



“Cruise ships design and construction”

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ΕΠΙΒΛΕΠΩΝ ΚΑΘΗΓΗΤΗΣ: ΠΑΝΑΓΟΠΟΥΛΟΥ ΜΑΡΙΑ

ΘΕΜΑ:

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ΤΟΥ ΣΠΟΥΔΑΣΤΗ: ΚΟΡΤΕΣΙΔΗ ΦΩΤΙΟΥ

Α.Γ.Μ: 3244

Ημερομηνία ανάληψης της εργασίας: 22/04/2013

Ημερομηνία παράδοσης της εργασίας: /10/2017

A/A	Όνοματεπώνυμο	Ειδικότης	Αξιολόγηση	Υπογραφή
1				
2				
3				
ΤΕΛΙΚΗ ΑΞΙΟΛΟΓΗΣΗ				

Ο ΔΙΕΥΘΥΝΤΗΣ ΣΧΟΛΗΣ : ΤΣΟΥΛΗΣ ΝΙΚΟΛΑΟΣ

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Abstract

This work deals with cruise ships and, especially, with their design and construction. In the first chapter, we will discuss about cruise ships in general, their history and origins, operators, organization (dining, crew, business model, ship naming etc.), regional industries.

The next chapter is dedicated to cruise ship designing. We will get informed about the interior design of the ships, the New Russia cruise ships designs and the revolutionary new expedition cruise ships designs.

In the end, we will focus on the cruise ships construction. We will discuss about the cruise ships engine, the engine room, conventional diesel cruise ships engine, diesel electric engine, emergency generators, categories of propulsions and cruise ship power.

CHAPTER 1: Introduction

A cruise ship is a passenger ship used for recreational and leisure voyages, in which the journey itself and the onboard amenities, attractions, activities and entertainment options are integral part of the cruise experience.

The rapid growth and specialization process experienced by the cruise industry in the last decades has also affected the design and general aesthetics, materials, size and overall onboard functionalities, equipment and amenities of modern cruise ships and recreational vessels to satisfy a clientele more and more numerous and sensitive to quality, who demands the most diversified services with assurance of satisfaction and excellence, while providing solutions to the growing concerns about the cruise industry's environmental impact on marine and coastal communities and ecosystems.

Nowadays, every continent and region on Earth can be visited onboard a cruise or recreational ship, including the most exotic, faraway places and secluded destinations.

In the same way, and along the last years, a good number of vessels managed by companies and organizations unrelated to the cruise industry have been redesigned or adapted to offer cruise services to passengers looking for unconventional experiences.

CHAPTER 2: CRUISE SHIPS

2.1 Definition

A cruise ship or cruise liner is a passenger ship used for pleasure voyages, where the voyage itself and the ship's amenities are a part of the experience, as well as the different destinations along the way, i.e., ports of call. Transportation is not the only purpose of cruising, particularly on cruises that return passengers to their originating port (also known as a *closed-loop cruise*), with the ports of call usually in a specified region of a continent. There are even "cruises to nowhere" or "nowhere voyages" where the ship makes 2–3 night round trips without any ports of call.

By contrast, dedicated transport oriented ocean liners do "line voyages" and typically transport passengers from one point to another, rather than on round trips. Traditionally, a liner for the transoceanic trade will be built to a higher standard than a typical cruise ship, including higher freeboard and stronger plating to withstand rough seas and adverse conditions encountered in the open ocean, such as the North Atlantic. Ocean liners also usually have larger capacities for fuel, food, and other stores for consumption on long voyages, compared to dedicated cruise ships, but they no longer exist with the exception of some preserved liners and *Queen Mary 2* when on scheduled North Atlantic voyages.

Although often luxurious, ocean liners had characteristics that made them unsuitable for cruising, such as high fuel consumption, deep draught that prevented their entering shallow ports, enclosed weatherproof decks that were not appropriate for tropical weather, and cabins designed to maximize passenger numbers rather than comfort (such as a high proportion of windowless suites). The gradual evolution of passenger ship design from ocean liners to cruise ships has seen passenger cabins shifted from inside the hull to the superstructure with private verandas. The modern cruise ships, while sacrificing some qualities of seaworthiness, have added amenities to cater to water tourists, and recent vessels have been described as "balcony-laden floating condominiums."

The distinction between ocean liners and cruise ships has blurred, particularly with respect to deployment. Differences in construction remain. Larger cruise ships have also engaged in longer trips such as transoceanic voyages which may not return to the same port for months (longer round trips). Some former ocean liners operate as cruise ships, such as *Marco Polo*. This number is diminishing. The only dedicated transatlantic ocean liner in operation as a liner of December 2013 is *Queen Mary 2* of the Cunard fleet. She also has the amenities of contemporary cruise ships and sees significant service on cruise.

Cruising has become a major part of the tourism industry, accounting for U.S.\$29.4 billion with over 19 million passengers carried worldwide in 2011. The industry's rapid growth has seen nine or more newly built ships catering to a North American clientele added every year since 2001, as well as others servicing European clientele. Smaller markets, such as the Asia-Pacific region, are generally serviced by older ships. These are displaced by new ships in the high growth areas.

The world's largest cruise ship is currently Royal Caribbean International's *Harmony of the Seas* beating her sister ships (Allure of the Seas and Oasis of the Seas) by about 2.15 meters.

2.2 History

2.2.1 Origins

The birth of leisure cruising began with the formation of the Peninsular & Oriental Steam Navigation Company in 1822. The company started out as a shipping line with routes between England and the Iberian Peninsula, adopting the name Peninsular Steam Navigation Company. It won its first contract to deliver mail in 1837. In 1840, it began mail delivery to Alexandria, Egypt, via Gibraltar and Malta. The company was incorporated by Royal Charter the same year, becoming the Peninsular and Oriental Steam Navigation Company.



RMS Strathaird, a P&O cruise ship of the early 20th century. The company began offering luxury cruise services in 1844. (https://en.wikipedia.org/wiki/Cruise_ship)

P&O first introduced passenger cruising services in 1844, advertising sea tours to destinations such as Gibraltar, Malta and Athens, sailing from Southampton. The forerunner of modern cruise holidays, these voyages were the first of their kind, and P&O Cruises has been recognised as the world's oldest cruise line. The company later introduced round trips to destinations such as Alexandria and Constantinople. It underwent a period of rapid expansion in the latter half of the 19th century, commissioning larger and more luxurious ships to serve the steadily expanding market. Notable ships of the era include the SS Ravenna built in 1880, which became the first ship to be built with a total steel superstructure, and the SS Valetta built in 1889, which was the first ship to use electric lights.

Some sources mention Francesco I, flying the flag of the Kingdom of the Two Sicilies (Italy), as the first cruise ship. She was built in 1831 and sailed from Naples in early June 1833, preceded by an advertising campaign. The cruise ship was boarded by nobles, authorities, and royal princes from all over Europe. In just over three months, the ship sailed to Taormina, Catania, Syracuse, Malta, Corfu, Patras, Delphi, Zante, Athens, Smyrna, Constantinople, delighting passengers with excursions and guided tours, dancing, card tables on the deck and parties on board. However, it was restricted to the aristocracy of Europe and was not a commercial endeavour.



Prinzessin Victoria Luise was the first purpose-built cruise ship. (https://en.wikipedia.org/wiki/Cruise_ship)

The cruise of the German ship *Augusta Victoria* in the Mediterranean and the Near East from 22 January to 22 March 1891, with 241 passengers including Albert Ballin and wife, popularized the cruise to a wider market. Christian Wilhelm Allers published an illustrated account of it as *Backschisch* (Baksheesh).

The first vessel built exclusively for luxury cruising, was *Prinzessin Victoria Luise* of Germany, designed by Albert Ballin, general manager of Hamburg-America Line. The ship was completed in 1900.

The practice of luxury cruising made steady inroads on the more established market for transatlantic crossings. In the competition for passengers, ocean liners added luxuries — *Titanic* being the most famous example — such as fine dining, luxury services, and staterooms with finer appointments. In the late 19th century, Albert Ballin, director of the Hamburg-America Line, was the first to send his transatlantic ships out on long southern cruises during the worst of the winter season of the North Atlantic. Other companies followed suit. Some of them built specialized ships designed for easy transformation between summer crossings and winter cruising.

In 1896, there were three luxury liners for transportation, for the Europe to North America trip. These were European-owned. In 1906, the number had increased to seven. The British Inman Line owned *City of Paris*, the Cunard Line had *Compania* and *Lucania*. The White Star Line owned *Majestic* and *Teutonic*. *La Lorraine* and *La Savoie* were owned by the French *Compagnie Générale Transatlantique*.

2.2.2 From luxury ocean liners to "megaship" cruising

With the advent of large passenger jet aircraft in the 1960s, intercontinental travelers switched from ships to planes sending the ocean liner trade into a terminal decline. Certain characteristics of older ocean liners made them unsuitable for cruising duties, such as high fuel consumption, deep draught preventing them from entering shallow ports, and cabins (often windowless) designed to maximize passenger numbers rather than comfort.



Queen Elizabeth 2 was reinvented as a luxury ocean liner following the advent of the jet airliner. (https://en.wikipedia.org/wiki/Cruise_ship)

Ocean liner services aimed at passengers ceased in 1986, with the notable exception of transatlantic crossings operated by the British shipping company Cunard Line, catering to a niche market of those who appreciated the several days at sea. In an attempt to shift the focus of the market from passenger travel to cruising with entertainment value, Cunard Line pioneered the luxury cruise transatlantic service on board the Queen Elizabeth 2 ocean liner. International celebrities were hired to perform cabaret acts onboard and the crossing was advertised as a vacation in itself.

Queen Elizabeth 2 also inaugurated "one-class cruising" where all passengers received the same quality berthing and facilities. This revitalized the market as the appeal of luxury cruising began to catch on, on both sides of the Atlantic. The 1970s television series *Love Boat*, helped to popularize the concept as a romantic opportunity for couples. Another ship to make this transition was SS Norway, originally the ocean liner SS France and later converted to cruising duties as the Caribbean's first "super-ship."



Sovereign of the Seas was the first "megaship" (in service 1988) (https://en.wikipedia.org/wiki/Cruise_ship)

Contemporary cruise ships built in the late 1980s and later, such as *Sovereign*-class which broke the size record held for decades by *Norway*, showed characteristics of size and strength once reserved for ocean liners — some have undertaken regular scheduled transatlantic crossings. The *Sovereign*-class ships were the first "megaships" to be built for the mass cruising market, they also were the first series of cruise ships to include a multi-story atrium with glass elevators. They also had a single deck devoted entirely to cabins with private balconies instead of oceanview cabins. Other cruise lines soon launched ships with similar attributes, such as the *Fantasy*-class, leading up to the Panamax-type *Vista*-class, designed such that two thirds of the oceanview staterooms have verandas. As the veranda suites were particularly lucrative for cruise lines, something which was lacking in older ocean liners, recent cruise ships have been designed to maximize such amenities and have been described as "balcony-laden floating condominiums."



