

# ADVANCED AIR QUALITY SYSTEMS

In 2013, we announced our plans to install advanced air quality systems (AAQS), generically known as exhaust gas cleaning systems (EGCS) or scrubbers, on our ships. These systems remove sulfur compounds and particulate matter from our ships' engine exhaust at any operating state of a ship – at sea, during maneuvering and in port. Due to the initial limited availability of ship-ready AAQS for marine applications, Carnival Corporation led the way in developing the technology to successfully function in the restricted spaces available on cruise ships. Making the necessary investments, -- totaling approximately \$500 million of installations to date -- has led to a significant development in shipboard environmental technology.

As of FY2018, 74% of our fleet is equipped with AAQS and we plan to develop and deploy the systems on more than 85 ships across our global fleet by 2020 – significantly improving the quality of air emissions from our ships and reinforcing our environmental commitment.

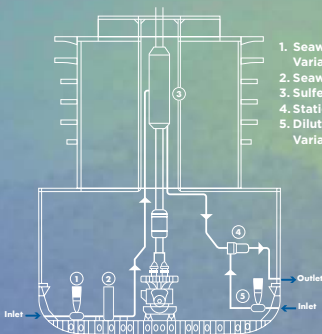
Through extensive independent testing, the systems have proven capable of outperforming low-sulfur fuel alternatives such as marine gas oil (MGO) in terms of overall cleaner air emissions and no negative environmental impact to oceans and seas, all as originally intended by the International Maritime Organization (IMO). Ships using AAQS to scrub heavy fuel oil (HFO) are also effective in reducing particulate matter and typically have lower sulfur oxide (SO<sub>2</sub>) emission levels than MGO, as well as lower NO<sub>x</sub> and fewer polycyclic aromatic hydrocarbons (PAHs).

## OPEN LOOP SYSTEM

Carnival Corporation's AAQS are open loop systems that use a sea water spray for removing sulfur from engine exhaust, converting it to sulfates (which are abundant in the sea) before returning the seawater to the ocean. The seawater is monitored by pH, PAH and Turbidity sensors through this process to ensure that it meets or exceeds the IMO required standards before returning to the ocean. A further filtration process while in port ensures a seawater quality meeting other applicable environmental standards for operations.

## CARNIVAL'S OPEN LOOP ADVANCED AIR QUALITY SYSTEM

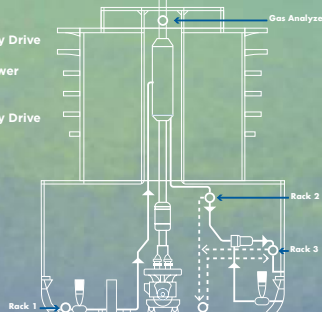
### MAIN SYSTEM COMPONENTS



1. Seawater Pump & Variable Frequency Drive
2. Seawater Filter
3. Sulfur Removal Tower
4. Static Mixer
5. Dilution Pump & Variable Frequency Drive

### COMPLIANCE MONITORING EQUIPMENT

Compliance Monitoring Equipment is used to monitor the Compliance Parameters for Exhaust and EGCS wash water.



**Gas Analyzer** - measures the SO<sub>2</sub> and CO<sub>2</sub> content of the exhaust gases which allows the SO<sub>2</sub>/CO<sub>2</sub> ratio to be calculated.

**Sea Suction Rack (Rack 1)** - measures the PAH and Turbidity of the inlet wash water at the sea suction. Although not required for compliance, on some systems pH is also measured.

**DeSOx Outlet Rack (Rack 2)** - measures the PAH and Turbidity of the wash water at the outlet of the DeSOx Tower.

**Overboard Discharge Rack (Rack 3)** - measures the pH of the wash water at the overboard discharge.



## USING ADVANCED AIR QUALITY SYSTEMS

Removes **99%** of Sulfur

Removes **> 50%** of Particulate Matter

Reduces **10%** of Nitrogen Oxides

## INDEPENDENT TWO-YEAR SCIENTIFIC WASH WATER STUDY

In March 2019 we released the Carnival/DNVGL 2018 Wash Water Assessment a four-year scientific wash water study that collected 281 wash water samples from 53 Carnival ships, conducted lab analyses on each sample for 54 different parameters including PAHs and metals, and partnered with DNVGL to evaluate and compare the results to major national and international water quality standards. To provide further understanding and perspective on the quality of the discharged wash water, the study demonstrated that the AAQS wash water samples were well below the limits set by several major national and international land-based water quality standards up to and including the World Health Organization (WHO) standards for drinking water.

Specific to IMO wash water requirements, the study confirmed results from previous studies showing the quality of the water used in the AAQS process was always far below the IMO monitoring limits for PAHs and the annual limits for nitrates. In fact, when measured against IMO standards, the average wash water test results in this study were over 90 percent lower than maximum allowable levels. In many cases, the materials were completely undetectable in the laboratory testing process.

Other standards the results were compared against include, German Waste Water Ordinance, which as a "point source discharge" standard was the most directly applicable, and also the EU Industrial Emissions Standards and the Surface Water Standards of the EU's Water Framework Directive, both "water quality" standards. The AAQS test results compared favorably with all of these major benchmark standards, demonstrating that the composition of the water was not only consistently below, but in most cases, significantly below the most stringent limits. The full study briefing can be found at: [http://media.corporate-ir.net/media\\_files/IROL/14/140690/Carnival-DNVGL\\_Washwater\\_Analysis\\_2018.pdf](http://media.corporate-ir.net/media_files/IROL/14/140690/Carnival-DNVGL_Washwater_Analysis_2018.pdf)

## EMISSIONS PROFILE

To further enhance our emissions profile, we have also started to install a catalytic reactor on the engine exhaust to reduce particulate matter (PM) even before the exhaust reaches the AAQS tower, which also is effective in reducing PM. Our standard AAQS removes 99% of sulfur (in the form of SO<sub>2</sub>) and up to 75% of the particulate matter, including elemental and organic and black carbon, as well as PAHs. The combined effect of the AAQS, catalytic reactor and other systems is a further reduction of the particulate matter, including the very fine PM 10 and 2.5 particles. The use of AAQS with HFO fuel and other systems creates a reduction of between 5-15% compared to MGO fuel use.

