

CARNIVAL CORPORATION BACKGROUNDER

Advanced Air Quality Systems | May 2019

Carnival Corporation is a maritime industry leader recognized for developing innovative solutions that support sustainable operations and a healthy environment. Underscoring its commitment to operating responsibly, Carnival Corporation ensures sustainability is ingrained in every aspect of its business, as the company's very existence is dependent on protecting and maintaining healthy oceans, local waters and the communities in which it operates.

As part of this focus on sustainable operations, Carnival Corporation has installed Advanced Air Quality Systems – commonly referred to as exhaust gas cleaning systems (EGCS) or “scrubbers” – on more than 70 ships in its fleet, enabling clean air emissions that in many ways exceed low-sulfur fuel. In addition to improving the quality of air emissions, several recent studies have provided scientific evidence that Advanced Air Quality Systems have no negative impact on the marine environment.

The following summary provides facts and additional background on Advanced Air Quality Systems as a safe and effective solution for compliance with International Maritime Organization (IMO) 2020 requirements, including comparisons to alternative compliance methods, such as low-sulfur fuel and other types of scrubber systems (open-loop, closed-loop and hybrid), and information on how these systems operate in a marine setting to meet or exceed environmental regulations for air and water quality.

KEY UPFRONT HIGHLIGHTS:

- Open-loop AAQS that use heavy fuel oil (HFO) produce an equivalent or better environmental outcome than burning marine gas oil (MGO), with almost all sulfur (SO₂) removed from air emissions.
- With AAQS, the sulfur is removed from the exhaust and entrained in the wash water and returned to the ocean – the world's natural reservoir of sulfur.
- AAQS operation results in less SO₂, less nitrous oxide (NO_x), fewer PAHs and the same or less particulate matter (PM), especially small particulates, as compared to MGO.
- AAQS wash water meets major national and international water quality standards and even the World Health Organization (WHO) drinking water standards.

This evidence is supported by multiple studies including a June 2018 report by Japan's Ministry of Land, Infrastructure, Transport and Tourism and a two-year study of 281 wash-water samples from 53 Carnival Corporation ships equipped with Advance Air Quality Systems, which were then analyzed for 54 parameters by independent laboratories accredited by the International Organization for Standardization (ISO), using standardized U.S. Environmental Protection Agency methods. Following the lab phase, DNV GL, a leading classification society and recognized advisor for the maritime industry, reviewed the laboratory test data, comparing the results to major point source discharge limits and water quality standards.¹

Important Facts:

- Marine transport delivers about **90 percent** of all global trade.
 - There are over **50,000** ships of 1,000 gross tons or more sailing on the ocean.
 - **80 percent** of all ships in operation are cargo ships, mostly containers and bulkers.
 - By the end of 2019, about **2,600** will be installed with scrubbers, or **five percent**.
 - Behind cargo, oil tankers, military and transport ships, cruise ships make up a very small portion of this volume with **280** ships, equating to about **one half of one percent** of the total ships on the ocean over 1,000 gross tons.
- Carnival Corporation has a long-standing deep commitment to sustainability and the environment, as healthy oceans and communities are essential to annually providing great vacations to millions of guests.

¹ Carnival Corporation's AAQS study results and details are available [HERE](#).

- Healthy oceans are vital to Carnival Corporation's business.
- Healthy destination communities that guests want to visit are also vital to the corporation's business.
- Carnival Corporation has a carbon footprint, just like the airline industry, the automobile industry and any individual, household or community. The company has taken tangible steps through its annual sustainability plan to minimize its footprint and continuously pursue innovative ways to reduce its overall carbon footprint.
- There is greenhouse gas emission from both the production of fossil fuels and the burning of fossil fuels, so both aspects of this process must be considered in the selection and use of fuel power, and the overall consideration of a carbon footprint.
- MGO is the lowest sulfur fuel on the marine market in consideration.
 - The production of MGO fuel requires more refining than other fuel options. Typically, about **seven percent** more energy is invested in the production of MGO than in the production of HFO.
 - However, the air emissions of burning MGO have equivalent and in some cases higher particulate matter and slightly higher NOx than emissions from an AAQS-equipped ship.
 - Carnival Corporation, along with many companies in the shipping industry, has made significant investments in Advanced Air Quality Systems, which are accepted by IMO as equivalent to MGO, based on the ability to improve air emissions without impacting the ocean environment.
- HFO is a residual by-product of the crude oil refining process and does not require further refining, which avoids the energy penalty related to the refining process of MGO.
 - HFO is used with open-loop, closed-loop and hybrid systems today.
- Sulfur is one of the most naturally occurring components of seawater.
 - It is the third most common compound in the ocean in the form of sulfates, the same form in which it is returned to the sea.
 - It is assimilated by sea organisms and key to certain metabolic processes and found in most proteins in the form of amino acids.
 - If all the sulfur in the ocean was collected together, it would amount to five feet in depth across the entire ocean. In comparison, all the sulfur in the world from all the oil and gas reserves would equal the thickness of a sheet of paper.
 - The most environmentally harmful place for sulfur and particulates is in the air where they can contribute to the formation of acid rain and adversely affect human health.