Oasis of the Seas (in service 2009) (https://en.wikipedia.org/wiki/Cruise_ship)

Until 1975-1980, cruises offered shuffleboard, deck chairs, "drinks with umbrellas and little else for a few hundred passengers." After 1980, they offered increasing amenities. As of 2010, city-sized ships have dozens of amenities.

There have been nine or more new cruise ships added every year since 2001, including the 11 members of the Vista-class, and all at 100,000 GT or greater. The only comparable ocean liner to be completed in recent years has been Cunard Line's Queen Mary 2 in 2004. Following the retirement of her running mate Queen Elizabeth 2 in November 2008, Queen Mary 2 is the only liner operating on transatlantic routes, though she also sees significant service on cruise routes.

Queen Mary 2 was for a time the largest passenger ship before being surpassed by Royal Caribbean International's Freedom-class vessels in 2006. The Freedom-class ships were in turn overtaken by RCI's Oasis-class vessels which entered service in 2009 and 2010. A distinctive feature of Oasis-class ships is the split "open-atrium" structure, made possible by the hull's extraordinary width, with the 6-deck high "Central Park" and "Boardwalk" outdoor areas running down the middle of the ship and verandas on all decks.

In two short decades (1988-2009), the largest class cruise ships have grown a third longer (268 m to 360 m), almost doubled their widths (32.2 m to 60.5 m), doubled the total passengers (2,744 to 5,400), and tripled in weight (73,000 GT to 225,000 GT). Also, the "megaships" went from a single deck with verandas to all decks with verandas. Whereas the golden age of ocean liners has faded, the golden age of cruise ships may well be these recent decades and decades to come.

2.3 Operators and cruise lines



Celebrity Solstice in Port Melbourne, Australia (https://en.wikipedia.org/wiki/Cruise_ship)

Operators of cruise ships are known as cruise lines. A cruise line is a company that operates cruise ships and markets cruises to the public. Cruise lines have a dual character; they are partly in the

transportation business, and partly in the leisure entertainment business, a duality that carries down into the ships themselves, which have both a crew headed by the ship's captain, and a hospitality staff headed by the equivalent of a hotel manager. Among cruise lines, some are direct descendants of the traditional passenger shipping lines (such as Cunard), while others were founded from the 1960s specifically for cruising.

Historically, the cruise ship business has been volatile. The ships are large capital investments with high operating costs. A persistent decrease in bookings can put a company in financial jeopardy. Cruise lines have sold, renovated, or renamed their ships to keep up with travel trends. The cruise lines operate their ships virtually 24 hours a day, seven days a week, 52 weeks a year. A ship which is out of service for routine maintenance means the loss of tens of millions of dollars. If the maintenance is unscheduled, it can result, potentially, in thousands of dissatisfied customers.

A wave of failures and consolidations in the 1990s has led to many cruise lines to be bought by much larger holding companies and to operate as "brands" within larger holding corporations, much as a large automobile company holding several makes of cars. Brands exist partly because of repeat customer loyalty, and also to offer different levels of quality and service. For instance, Carnival Corporation & plc owns both Carnival Cruise Line, whose former image were vessels that had a reputation as "party ships" for younger travelers, but have become large, modern, yet still profitable, and Holland America Line, whose ships cultivate an image of classic elegance. In 2004, Carnival Corporation had merged Cunard's headquarters with that of Princess Cruises in Santa Clarita, California so that administrative, financial and technology services could be combined, ending Cunard's history where it had operated as a standalone company (subsidiary) regardless of parent ownership. However, Cunard did regain some independence in 2009 when its headquarters were moved to Carnival House in Southampton.

The common practice in the cruise industry in listing cruise ship transfers and orders is to list the smaller operating company, not the larger holding corporation, as the recipient cruise line of the sale, transfer, or new order. In other words, Carnival Cruise Line and Holland America Line, for example, are the cruise lines from this common industry practice point of view; whereas Carnival Corporation & plc and Royal Caribbean Cruises Ltd., for example, can be considered holding corporations of cruise lines. This industry practice of using the smaller operating company, not the larger holding corporation, is also followed in the list of cruise lines and in member-based reviews of cruise lines.

Some cruise lines have specialties; for example, Saga Cruises only allows passengers over 50 years old aboard their ships, and Star Clippers and formerly Windjammer Barefoot Cruises and Windstar Cruises only operate tall ships. Regent Seven Seas Cruises operates medium-sized vessels—smaller than the "megaships" of Carnival and Royal Caribbean—designed such that 90% of their suites are balconies. Several specialty lines offer "expedition cruising" or only operate small ships, visiting certain destinations such as the Arctic and Antarctica, or the Galápagos Islands. John W. Brown, which formerly operated as part of the United States Merchant Marine during World War II before being converted to a museum ship, still gets underway several times a year for six-hour "Living History Cruises" that take the ship through Baltimore Harbor, down the Patapsco River, and into the Chesapeake Bay, and she is also the largest cruise ship operating under the American flag on the United States East Coast.

Currently the five largest cruise line holding companies and operators in the world are Carnival Corporation & plc, Royal Caribbean Cruises Ltd., Star Cruises (which owns 50% of Norwegian Cruise Line; NCL in its own right is the third largest line), MSC Cruises, and Louis Cruise Lines. Louis Cruises has largely grown its fleet through purchasing older second- or third-hand ships, while the other four operators have largely constructed their own vessels and combined own the majority of the "megaships".

2.4 Organization



Disney Magic (https://en.wikipedia.org/wiki/Cruise_ship)



AIDAdiva in Izmir (https://en.wikipedia.org/wiki/Cruise_ship)

Cruise ships are organized much like floating hotels, with a complete hospitality staff in addition to the usual ship's crew. It is not uncommon for the most luxurious ships to have more crew and staff than passengers.

2.4.1 Dining



Island Princess in Cabo San Lucas

Dining on almost all cruise ships is included in the cruise price.

Traditionally, the ships' restaurants organize two dinner services per day, early dining and late dining, and passengers are allocated a set dining time for the entire cruise; a recent trend is to allow diners to dine whenever they want. Having two dinner times allows the ship to have enough time and space to accommodate all of their guests. Having two different dinner services can cause some conflicts with some of the ship's events (such as shows and performances) for the late diners, but this problem is usually fixed by having a shorter version of the event take place before late dinner. Cunard Line ships maintain the class tradition of ocean liners and have separate dining rooms for different types of suites, while Celebrity Cruises and Princess Cruises have a standard dining room and "upgrade" specialty restaurants that require pre-booking and cover charges. Many cruises schedule one or more "formal dining" nights. Guests dress "formally", however that is defined for the ship, often suits and ties or even tuxedos for men, and formal dresses for women. The menu is more upscale than usual.

Besides the dining room, modern cruise ships often contain one or more casual buffet-style eateries, which may be open 24 hours and with menus that vary throughout the day to provide meals ranging from breakfast to late-night snacks. Ships also feature numerous bars and nightclubs for passenger entertainment; the majority of cruise lines do not include alcoholic beverages in their fares and passengers are expected to pay for drinks as they consume them. Most cruise lines also prohibit passengers from bringing aboard and consuming their own beverages, including alcohol, while aboard. Alcohol purchased duty-free is sealed and returned to passengers when they debark.

There is often a central galley responsible for serving all major restaurants aboard the ship, though specialty restaurants may have their own separate galleys.

As with any vessel, adequate provisioning is crucial, especially on a cruise ship serving several thousand meals at each seating. For example, a quasi "military operation" is required to load and unload 3600 passengers and eight tons of food at the beginning and end of each cruise, for the Royal Princess.

2.4.2 Other on-board facilities

Most modern cruise ships feature the following facilities:

- Casino — Only open when the ship is at sea to avoid conflict with local laws
- Shops — Only open when ship is at sea to avoid merchandising licensing and local taxes
- Spa
- Fitness center
- Library
- Theatre with Broadway-style shows
- Cinema
- Indoor and/or outdoor swimming pool with water slides
- Hot tub

- Buffet restaurant
- Lounges
- Gym
- Clubs
- Basketball courts
- Tennis courts
- Pool tables
- Ping pong tables
- Infirmary

Some ships have bowling alleys, ice skating rinks, rock climbing walls, sky-diving simulator, miniature golf courses, video arcades, ziplines, surfing simulators, basketball courts, tennis courts, chain restaurants and/or ropes obstacle courses.

2.4.3 Crew

Crew is usually hired on three to eleven month contracts which may then be renewed as mutually agreed, which is based upon service ratings from passengers as well as the cyclical nature of the cruise line operator. Most staff work 77-hour work weeks for 10 months continuously followed by 2 months of vacation.

There are no paid vacations or pensions for service, non-management crew, depending on the level of the position and the type of the contract. Non-service and management crew members get paid vacation, medical, retirement options, and can participate in the company's group insurance plan.

The direct salary is low for North American standards, though restaurant staff have considerable earning potential from passenger tips. Crew members do not have any expenses while on board as food and accommodation, medical care, and transportation for most employees, are included. This makes a cruise ship career financially attractive enough to compensate for lack of employment benefits.

Living arrangements vary by cruise line, but mostly by shipboard position. In general two employees share a cabin with a shower, commode and a desk with a television set, while senior officers are assigned single cabins. There is a set of facilities for the crew separate from that of passengers, such as mess rooms and bars, recreation rooms, prayer rooms/mosques, and fitness center, with some larger ships even having a crew deck with a swimming pool and hot tubs.

For the largest cruise operators, most "hotel staff" are hired from under-industrialized countries in Asia, Eastern Europe, the Caribbean, and Central America. While several cruise lines are headquartered in the United States, like most international shipping company, ships are registered in countries including the Netherlands, the UK, the Bahamas, and Panama. The International Labour Organization's 2006 Maritime Labour Convention,^[31] also known as the "Seafarers' Bill of Rights, provides comprehensive rights and protections for all crewmembers. The ILO sets rigorous standards regarding hours of work and rest, health and safety, and living conditions for crewmembers and requires governments to ensure ships are in compliance. For cruise routes around Hawaii, operators

are required to register their ships in the United States and the crew is unionized, so these cruises are typically much more expensive than Caribbean and Mediterranean.

