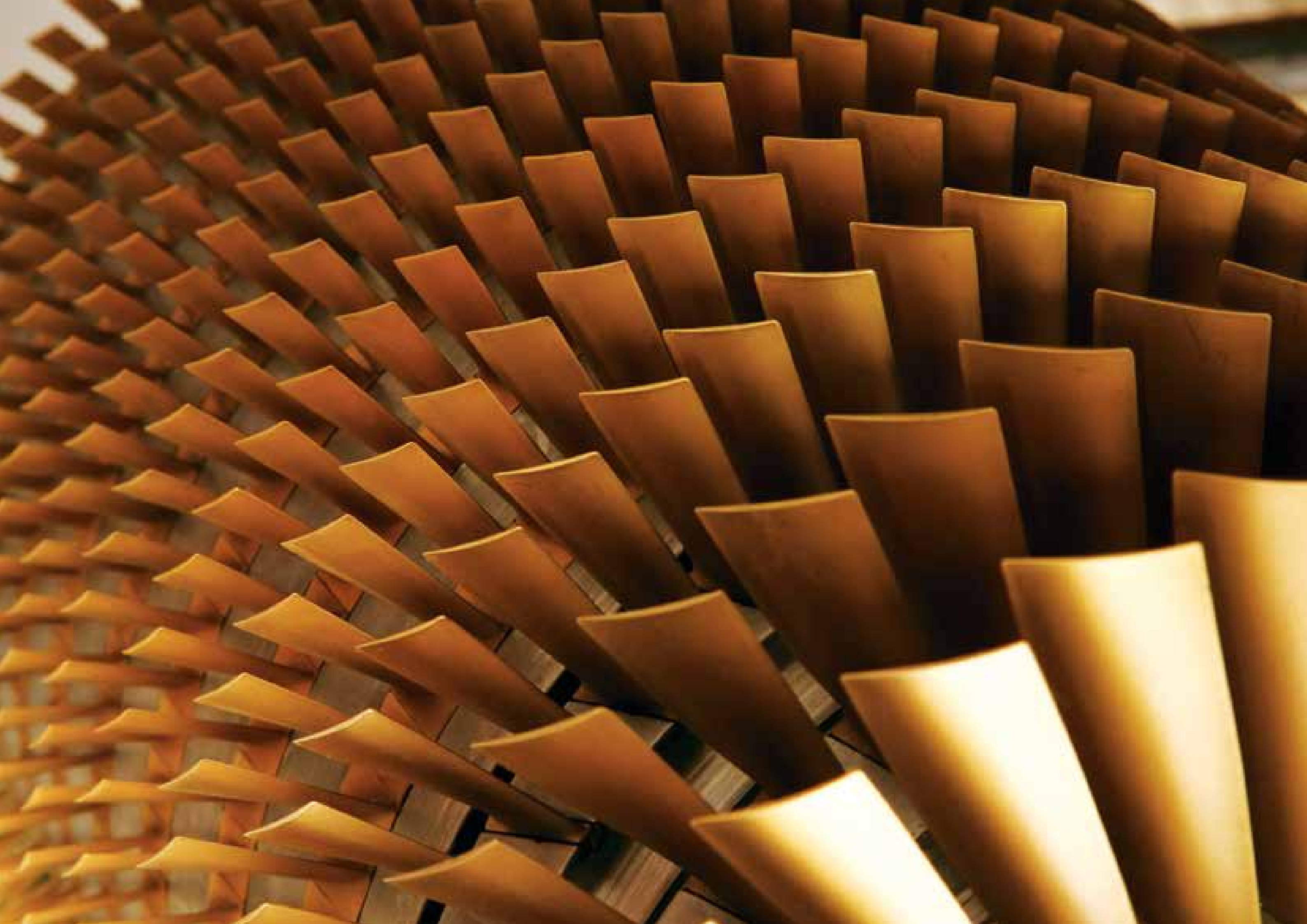
In order for sodium sulfate to attack turbine materials, it must be in a molten state. However, the melting point of Na_2SO_4 shifts downwards when in the presence of sodium chloride. This reduction can be from over 1600°F (~875 °C) to as low as 1110°F (~600 °C), which greatly increases the potential for corrosion.