All AAQS comply with international regulations and are certified by a classification society. In addition, all systems are equipped with continuous monitoring equipment to automatically record required parameters – specifically SO<sub>2</sub> in the exhaust gas and pH, PAH and Turbidity in the wash water.

In 2018, Carnival Corporation was a founding member of Clean Shipping Alliance 2020, a new industry association consisting of 39 leading shipping and maritime companies, and providing education and information on the benefits of AAQS, as well as a public voice. Collectively, these companies represent over 3,000 ships across the sectors of commercial shipping and cruising.

# PIONEERING LIQUEFIED NATURAL GAS (LNG)

Reflecting on our commitment to sustainability, we are continuing to pioneer the use of liquefied natural gas (LNG), the world's cleanest fossil fuel, and are expanding our LNG investment.

We began the implementation of our LNG vision by using LNG in port. In 2015, *AIDAsof* was the first cruise ship in the world to be supplied with power by an LNG Hybrid barge while in Hamburg, Germany. The LNG Hybrid Barge, a unique pilot project with Becker Marine Systems, was designed, constructed and commissioned in three years. Since then, we have expanded our LNG capabilities to supply LNG directly to two ships, each with a dual-fuel powered engine (*AIDAprima* and *AIDAperla*). These ships use LNG while in port drawing fuel directly from trucks alongside the ship.

In 2018, we made history with the launch of *AIDAnova*, the first cruise ship in the world powered by LNG both at sea and in port. Leading the cruise industry's use of LNG to power cruise ships, we have a further 10 sister vessels due for delivery between 2019 and 2025 for Costa Cruises, AIDA Cruises, P&O Cruises UK, Carnival Cruise Line and Princess Cruises.

## FIRST CRUISE SHIP POWERED BY LNG AT SEA AND IN PORT

We began construction on *AIDAnova* in 2016 and the history-making ship joined the fleet in late 2018. The largest cruise ship ever built at a German shipyard, *AIDAnova* also marks an exciting new generation of "green" cruise ships that will be powered at sea and in port by LNG. In December 2018, *AIDAnova* made its maiden call in the Canary Islands at the Santa Cruz de Tenerife Terminal, a concession operated by Carnival Corporation that can accommodate next-generation "green" cruise ships powered by LNG. The first LNG supply for *AIDAnova* at the port took place upon its arrival and was made possible through our partnership with Shell.

## SWITCHING FROM MARINE DIESEL TO LNG

0 Sulfur Dioxide Emissions

95-100% Reduction in Particulate Matter

85% Reduction in Nitrogen Oxides

Up to 20% Reduction in Carbon Emissions



## STRENGTHENING OUR LNG SUPPLY CHAIN

In 2017, we expanded our partnership with Shell to fuel North America's first next-generation LNG-powered cruise ships - the first of which, the *Mardi Gras*, will arrive in October 2020. As part of the agreement, the two ships, built with a next-generation "green cruising" ship design, will be fueled through Shell's Partner Quality LNG transport (Q-LNG) Bunker Barge (LBB) - a project that is part of Shell's strategic plan to develop a global LNG bunkering network. The ocean-going LBB, which is designed to support growing cruise line demand for LNG as a marine fuel, will be the first of its kind in the U.S. and will allow these ships to refuel with LNG at ports along the southern U.S. East Coast.

We are proud to be on the forefront of advancing LNG as a fuel source for the cruise industry. One of the keys to establishing LNG as a standard for powering cruise ships is building out an extensive, safe and reliable infrastructure across the globe for this clean burning fossil fuel. We are looking forward to working closely with Shell as they help to bring LNG to North America in what we hope will be the first step in building a strong foundation for the future of LNG fuel supply for cruise ships in the region.

## EXPANDING OUR LNG SHIP ORDERS TO 2025

Looking to 2019, we have 10 next-generation cruise ships on order that will be the first in the industry to be powered by LNG at sea and in port. We began construction on *Costa Smeralda* in 2017. The new Costa Cruises ship will be the brand's first ship powered by LNG and is expected to join the fleet in late 2019. *Costa Smeralda* will be the world's first LNG-powered ship to be broadly marketed to consumers from multiple countries, including Italy, France, Spain, Germany and Switzerland. A second Costa LNG ship is scheduled for delivery in 2021. P&O Cruises UK will launch *Iona* in 2020 as the brand's first LNG ship. *Iona* will also debut as the largest cruise ship ever built for the British market. P&O's second LNG ship is scheduled for delivery in 2022. Carnival Cruise Line's *Mardi Gras* will debut in 2020 as the first cruise ship in North America powered by LNG and will be the largest Carnival Cruise Line ship ever constructed. The brand's second LNG ship is scheduled for delivery in 2022. Our Princess Cruises brand also has two LNG ships on order with expected delivery dates in 2023 and 2025. In addition to the new *AIDAnova*, our AIDA Cruises brand has two additional LNG ships on order due in 2021 and 2023.

## LNG PROGRAM TIMELINE