2.4.4 Business model

Most cruise lines since the 2000s have priced the cruising experience, to some extent, a la carte, as passengers spending aboard generates significantly more from ticket sales. The passenger's ticket includes the stateroom accommodation, room service, unlimited meals in the main dining room (or main restaurant) and buffet, access to shows, and use of pool and gym facilities, while there is a daily gratuity charge to cover housekeeping and waiter service. However, there are extra charges for alcohol and soft drinks, official cruise photos, Internet and wi-fi access, and specialty restaurants; it has been reported that the casino and photos have high profit margins. Cruise lines earn significantly from selling onshore excursions (keeping 50 percent or more of what passengers spend for these tours) offered by local contractors. In addition, cruise ships earn significant commissions for sales from onshore stores that are promoted on board as "preferred" (as much as 40 percent of gross sales). Facilitating this practice are modern cruise terminals with establishments of duty-free shops inside a perimeter accessible only by passengers and not locals. Ports of call have often oriented their own businesses and facilities towards meeting the needs of visiting cruise ships. In one case, Icy Strait Point in Alaska, the entire destination was created explicitly and solely for cruise ship visitors.

Travel to and from the port of departure are the passengers' responsibility, although purchasing a transfer pass from the cruise line for the trip between the airport and cruise terminal will guarantee that the ship will not leave until the passenger is aboard. Similarly, if the passenger books a shore excursion with the cruise line and the tour runs late, the ship is obligated to remain until the passenger returns.

Luxury cruise lines such as Regent Seven Seas Cruises and Crystal Cruises market their fares as "all-inclusive". For example, base fare on Regent Seven Seas ships includes most alcoholic beverages onboard ship and most shore excursions in ports of call, as well as all gratuities that would normally be paid to hotel staff on the ship. The fare may also include a one-night hotel stay before boarding, and airfare to and from the cruise's origin and destination ports.

2.4.5 Ship naming

Older cruise ships have had multiple owners. it is usual for the transfer of ownership to entail a refitting and a name change. Some ships have had a dozen or more identities.

Many cruise lines have a common naming scheme they use for their ships. Some lines use their name as a prefix or suffix in the ship name (such as the prefixes of "Carnival", "AIDA", "Disney", or "Norwegian" and the suffix of "Princess"). Other lines use a unique word or phrase (such as the prefix of "Pacific" for P&O Cruises Australia or the suffixes of "of the Seas" for Royal Caribbean International or "-dam" for ships of the Holland America Line). The addition of these prefixes and suffixes allows multiple cruise lines to use the same popular ship names while maintaining a unique identifier for each ship.

2.4.6 Cruise ships utilization

Due to slower speed and reduced seaworthiness, as well as being largely introduced after several major wars, cruise ships have never been used as troop transport vessels. By contrast, ocean liners were often seen as the pride of their country and used to rival liners of other nations, and have been requisitioned during both World Wars and the Falklands War to transport soldiers and serve as hospital ships.

Cruise ships and former liners often find employment in applications other than those for which they were built. A shortage of hotel accommodation for the 2004 Summer Olympics led to a plan to moor a number of cruise ships in Athens to provide tourist accommodation.

On 1 September 2005, the U.S. Federal Emergency Management Agency (FEMA) contracted three Carnival Cruise Lines vessels (Carnival Fantasy, the former Carnival Holiday, and the Carnival Sensation) to house Hurricane Katrina evacuees.

In 2010, in response to the shutdown of UK airspace due to the eruption of Iceland's Eyjafjallajökull volcano, the newly completed Celebrity Eclipse was used to rescue 2000 British tourists stranded in Spain as an act of goodwill by the owners. The ship departed from Southampton for Bilbao on 21 April, and returned on 23 April.

2.5 Regional industries

Most cruise ships sail the Caribbean or the Mediterranean. Others operate elsewhere in places like Alaska, the South Pacific, the Baltic Sea and New England. A cruise ship that is moving from one of these regions to another will commonly operate a repositioning cruise while doing so. Expedition cruise lines, which usually operate small ships, visit certain more specialized destinations such as the Arctic and Antarctica, or the Galápagos Islands.

The number of cruise tourists worldwide in 2005 was estimated at some 14 million. The main region for cruising was North America (70% of cruises), where the Caribbean islands were the most popular destinations.

The second most popular region was continental Europe (13%), where the fastest growing segment is cruises in the Baltic Sea. The most visited Baltic ports are Copenhagen, St. Petersburg, Tallinn, Stockholm and Helsinki. The seaport of St. Petersburg, the main Baltic port of call, received 426,500 passengers during the 2009 cruise season.

According to 2010 CEMAR statistics the Mediterranean cruise market is going through a fast and fundamental change; Italy has won prime position as a destination for European cruises, and destination for the whole of the Mediterranean basin. The most visited ports in Mediterranean Sea are Barcelona (Spain), Civitavecchia (Italy), Palma (Spain) and Venice (Italy).

2013 saw the entrance of the first Chinese company into the cruise market. China's first luxury cruise ship, Henna, made her maiden voyage from Sanya Phoenix Island International Port in late January.

2.5.1 Caribbean cruising industry

The Caribbean cruising industry is one of the largest in the world, responsible for over \$2 billion in direct revenue to the Caribbean islands in 2012. Over 45,000 people from the Caribbean are directly employed in the cruise industry. An estimated 17,457,600 cruise passengers visited the islands in the 2011-2012 cruise year (May 2011 to April 2012.) Cruise lines operating in the Caribbean include Royal Caribbean International, Princess Cruises, Carnival Cruise Line, Celebrity Cruises, Disney Cruise Line, Holland America, P&O, Cunard, Crystal Cruises, Pullmantur Cruises and Norwegian Cruise Line. There are also smaller cruise lines that cater to a more intimate feeling among their guests. The three largest cruise operators are Carnival Corporation, Royal Caribbean International, and Star Cruises/Norwegian Cruise Lines.

Many American cruise lines to the Caribbean depart out of the Port of Miami, with "nearly one-third of the cruises sailing out of Miami in recent years". Other cruise ships depart from Port Everglades (in Fort Lauderdale), Port Canaveral (approximately 45 miles (72 km) east of Orlando), New York, Tampa, Galveston, New Orleans, Cape Liberty, Baltimore, Jacksonville, Charleston, Norfolk, Mobile, and San Juan, Puerto Rico. Some UK cruise lines base their ships out of Barbados for the Caribbean season, operating direct charter flights out of the UK.

CHAPTER 3: Cruise ship design

Cruise ship building process involves numerous complex research and testing procedures. The cruise ship design company (which work is also called naval architecture) analyses and provides solutions to meet the Marine and Shipbuilding Industry's requirements, submitting the basic and detailed

designs, ship equipment designs and production drawings to the shipbuilding company. The design firm also provides engineers with analysis, simulations, diagnosis, manufacture, repair and other data by using the latest CAE (Computer Aided Engineering) technology. The ship cabins manufacturer is able to design and produce various types of ready-to-install ship cabins and bathrooms for virtually all passenger ships - big and small, luxury, ferries, Ro-Ros, research, etc. The ship builder also hires a company to provide the so called "Lifecycle Services", pertaining mostly to the industry's rules and regulations. Some of these services are retrofitting and refurbishing, and keeping regular updates regarding new rules and requirements.

It's a common modern practice big cruise ships to be built of pre-made huge sections. Entire multi-deck segments are built at another place, transported or slipway to the shipyard and lifted into place. The sections often feature even pre-installed equipment, cables, pipes and other components - it saves a lot of shipbuilding time, and it surely saves lots of money. This technique was used for the first time in the construction of the Cunard's Queen Mary 2 ship (2002-2004) by the French "Chantiers de l'Atlantique" company. Next photo shows a pre-made section for the Symphony Of The Seas ship construction.



(<http://www.cruisemapper.com/wiki/757-cruise-ship-building-construction-design>)

The ice-going cruise ships building is so expensive as to hull strength and engines power, that the best option is to buy an unfinished vessel or to refit an existing Ice-class ship (often an ex navy vessel), like the case of the Regent Seven Seas Navigator ship. Constructed as a naval support ship and strengthened for navigation in ice, the Navigator ship's hull was purchased from the former USSR (now Russia), while its superstructure was finished later at the T. Mariotti shipyards in Genoa, Italy.

This is an amazingly detailed cruise ship design infographic showing what is what and where on a typical cruise passenger vessel.

Another city protected by UTC Fire & Security
 No service interruption. No noise. No vibration. No smoke. No panic. Just the sound of silence, one nonevent at a time.

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 We protect you from fire when an ocean of water can't. We make more than 14 million fire extinguishers annually for use on oceans and land worldwide.

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 Our 3.7 million electronic locks in 22,000 hotels worldwide can stand up to 3,600 pounds of pressure. Or 10 blows with up to 75 pounds of blunt force. For 135 years.

Security is big business.
 We provide security solutions to 72% of the Fortune 100 companies and 44% of the Fortune 500.

Flambé, available only in the dining room.
 In the galley, our wet chemical system uses a patented process that simultaneously turns cooking grease into combustion resistant soap, vaporizes water to create steam for cooling, and interrupts combustion's chemical chain reaction.

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 Our advanced fire suppression systems use heat absorption and molecular level chemistry to put out fires in 30 seconds or less without depleting available oxygen.

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 Made for ships, our visual display system maps every detector on board and provides pre-warnings and alarms. In the event of smoke, it helps direct passengers safely to fire doors.

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 Globally, we supply 6,835 miles of firefighting hose annually, enough to stretch from Beijing to New York City.

Colorless. Tasteless. Odorless.
 Carbon monoxide is a leading cause of accidental poisoning. With our CO alarms, that doesn't have to happen anywhere on land. Or sea.

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 When a vacation is this romantic, it's important that every stateroom be equipped with a Kidde® fire extinguisher.

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 Whether in a ship's casino or one of the world's largest in Macau, access control and employee security are critical. Along with other features, our systems prevent shared identities so an ID can't be scanned and passed to someone else for use.