Approaches to Salt Filtration

Many filtration companies have a poor understanding of the marine environment and the special requirements of gas turbines. Their approach is to try to utilize inlet systems developed for land-based applications, and often ones that have not been optimized to protect turbines.

The use of such systems generally results in turbine problems. This is unsurprising considering that the level of salt in a typical land-based location is less than 0.008 ppm, whereas the offshore equivalent is 0.1 ppm, rising to over 10 ppm during severe storms. Furthermore, many systems fail to be able to deal with salt in both dry and wet forms.

Parker Hannifin has a different philosophy. All Parker Hannifin products are developed specifically with the protection of gas turbines in mind. And all of our offshore, coastal and marine systems utilize SRS Technology.



Input/Output — The Numbers

Clearly it is important to be sure that a filtration system is, or will be, providing adequate protection. Turbine manufacturers often provide a salt inlet limit for their engines, typically as an average (or average and maximum) sodium chloride ppm level.

The onus is then on the providers of filtration systems to demonstrate that their equipment will meet this criteria. But when assessing the performance of a system it is essential to know the details of any testing. For example, if the output of a system is claimed to be 0.001 ppm, what input was the product subjected to? This input must be viewed not only in terms of input concentration, but also aerosol size distribution.

The use of standardized aerosol inputs is one solution to this problem, and Parker Hannifin utilizes the MMBL standard which defines both concentration and a detailed droplet size distribution. This is similar to the NGTE 30 knot aerosol standard. However, while the use of these standards is helpful in comparing alternative systems, nothing can beat an in-depth knowledge of the conditions at the actual system location.

The Parker Hannifin Approach — SRS Technology

Our approach to salt filtration evolved from test work in the early 1970's with propulsion turbines on warships. This provided the understanding that salt aerosols can enter an inlet in both wet and dry states, and when dry aerosols are captured by a filter, a subsequent rise in humidity could result in a phase change.

Having gained an understanding of the environment, we set about producing a filtration solution, and SRS Technology was born. SRS Technology is not a product, but more a technical philosophy that is utilized in all Parker Hannifin maritime GT protection systems.

The SRS Technology concept requires the use of three core stages, but can be augmented with additional stages to suit particular environments. Stage 1 removes coarse salt aerosols, precipitation, and bulk seawater. Stage 2 is a filter/coalescer which captures dry particulates including salt, and also facilitates the coalescence of fine saltwater droplets into larger ones. Stage 3 captures droplets that have been re-entrained into the air from Stage 2.

Parker Hannifin - Experts in Salt Protection

As one of the world's leading suppliers of air inlet filtration systems for offshore and marine gas turbines, Parker Hannifin is at the forefront of engine salt protection technology. For forty years we have been developing and refining our offshore and marine product range to give the optimum protection against all maritime contaminants. In order to do this we have had to work closely with our customers and gain an intimate understanding of their operating environments.

As well as listening carefully to what our customers tell us, Parker Hannifin has also conducted significant levels of research into the marine environment, both independently through our R&D programs and collaboratively with academic institutions. In addition, we have carried out air sampling on platforms and FPSOs throughout the world enabling us to produce an extensive databank of offshore environmental conditions.

Through these efforts Parker Hannifin has been able to develop a range of world-class products, expressly designed to protect turbines operating in offshore, marine and coastal locations. But, we won't rest on our laurels: Parker Hannifin is committed to the ongoing and continuous improvement of all our products. And we continue to work in partnership with our customers to provide the highest levels of protection for turbines operating in the challenging marine environment.

altair®

ALATAIR021 (06/2018)

For more information, contact your **Parker Hannifin Gas Turbine Filtration** representative:

11501 Outlook Street, Suite 100 | Overland Park, KS 66211
T: +1.800.821.2222 | T: +1.816.356.8400 | F: +1.816.353.1873

3 Omega Park | Alton, GU34 2QE | United Kingdom
T: +44 (0) 1420 541188 | F: 44 (0) 1420 541298
Email: altairclearcurrent@parker.com

www.parker.com/gtf

Parker

ENGINEERING YOUR SUCCESS.