Advanced Air Quality Systems:

- Carnival Corporation has engaged extensive technical and scientific expertise in the development of what it believes is the current best all-around solution—the use of open-loop AAQS with HFO—to meet the increased environmental protection regulations and dramatically reduce the human risk factors.
- This solution helps manage the commercial business risk facing the larger maritime industry in light of global regulations, such as higher MGO costs likely to rise further based on much higher demand. However, the company's leadership team has made it clear from the beginning that the investment and implementation of this solution depends on extensive ongoing testing proving it meets all existing regulations while significantly improving air quality with no adverse environmental impact.
- Open- and closed-loop Advanced Air Quality Systems have been adapted from land-based technology that has been in widely accepted use for decades.
- Carnival Corporation has been working since 2006 to develop these systems—first introduced on one ship in 2006, and tested and iterated extensively to evaluate suitability and effectiveness.

- Carnival Corporation invested six years into research, testing and continued learning before installing AAQS on the second ship in the fleet in 2012, which became the corporate standard.
- The corporation first received support of the U.S. Environmental Protection Agency (EPA), the U.S. Coast Guard and Transport Canada in September 2013 to implement AAQS on 32 ships, becoming the first to use the systems in restricted spaces on existing ships.
- The company has installed over **200** AAQS on more than **70** ships in its global fleet.
- To date, Carnival Corporation has invested over \$500 million in the development, testing, manufacturing and deployment of AAQS.
- By 2020, the company expects **85 percent** of its global fleet to be installed with AAQS.
- Carnival Corporation has engaged various scientific, non-governmental organizations (NGOs) and regulatory bodies to explore AAQS use as partners to verify and validate the capability for these systems to perform within regulation and reliably at scale.
- Monitoring and testing of these systems is continuous, which is important to ensure the health and safety of the systems. Flag states certify the systems while port states audit the systems.
- AAQS are a key component of Carnival Corporation's 2020 sustainability goals, in addition to its industry-leading adoption of liquefied natural gas (LNG), the world's cleanest burning fossil fuel, and cold ironing capabilities, as well as initiatives to optimize onboard energy usage and reduce fuel consumption.
 - The company has announced plans to introduce 11 LNG-powered cruise ships in coming years, including the world's first ship of this kind, AIDAnova, launched in December 2018.
 - In addition, over 40 percent of the company's fleet has "cold ironing" capabilities, enabling ships to use shoreside electric power where available while in port.

Advantages of AAQS:

- The systems utilize HFO, which is less expensive, readily available and produces less NOx and PM than MGO.
- AAQS reduces the amount of potentially acid-rain-inducing sulfur into the atmosphere, and instead returns the sulfur (via the wash water) into the ocean where it naturally occurs and resides.
- This process bypasses the dangerous air phase of the sulfur cycle, avoiding the risks to human health and harmful acid rain.
- Studies have shown that engine exhaust when using open-loop AAQS and HFO contain proportionally **less PAH** (polycyclic aromatic hydrocarbons) compared to MGO emissions, which are hazardous to human health.
- On average, AAQS capture about **75 percent** of total particulate matter (PM) in air emissions, and the systems have the ability to reduce PM by as much as **90 percent**.

Water Fuel Emulsion (WFE):

- Most of the company's more than 70 certified AAQS ships have water in fuel emulsion (WFE) systems installed, which enables more complete fuel-burning and a cooler burning engine. This more complete burn results in less particulate matter, and the lower combustion temperatures produce less NOx (e.g., 10% water = 10% NOx reduction).
 - WFE reduces total PM by **30 to 50 percent** and NOx by **10 percent**.

Open-Loop Systems:

- Meet all IMO criteria as a safe and effective solution for compliance with 2020 regulations.
- Do not require the onboard storage of the wash water emissions, as the wash water is returned to the ocean with nearly the same characteristics of surrounding ambient water.
 - The wash water returned to the ocean **meets and often exceeds the parameters and criteria of major national and international water standards** – including the WHO drinking water standards (noted in the 2018 Carnival Corporation-DNV GL wash-water study).