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CARRIER | HAMILTON SUNDBRAND | OTIS | PRATT & WHITNEY | SIKORSKY | UTC FIRE & SECURITY | UTC POWER | NYSE: UTX

UTC's past performance provides no assurance of future performance. Future performance may vary materially from prior periods reports submitted to the SEC periodically. Cumulative total shareholder return for decade ending 2006.

due to a number of risk factors, including those described in UTC's 10-K, 10-Q and 8-K

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Marine design solutions for cruise ships are truly amazing and unique, using the latest innovations, technologies and materials to ensure difference from other existing passenger ships. Special on-board features, such as the Royal Caribbean ships' rock-climbing walls, ice-skating rinks, surf simulators, wave pools and the 9-deck high Zip-line are an irresistible temptation and a true allure for all the ship vacation fun fans. As to the common features, all big passenger ships have a several decks high Atrium, at least 3 huge swimming pools, a Spa-Fitness complex, a grand casino, a library, duty-free shops, 2 huge capacity main restaurants, a grand theater, a disco, kids and teen areas, numerous bars and lounges, and all new big ships feature an open around-ship Promenade. As to the biggest of all - the Allure and Oasis ships - each of them has 2,706 cabins - nothing short to a floating resort.

3.1 Cruise ship interior design

What about cruise ship interior designs? An example is SMC Design, which was appointed by Cunard Line to lead the development of the interior spaces aboard Queen Mary 2, in preparation for her major refit in 2016. Cunard's flagship had a multi-million 25-day extensive refurbishment (May 27-June 21, 2016) that boasted new interior designs. The most iconic liner in the world opened the next chapter in her illustrious career. The announcement of the designer company followed the news that QM2 will gain 15 brand new single cabins and additional 30 Britannia Club rooms during the refit. The popular onboard kennels were expanded in order to cater for the high demand this extraordinary facility already attracts.

SMC Design was established in 1994. The based in London design consultancy specializes in maritime sector. SMC Design's team has worked on many cruise vessels - from small yachts to some of the biggest ships ever built. It also has a working history with Cunard ships, leading previous refits of QE2, Cunard Princess and Cunard Countess, while also being involved in its current fleet design: Queen Victoria, Queen Elizabeth and Queen Mary 2. Andy Collier, SMC Managing Director, was part of the launch design team of QM2 at the beginning of the Century. She was then the first Atlantic liner being built for more than 35 years.

The new designs of Queen Mary 2 focus on updating her iconic art deco lines. The original Art Deco Queen Mary has been the source of inspiration with the new designs, bringing Cunard's glamorous past into 21st Century. With new colour schemes, carpets and furniture, as well as more decorative fittings installed throughout, the design approach of the largest ocean liner in the world is set to ensure QM2 retains leading position in Cunard fleet.

3.2 New Russian cruise ship designs

In August 2016, at Lotus shipyard (Astrakhan, Russian) part of ASC (United Shipbuilding Company) the keel was laid for the 1st Russian passenger cruise ship in decades. Support for the new class of even vessel is coming from Russian Federation president Vladimir Putin, who expressed hope that this will be the first but not the last of a series of such ships.



(<http://www.cruisemapper.com/wiki/757-cruise-ship-building-construction-design>)

The Marine Engineering Bureau office engineers developed the Concept PV300VD cruise ship, the first of which is to be completed within 3 years. The project belongs to Saint Petersburg team of Marine Engineering Bureau SPb, that has been working in Russia for 16 years. Its other branch is in Odessa. Such vessels were not generally built in the old Soviet Union.

The last built in the USSR, 2 river cruise ships, Soviet Union and Lenin, were built at Gorky plant in 1959-1960. Then, as with its ocean ships, the Soviet Union bought foreign-built river ships, until 1989-1990. However, these were not entirely foreign as they were created to Soviet order and developed for operation in Russian conditions. These vessels were built mainly in Austria, East Germany and Czechoslovakia. After 1990, Russian river boats were no longer built and the business was carried on for years utilising old tonnage. The same happened with the Russian passenger fleet as they were banned in North America after Russia's invasion in Afghanistan.

Today, shipping conditions in Russia are different. The new ships are planned to be “river-sea” ships. This class is needed in order to navigate large lakes. Russian river cruise ships are much more powerful than typical Danube and Rhine vessels. Dimensions for the new 310-passenger ships will be 463 x 55 feet. The PV300VD concept emerged in 2010-2015 by order of Russian Federal Marine Agency. Program's state customer and coordinator is the Minister of Industry and Trade, and completion is scheduled for 2019. The cost of a ship varies between 2.5 to 3.5 billion rubles and payback period is 5 to 20 years. 3 such ships are foreseen at the stage, though more could follow.

The routes foreseen for the new Russian ships are in season (May to October) between Moscow and Saint Petersburg, then taking travelers from Moscow to Samara and Rostov-on-Don, in the winter embarking in the Eastern Mediterranean and possibly Red Sea: for example, Rostov-on-Don-Yalta-Odessa-Istanbul-Alexandria. There are talks about navigation in Crimea, Sevastopol, and Sochi, on more interesting routes in the Caspian sea.

The newbuilds could carry about 500,000 passengers annually, of which about 100,000 foreign tourists. The number of foreigners declined by nearly a half in 2014 as western tour operators cut Russian programmes and westerners stayed away. According to the Ministry of Industry and trade, buyers of the new ship would be operators like Mosturflot (GK Sea and River shipping company), Vodohod and Orthodox. Given the high cost of the vessels, it is planned to lease them to operators. The main difference of this 4-deck ship is that it will be able to navigate not only rivers, but seas as well. The vessels will also be more luxurious than past ships and will include western amenities, such as French balconies and comfortable large suites.

3.3 Revolutionary new expedition cruise ship designs

A new contract was awarded to the shipbuilder Uljanik (Croatia) for a 10,000-GT, 237-passenger luxury cruise ship scheduled for delivery in 2018. Based on these dimensions, the new ship will be the same general size as Ponant's current fleet the latest of which, Le Lyrial, was built by at Fincantieri's Ancona (Italy) shipyard. Uljanik has not disclosed the identity of the purchaser, but new ships are also expected from Lindblad and Seabourn in 2018.

Other designs fitting this broad expedition cruise vessel category include:



STX France's Project Ulysseas, a 145m, 200-passenger design revealed in March 2015.
(<http://www.cruisemapper.com/wiki/757-cruise-ship-building-construction-design>)



(<http://www.cruisemapper.com/wiki/757-cruise-ship-building-construction-design>)

Next design (by Aker Arctic) is of an expedition ship ordered by the UK-based company Polar Cruise Enterprises Ltd. The vessel has LOA length of 135.5 m, Beam 17.8 m, Draught 5.5 m, Propulsion 2x 3.5 MW azimuth thrusters, Engines 4x MAK 6M32C (2,88 MW each) allowing cruising speed 13 knots.



Knud E Hansen's expedition ship design with 150 cabins and heavy-duty, ice-rated hull.
(<http://www.cruisemapper.com/wiki/757-cruise-ship-building-construction-design>)



(<http://www.cruisemapper.com/wiki/757-cruise-ship-building-construction-design>)

Next images show expedition yacht cruise ship design by the Dutch shipbuilder Damen Group. The vessel is "Polar Class 6" (with ice-strengthened hull) and has endurance 30 days autonomous cruising.



(<http://www.cruisemapper.com/wiki/757-cruise-ship-building-construction-design>)

The ship has approx 1100 m² public space and 2500 m² outdoor deck space. Max capacity is 115 passengers. Propulsion is diesel-mechanical hybrid and encompasses IMO Tier 3 compliant medium speed engines.

3.4 Cruise ship building vs ship refurbishments

Unlike the scheduled cruise ship refurbishments, major refits may include even a cruise ship lengthening, like in the case of Royal Caribbean ship Enchantment of the Seas lengthened in 2005 (see the photo below). The Enchantment ship lengthening cost ~ US\$55 million, it was a process of cutting the ship in two and inserting a whole new 73 ft (22 m) 3,500 tons midsection, pre-built at the Aker Finnyards.

The month-long dry-dock at the Keppel Verolme shipyards (Rotterdam, The Netherlands) resulted in adding 151 brand new cabins, a 50% bigger Pool Deck area, a new kids area, a teen center, several new bars and lounges, an expanded main dining room, a new specialty restaurant. This "refurbishment cost" record was recently beaten by the CCL line and the US\$155 million Carnival Destiny refit 2013 producing a brand new ship named Carnival Sunshine!

The average cost of building a cruise ship is around US \$450 for mid-sized vessels and up to \$800 million for bigger cruise ships. These prices, along with the current economy status force

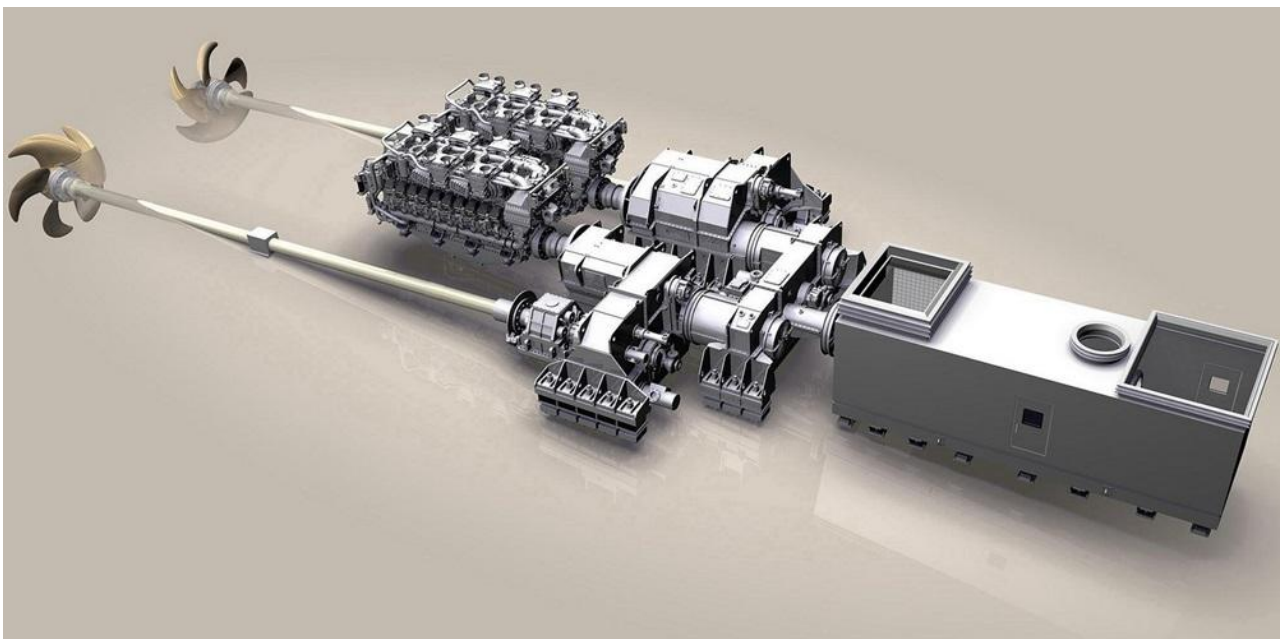
many cruise lines to hold off from building new ships - the biggest expense of all. As a rule, all new cruise ships on order/currently under construction are by contracts signed years ago when the dollar had a good rate.

Cruise ship building prices are high enough to not meet the return requirement. Even the mighty Carnival Corporation (the largest cruise company in the world) puts its ship building plans on hold. Royal Caribbean is one of the few companies continuing to place orders for new ships - and not any ships, but the ever largest, the most innovative, the most expensive in the world. Still, most passenger ship lines are trying to keep their current fleet fresh and good looking. Two of the best examples are Holland America with its \$450 million SOE program for ship renovations, and Carnival investing over \$250 million to fully refit and refurbish 8 of its oldest vessels.

CHAPTER 4: Cruise ships construction

4.1 Cruise Ship Engine

Without a source of power, these huge cruise vessels would be nothing more than drifting aimlessly hotels. A large number of older ships use diesel reciprocating engines for generating power for propulsion. Cruise ship engine power is supplied through transmission to the propeller shafts. These transmissions determine the revolutions of propellers. Modern ships use either diesel electric engines or gas turbines as a source of power for propulsion, and for ship's systems. Some of the larger ships depend on two power sources - one for electrical power and one for propulsion.



(<http://www.cruisemapper.com/wiki/752-cruise-ship-engine-propulsion-fuel>)

Gas turbine engines, as being aero derivative, generate heat which is transformed from mechanical energy in electrical power. Compressed air is fired in combustion chamber, to achieve this. Hot exhaust is made over a turbine which spins to drive mechanically a shaft. The power can be used to spin the electrical generators. The same way do diesel-electric engines work, yet they use direct drive system, not a turbine. The output shafts, to produce electrical power, are connected to the electrical generators.

Both engine types need a lot of fuel. Cunard QE2, for example, consumes daily 380 tons of fuel when she's traveling at 28.5 knots speed and carries fuel enough to sail for 12 days. Usually ships fill up at various ports, and use fueling barges as floating gas stations. Vessels use lower-grade diesel which tends not to burn as purely as diesel-powered road-going vehicles.

All ships rely on the propellers to be pushed through water. These, referred to commonly as screws, provide forward and reverse motion. Airplanes, for example, require tremendous speeds of propellers to provide forward motion for flight, but ship propellers don't need to turn so fast and rely on torque power. Therefore, they travel slowly, and rarely top 30 knots (for more info follow our speed-link above).

4.2 Cruise ship engine room

The basic detail about the cruise ship engine room is its location. Ships' heaviest weights have to be situated at the lowest possible place because of stability, and usually engines are mounted above the keel.



(<http://www.cruisemapper.com/wiki/752-cruise-ship-engine-propulsion-fuel>)

Ship's lowest decks are almost entirely full of machinery. An area creating enough power for driving such an enormous vessel through water needs to be really big - very often engine rooms occupy at least three decks. But rather than long halls stretching length of hulls, machinery is almost always divided into smaller compartments - one might house main engines, and another might contain air-conditioning system. This compartmentalization is for safety reasons. If a penetration to the hull or fire happens, multiple compartments help contain the damage.

Rarely, engines are not placed at the bottom of ship - four main diesel engines on RMS Queen Mary 2, are placed above the keel, and two smaller gas turbines are on top, aft of funnel.

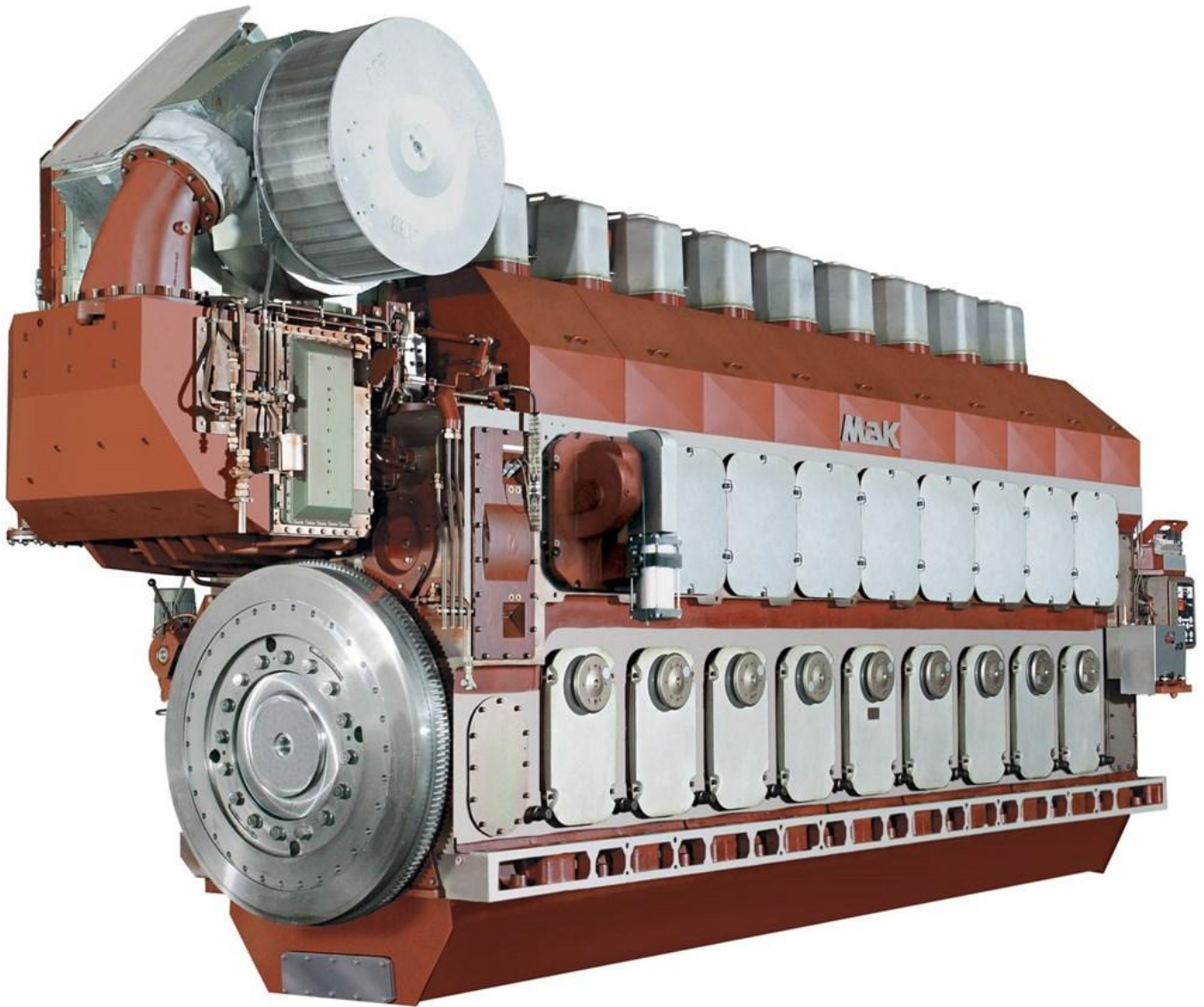
An interesting fact is that it was not unusual for older liners to feature 2 engine rooms. Gradually, technology allowed consolidation of engine spaces. However, legislation today requires vessels to have equipment duplication and 2 engine rooms.

In May 2015, Wartsila Corporation and Carnival Corporation partnered to optimize cruise ship engine room operations of all the 101 ships across corporation's 9 global brands. The deal was signed by Micky Arison (Carnival's Chairman) and Bjorn Rosengren (Wartsila's President and CEO).

- The plan included installing Wartsila's latest marine solutions, first tested on several Carnival Cruise Line vessels in pilot projects. The new systems and technologies included engine control and monitoring systems, safety and fuel efficiency equipment.
- Wartsila's "Asset Performance Optimization Solution" package allows obtaining optimal performance from Wartsila marine diesel engines, recommends how to deal with potential issues, maximizes ship performance, ensures full-capacity systems operations, increases predictability of fuel management and maintenance needs. Wartsila's fuel engine package was specifically designed to reduce fuel consumption.
- Wartsila Marine technologies aim to optimize ship performance, but also allow to locate deviations from normal parameters of equipment and engines. This allows emerging problems and engine fault sources to be fixed before they occur.

4.3 Conventional diesel cruise ship engine

Today's direct-drive diesels feature one main advantage - the option to use shaft generator, which is a device using the circular motion of propeller shaft in order to generate electricity needed for hotel services, like cooking and lighting.



(<http://www.cruisemapper.com/wiki/752-cruise-ship-engine-propulsion-fuel>)

Shaft generators can be used only while the ship is moving with fairly constant cruising speed. This is what the NCL Epic cruise ship engine looks like:

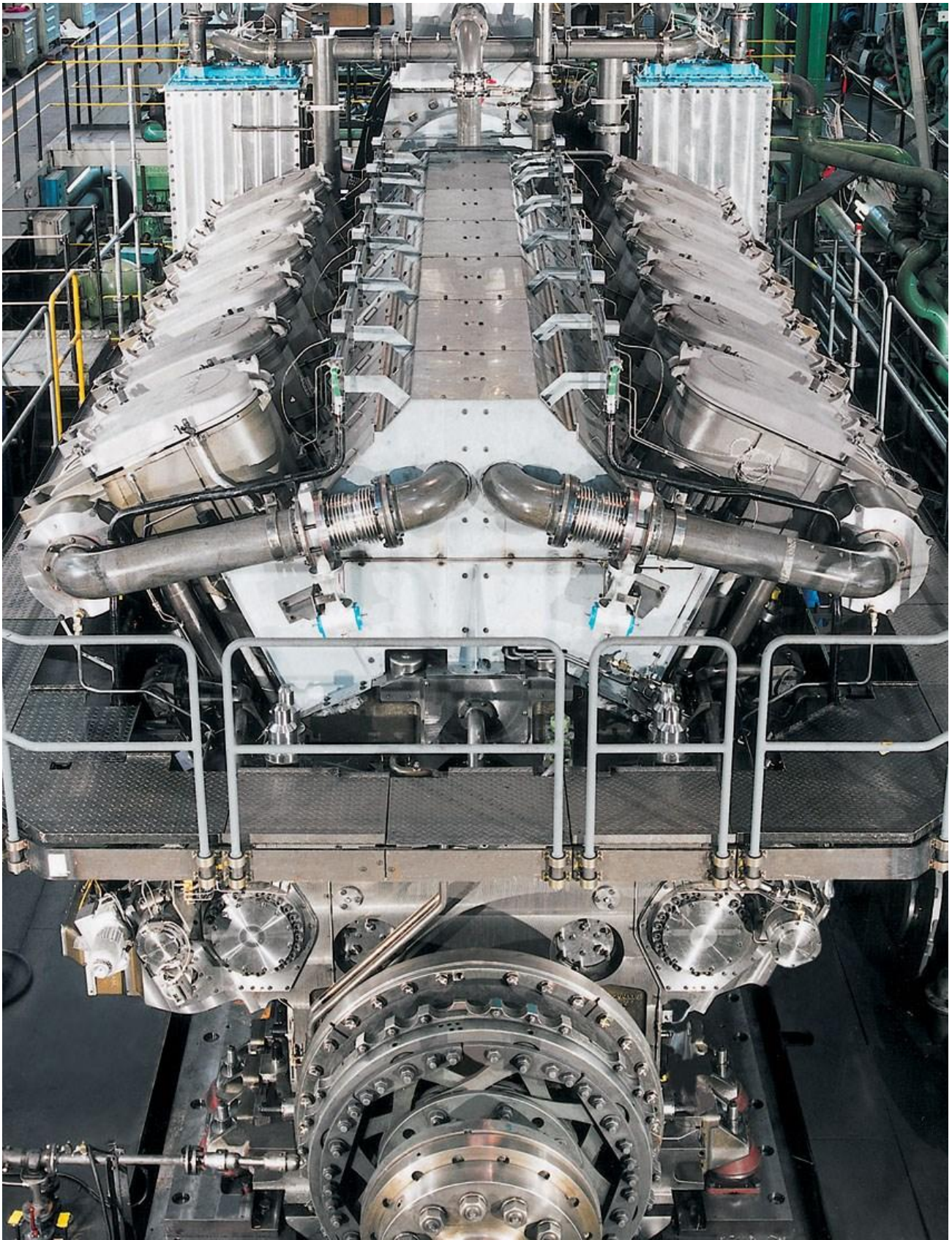
4.4 Diesel electric cruise ship engine

Almost all new ships feature a diesel-electric propulsion form. On these ships, main engines are not connected to propeller shafts, and instead of it they are directly connected to big generators in order to produce electricity, which is sent in turn to electric motors, that then power and help turn the propellers. Main advantage of the diesel-electric cruise ship engine systems is efficiency as they allow main engines to operate near the most efficient speed, no matter if the ship is moving at 5 or 25 knots.

Losing electrical power is devastating to ships. Main engines and generators require electricity and it's needed to keep them going. Pumps that are driven electrically take in cold water from ocean to

cool the engines, and electrical pumps get fuel from fuel tanks and supply it to the engine. Electrical power is vital for many operational functions - without it, ships come to a halt.

Large equipment (propulsion motor, bow thrusters) requires electricity of high voltage. As for smaller machinery (cabin lights, galley equipment), the electricity goes through transformer and is thus stepped down into lower voltage. Large cables snake through all the ship to distribute electrical power. They carry power from generators to switchboards, through passageways, public rooms, crew and passenger cabins. Cabling can be the weak point in the distribution system. If the electrical cables aren't truly redundant, even ships that feature two engine rooms suffer power failure.

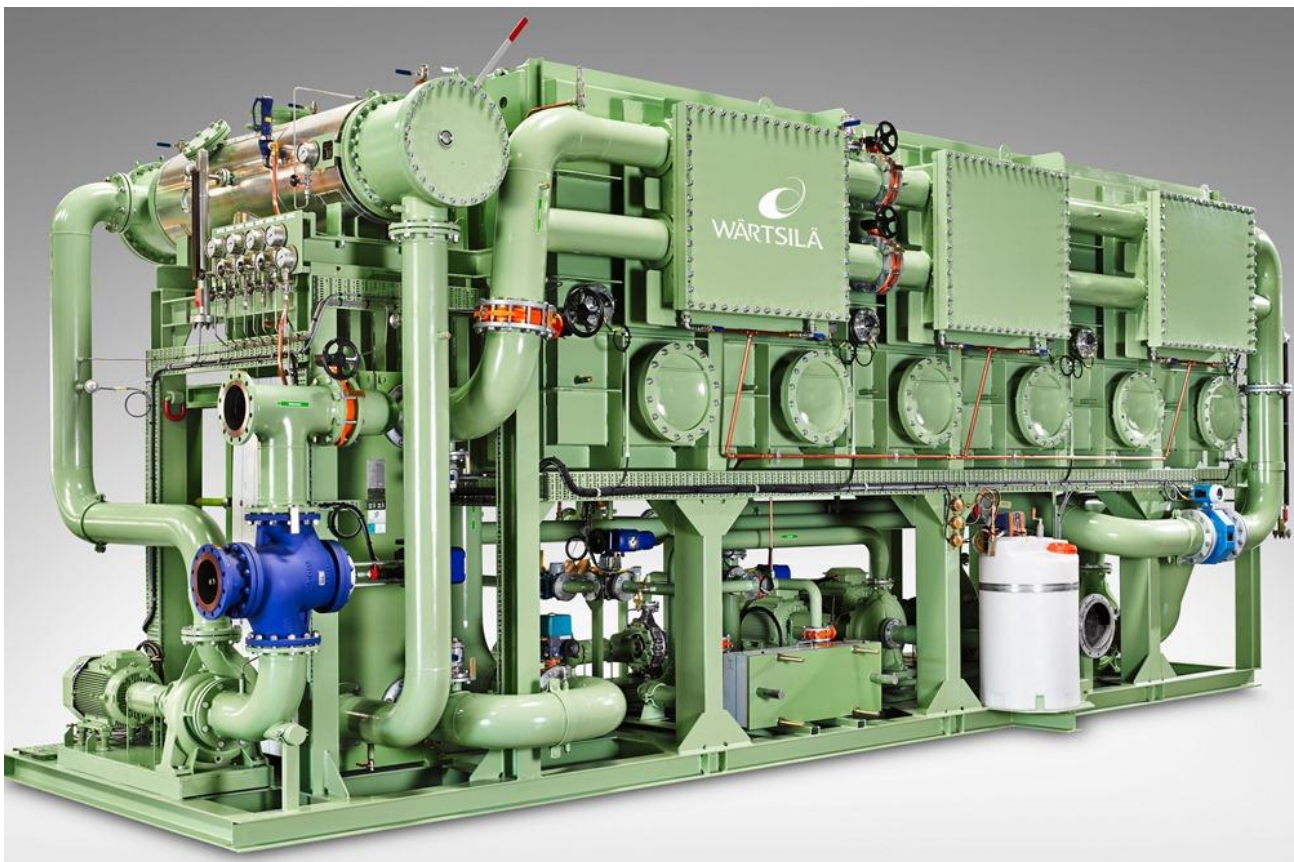


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While ships are docked, generators and main engines produce more power than needed. They are turned off in port, and smaller generators supply "hotel" load (lights, air-conditioning, galley, etc.). Moving through water takes up vast majority of ship's power needs - about 85% of diesel-electric plant produced power goes to propeller, and the rest towards keeping lights on and crew and passengers comfortable.

4.5 Cruise ship Emergency Generators

All ships are supplied with emergency generator to maintain vital electrical power. Backup generators are located higher up and also outside engine room spaces to isolate them from damage or fire.



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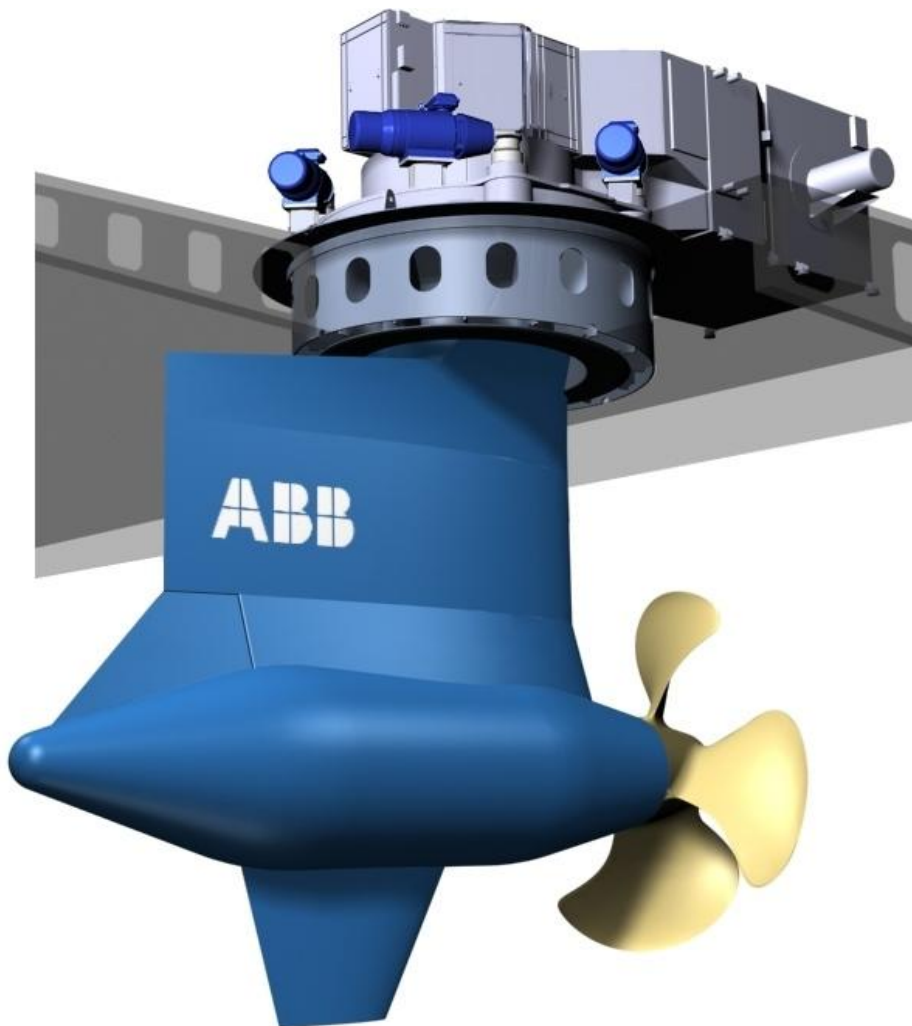
Big ships require much power, so they might have more than one emergency generators. Despite that, they don't have the capacity of main generators and engines, don't produce electricity enough to move the ship, and can't supply all the power needed in ports, because of constraints in space.