- Carnival Corporation is installing additional wash water filtration on its ships for use in ports. These filters capture much of the exhaust particulate that would have entered the atmosphere without AAQS. The residue in the filter is properly disposed in port.
- These systems do not require the addition of caustic substances, making them a simpler solution that does not increase human risk in terms of staff-handling and administration.
- These systems do not depend on land-based disposal equipment nor do they discharge any concentrated sludge to the sea.
- The two-year study released on February 19, 2019, by Japan's MLIT is a comprehensive look at the impact of years of intensive open-loop AAQS operations with wash water discharge in three Japanese coastal locations. It further confirms that there is no environmental impact of open-loop AAQS on the marine environment.
 - Note: the findings are consistent with the Carnival Corporation-DNV GL study results detailed below.

Carnival Corp. & DNV GL AAQS Wash Water Study:

- In March 2019, Carnival Corporation released the results of an independent, two-year scientific study analyzing wash water from AAQS.
- The study included **281** wash water samples from **53** Carnival Corporation ships with AAQS – creating the **marine industry's largest wash water data set**.
- Samples were analyzed for **54** parameters by using standardized EPA methods.
- Following the lab phase, DNV GL reviewed the test data, comparing results to major point source discharge limits and water quality standards.
- Results show the company's AAQS are far below the IMO's wash water monitoring limits for PAHs and the annual limits for nitrates.
 - Average wash water results were over **90 percent** lower than maximum allowable IMO levels – and in many cases, materials were completely undetectable in the testing.
- AAQS test results also met all major national and international water quality standards and the WHO's drinking water standards.
- The results are consistent with major published research on the subject, including the 2014 Swedish study by researchers Kent Salo and Erik Fridell that concluded scrubbers on ships using HFO can lower PM to a level below that of MGO.

Closed-Loop Systems or Hybrid Systems:

- These systems have about the same air-emissions profile as the open-loop AAQS.
- Emissions often exhibit a "white plume" above the stack.
- These systems require the storage of the wash water byproduct of the scrubbed fuel process.
 - Recycled wash water is slowly bled off into an onboard storage tank from where it is dewatered down to sludge and the water filtered and later discharged.
- The circulating wash water requires a basic chemical – normally caustic soda – to alter the pH of the liquids and neutralize the acidity.
- The caustic soda and materials are toxic and require safe, careful handling procedures and storage to avoid crew risk.
- Typically, the remaining sludge must be disposed in specified on-land facilities, where available, or, most commonly, are discharged at sea.
- Closed-loop operators report that **80 to 90 percent** of their AAQS operations are open loop; they typically only use closed-loop mode in port.
- The ability to operate an AAQS in closed-loop mode is not restricted in any ports, but the new Norwegian World Heritage Fjord rules will only allow their use if no visible plume is present, which currently is a difficult condition to meet.
- As lower closed-loop exhaust temperatures can cause exhaust gases to fall instead of rise from the exhaust stack, some ports and closed-loop operators report that stevedores, port visitors and environmental experts have objected to visible plumes and exhaust fumes descending onto land surrounding ports.

MGO fuel (without AAQS):

- This is the lowest-sulfur fuel and does not require or use an AAQS.
- Studies have shown a higher proportion of fine PM in the air emissions from MGO burn compared to ships using AAQS and operating on HFO.
- There is equal or greater atmospheric risk with the resulting burn of MGO.
- This fuel is significantly higher cost than HFO. **There is no trouble obtaining MGO today but there may be challenges in obtaining MGO in near term and possibly longer term after the 2020 global IMO regulation begins.**
- About **90 percent** of all global trade is carried by over **50,000** ships of 1,000 gross tons or more sailing on the ocean today – and only about **five percent** of these ocean vessels will have scrubbers by early 2020 – so fuel costs for almost all of these ships may **DOUBLE** next year as a result of switching from HFO to MGO for IMO 2020 compliance.
 - Rising fuel costs may have an effect on global shipping rates, cost of goods and could potentially impact retail prices for consumers.
 - Beyond higher prices, effects on global economy could include slowdowns in global trade and impacts to the global job market.

Clean Shipping Alliance 2020 (CSA 2020):

- Currently, the CSA 2020 membership includes **39** ship owners and operating companies, including Carnival Corporation, representing about 3,000 ships (not all with AAQS) that have come together to form an alliance and a collective industry voice supporting:
 - the January 2020 implementation of the Global ECA.
 - continued IMO-approved use of AAQS.
 - scientific studies demonstrating the environmental advantages of open-loop AAQS.
 - Engagement and education with media, ports, ship-owner associations, and local, national and international authorities.

Source: Carnival Corporation Corporate Communications