Emergency generators are instead used only for essential navigation systems - crucial communication equipment, critical pumps in engine room, emergency lighting. Should they also fail, vessels are required to have a battery backup. 24 hours of power are at least provided by battery rooms to smaller emergency equipment list.

Probably you've heard about Carnival cruise ship accidents related to power failures in 2013. At our Carnival Fun Ship 2.0 upgrades link you can learn how Carnival lines battle with this "unmaintained ships" image and implemented revolutionary new technology initiatives fleetwide - including an additional emergency backup generator on each of their vessels.

4.6 Cruise Ship Propulsion

The new cruise ship propulsion systems ABB Azipods XO (below photo) are more fuel efficient than traditional systems, also providing better maneuverability, maximizing speed, reducing bad emissions, which as a whole optimizes the ship's performance and enhances passenger safety.

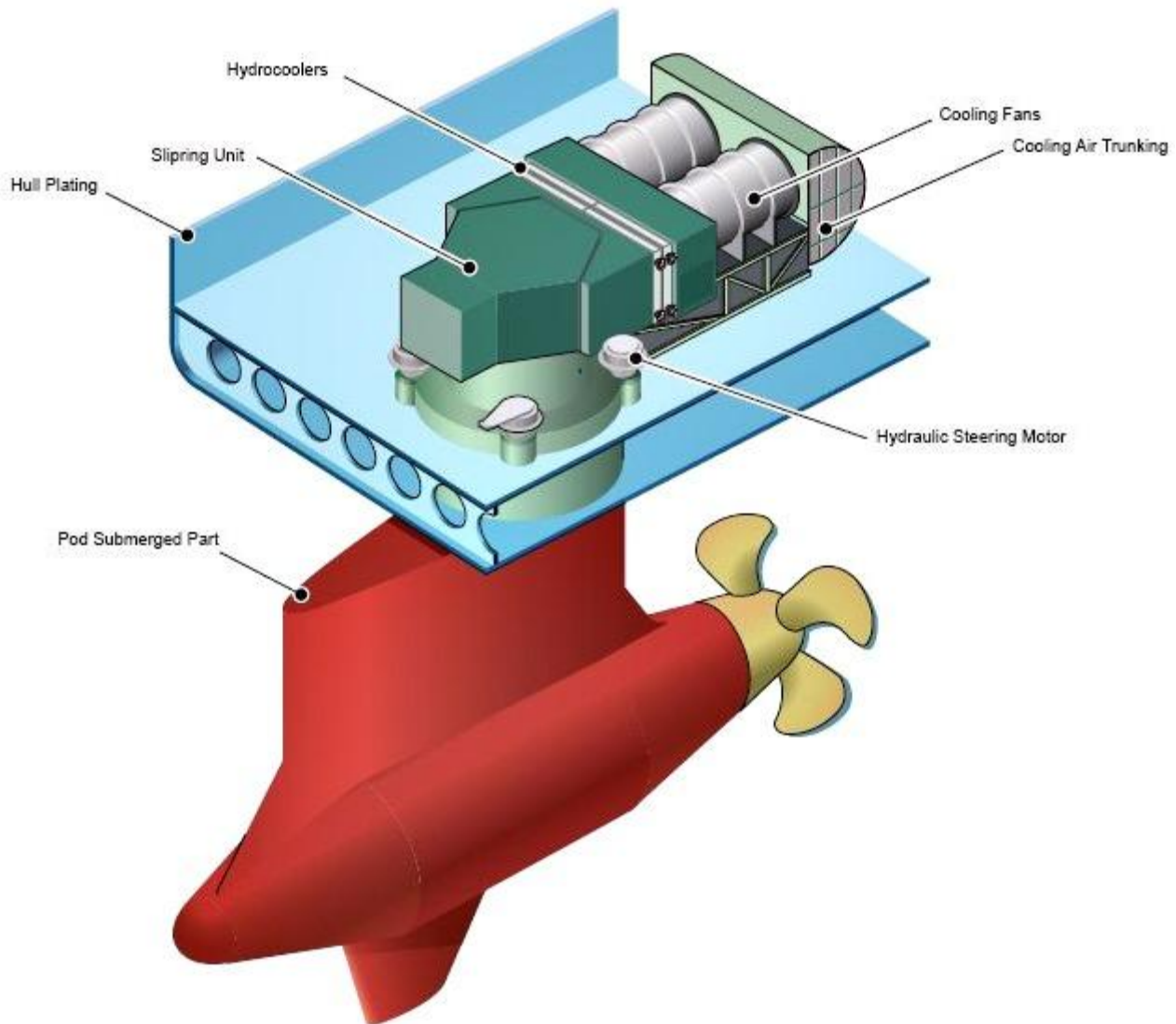


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New Azipod propulsion systems have major impact on the cruise ship's operating efficiency, reducing energy consumption and bad emissions by up to 20%.

4.6.1 Azipod cruise ship propulsion system

Azipod cruise ship propulsion system is situated outside hull in aft of the ship. Azipod turns in all directions (360 degrees) by a rudder, providing thrust in any directions, not possible for conventional systems.



(<http://www.cruisemapper.com/wiki/752-cruise-ship-engine-propulsion-fuel>)

The azipod is actually an electric propulsion system consisting of the following main components:

- Propulsion motor - used to produce or drive thrust. Rotating of the propeller is done by help of electric motor.
- Supply transformer - power produced by generators is 6600 KV, that is stepped down to necessary voltage by supply transformer and is provided to the motor in the pod.
- Frequency controller - used to change frequency of supplied power so that rotating motor speed can be controlled.

Azipod marine ship propulsion is a combination of both steering and propulsion systems. Conventional marine propulsion systems use two stroke engine connected to shaft, that passes through stern tube and shaft tunnel to connect to the propeller outside hull in aft part of ship. This system's steering is done by help of a rudder in the aft of propeller. The above photo shows Allure cruise ship's propulsion Azipods (2 units) before mounted onto the hull. Next photo shows the Oasis cruise ship's propulsion Azipods (both units as mounted on the hull).

The 3rd Oasis-class ship - Harmony of the Seas, is currently the most technologically advanced and energy-efficient cruise vessel ever built. It is equipped with a new-generation exhaust gas cleaning system (multi-stream scrubbers) and also features a hull lubrication system allowing the ship to float on air bubbles (created around the hull) thus reducing drag and increasing fuel efficiency.

However, the steering and propulsion systems in azipod arrangement, are combined into one part and the system consists of propeller (driven by electrical motor) turned by rudder (that is connected to the azipod system). The motor is inside the sealed pod, connected to propeller.

These ships incorporate a complete ABB propulsion - Azipods, electric power plant, computer automation and software. Crystal cruise ships are powered by two "Azipod D" units allowing navigation in polar destinations. Each of the Star Cruises "Global-Class" vessels has three "Azipod XO" thrusters. All ships have installed ABB's "Intelligent Maneuvering Interface" and the "OCTOPUS" software optimizing fuel consumption and energy management. All these ships were constructed by the German shipbuilder MV Werften. Currently, almost 2/3 of all large-sized cruise vessels, icebreaking ships and high ice-class cargo ships are with Azipod propulsion.

Advantages of Azipod propulsion marine systems

- A lot of space is saved by Azipod cruise ship propulsion system in the engine room - there is no propeller, engine, shafting or other arrangements. This saved space can be used for storing cargo.
- Great maneuverability - the propeller can turn in all directions and enables crash maneuvering stop distance that is better than conventional system's.
- Azipod cruise ship propulsion system can be placed below ship's height and provide more efficiency than conventional systems.
- In case the ships have large breadth, two (or more) azipod systems, independent from one another, can be used to provide subtle maneuvering.
- Side thruster's use is eliminated as pods can be used to provide side thrust.
- Low lube oil and fuel consumption.
- Lower vibrations and noise than conventional systems.
- Because emissions are low, it's environment friendly.

Disadvantages of the Azipod marine propulsion

- Requires great initial cost.
- Many diesel generators are needed for producing power.
- Power produced by motor is limited - the maximum available power now is 21 MW.
- Azipod cruise ship propulsion system can't be installed in heavy cargo ships which need large motors and a lot of power.

4.6.2 Royal Caribbean Quantum-class cruise ships propulsion

In April 2012 ABB made an USD 60 million contract to provide the Azipod propulsion systems for the new Royal Caribbean ships of the Quantum-class (Quantum, Anthem, Ovation) and Quantum Plus-class (Pulse, Passion). The former name of this vessel design was "Project Sunshine". Builder is Meyer Werft (Papenburg, Germany).

ABB also supplies the power generation, distribution systems, bow thrusters, and of course, the 2 x 20,500 kW propulsion Azipod XO units (at the photo at right), transformers and drives.

4.6.3 Epic cruise ship pod-propulsion

When entering service in 2004, the Cunard's QM2 was the biggest in the world at 150,000 GR tonnes. Her designer Stephen Payne showed the advantages of pod-propulsion giving vessels increased manoeuvrability. The propellers (screws) of the QM2 ship are mounted on the pods which rotate 360 degrees and provide advanced manoeuvrability. He made the choice to put pods - though relatively new and yet untested for big ships. Royal Caribbean vessels of Oasis, Freedom and Voyager classes have pod-propulsion as many other big ships, which is opposed to the fixed traditional screws which push in one direction only.

An interesting fact about cruise ship propulsion is that Norwegian Epic doesn't have pods, though slightly bigger than Queen Mary 2 (at 153,000 GR tonnes), because of NCL concerns about the new technology. Some of the lines (including Celebrity and Cunard) have suffered vessel breakdowns due to pod-bearing failures. Lots of voyages had to be cancelled, extensive dry-docking periods required for pod bearings to be replaced, and NCL didn't want to take the risk.

Currently, NCL Norwegian Epic has two rudders conventional non-Azipod screws. But how does she manage to manoeuvre if they can push in one direction only? One option is to make them bigger and more effective when manoeuvring, another is to add additional mini-pods or install full-sized pods. Only time will tell if any of these will actually ever happen.

4.6.4 Rolls-Royce cruise ship propulsion system "Promas Lite"

In November 2013, the manufacturing giant Rolls-Royce upgraded the Hurtigruten's cruise ship with its new, more fuel efficient "Promas Lite" propulsion system (integrated propeller-rudder system). This is an older ship, and Promas Lite was the perfect choice as it is a combined "propeller-rudder" system increasing the efficiency of older passenger vessels with lesser tonnage. The upgrade significantly reduced Hurtigruten's operating costs on this vessel. The improved propeller efficiency was estimated to be between 11-14% at cruising speed of 15 kn (17 mph / 28kph).

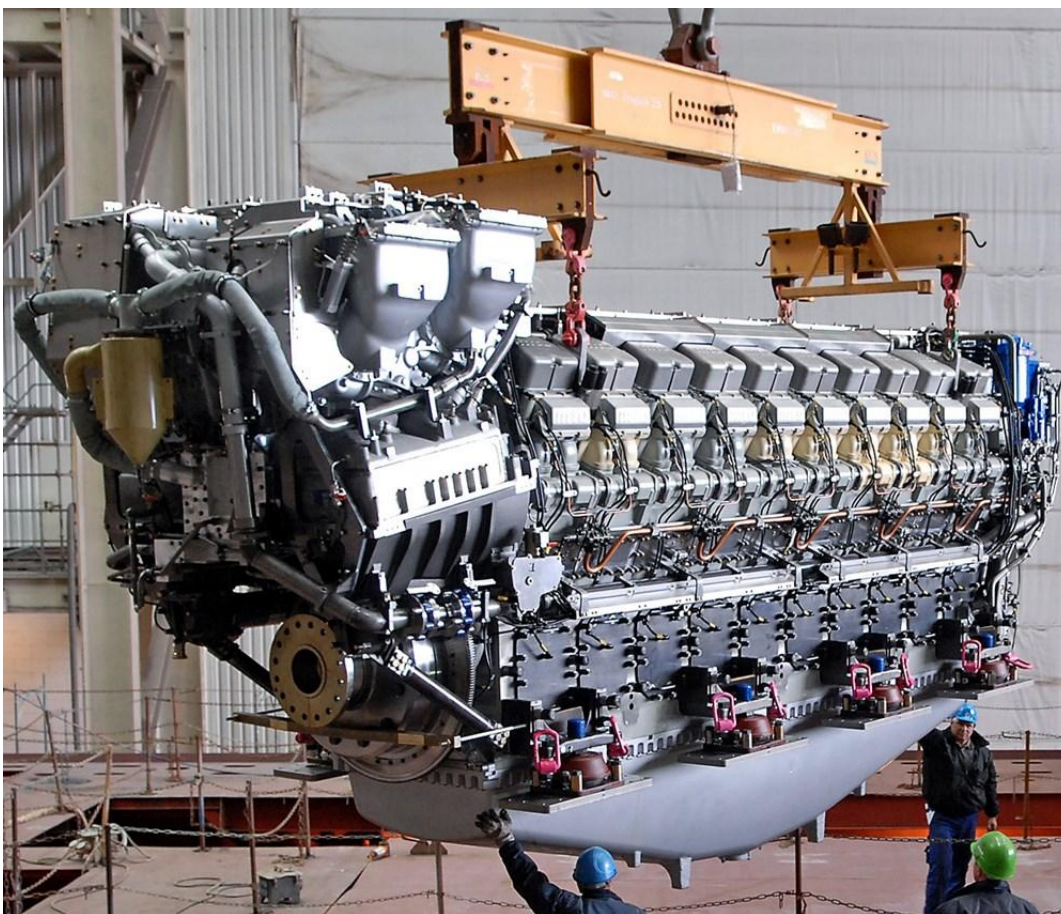
- Promas propulsion integrates propeller, hubcap, rudder bulb and the rudder into a single unit which can increase propulsion's efficiency by 3-8% (1-screw vessels) and by 2-6% (2-screw vessels). It also improves manoeuvrability, reduces fuel consumption and bad emissions.
- The new modular technology allows efficient and cost-effective custom-made systems to be built up from various existing and standard parts - mooring winches, anchor cable lifters, warping heads.

Hurtigruten was compensated with ~80% of its total investment in Promas Lite marine propulsion upgrades as the Norwegian Government has this NOx fund encouraging shipowners and operators to upgrade their vessels and invest in new marine technologies that reduce NOx emissions. The Promas Lite propulsion future clients, besides passenger ships, are marine vessels like fishing and freighter ships.

- After Norwegian Spirit (the first ship in NCL fleet with installed Promas Lite in 2011), in May 2014 the Star Cruises ship SuperStar Virgo became the first Southeast Asia cruise ship with the RR's Promas Lite propulsion.
- Fincantieri used Rolls-Royce's "Promas Lite" propulsion for all Viking Ocean Cruises ships.

4.7 Cruise Ship Power

The cruise ship engine power is responsible for driving propellers, and the other possibility is producing electricity that is used subsequently to drive propellers. Engine's effectiveness depends not only on the design but also the shape, weight and size of the ship. Power is measured in horsepower traditionally - one horsepower equals 746 watts. Next photo shows world's largest cruise ships' engine that powers each of the Royal Caribbean Oasis-class vessels.



(<http://www.cruisemapper.com/wiki/752-cruise-ship-engine-propulsion-fuel>)

4.7.1 Marine steam engines

Cruise industry began in 1844, when ships were propelled by steam engines, performing the driving of propellers by using steam as working fluid. The largest passenger steamship (before hitting an iceberg on April 14, 1912) was the Titanic, powered by both reciprocating engines and turbine, able to generate 50,000 horsepower (37 megawatts).

4.7.2 Marine diesel engines

Usually, ships are powered by four or five generator sets (medium-speed, 500 revol. per minute), fueled by diesel and creating 8-10 megawatts energy each. Power density of marine diesel medium-speed engine is 80 kilowatts per cubic meter. Ships that use diesel engines are required to carry exhaust-treatment systems and catalytic-reduction equipment to reduce the environmental impact.

4.7.3 Marine nuclear power engines

The building of the US first and only merchant nuclear-powered ship was commissioned in the 1950s by President Eisenhower. Of total cost \$46.9 million, on the fuel core and nuclear reactor was spent more than \$28 million. The ship operated only for five years (1965-1970) but due to the high running costs its service was terminated.

4.7.4 Marine gas turbines

The first company that fitted cruise vessels with gas turbines, was Royal Caribbean. Gas turbines are greener than diesel engines and allow ships sailing with reduced inventory and smaller maintenance crew. Gas turbines drive generators which in turn provide electricity to propeller motors. They recover heat from gas turbines' exhaust, which then is used to produce the electricity needed for onboard services (air conditioning, water heating).

Rolls Royce is the manufacturer of the world's largest GAS marine turbine "Rolls-Royce MT30". The turbine will provide the immense 109 MW of power for the 2 propellers, all the weaponry, radars, command sys, etc. of the new generation UK aircraft carriers of the Queen Elizabeth class. To this class belong HMS Queen Elizabeth (to be launched 2017) and HMS Prince of Wales (to be launched in 2020), each of them with a total power consumption of 80 MW.

4.7.5 Gas-turbine cruise ship power system

The first large vessel to use a new gas-turbine cruise ship propulsion system was Celebrity Millennium. This system will be more frequently used in new cruise ship buildings. It's innovative and, besides new activities available, economy of scale, marketing, represents an important element of ship design. System's advantages include:

- lower vibrations and noise level, better comfort, lower probability of failure;
- lower exploitation costs because of the easier maintenance;
- nocive emissions reduction, which is partially owed to gas oil instead of fuel (-90% oxide of sulphur; -80% oxide of azote).
- considerable gain of weight and volume, especially when with Azipod marine propulsion system (900 tons, 70 cabins added).

Gas turbines at this time are only interesting in building of high speed ships (warships, and especially aircraft carriers, or fast passenger vessels - Millennium max speed is 25kn), because of the better diesels' output in lower speed and higher price of gasoil instead of fuel for diesel engines.

Gas turbine cruise ship propulsion systems are able to avoid pre-heating systems needed for fuel in classic installations (risk of fire!), since they use gasoil. 1000 less important quantity of lubrication's oil is needed, too. Besides the other Millenium class ships ordered in Chantiers de l'Atlantique, Vantage class ships that use similar gas systems are the RCI-Celebrity group at Meyer Werft - the Radiance series. This fact is a turn in the search of lower costs for companies and lower prices for passengers.

4.7.6 LNG-powered cruise ships

In June 2015, Carnival Corporation announced the company's contract with Fincantieri to build four LNG-powered vessels with the industry's largest passenger capacity. This is part of the order with Meyer Werft and Fincantieri for a total of nine ships to be built in the period 2019-2022. The four new cruise ships will be the industry's first LNG (Liquefied Natural Gas) powered vessels using LNG in their hybrid engines. The gas is stored on the ship and used to generate all the power while at sea. The new Carnival ships' engines are not exclusively LNG-powered, but "dual fuel" (capable of burning both liquid marine fuel and natural gas). This design is for saving onboard space (reducing fuel storage space that is required).

The new fuel eliminates all the bad emissions - soot and sulphur oxides. In April 2016 MSC Cruises announced its contract with STX France for up to four LNG-powered ships with GT over 200,000 tons each. For comparison, Oasis of the Seas is 225,000 GT tons. The new MSC ships have 5400 passengers capacity at double occupancy each. The first one is scheduled for delivery in 2022. Its power plant will be based on a new prototype engine.

Using LNG to power large cruise ships is a new (2016) concept. Due to the LNG tanks' large sizes, this fuel is used usually on smaller passenger shipping vessels (ferries) operating on short itineraries. LNG bunkering facilities available in ports are very few. Compared to other fuels (including the marine gas oil), LNG is purer (no unburned residues, less greenhouse gas), more efficient, stable and cheaper (reduces fuel costs). The LNG technology also advances due to the IMO's future maritime emissions regulations, especially in ports and while operating in environmentally sensitive destinations.

The LNG cruise ship concept was first introduced by Wärtsilä (Finnish manufacturing company) and is based on drive shaft propulsion instead of azipods. The LNG tanks' location is in the upper deck area (right below the funnels). The Rolls Royce concept is based on azipods.

- AIDA prima (2016) is one of the world's most technologically advanced cruise vessels. The ship rides on a cushion of air, thus reducing frictions and fuel consumption, The new technology is called MALS ("Mitsubishi Air Lubrication System"), allowing the liner to glide on a air bubbles carpet.
- The ship's 4 main engines are dual-fuel (heavy oil and LNG gas oil) thus reducing fuel consumption. The ship has an advanced filtering system that reduces stack emissions

(greenhouse gases). The ship's propulsion features 1 pair of stabilizers and 2x ABB-pod drives (new XO-Pod series, power output per unit: is 3 MW). Total power output is 48 MW.

- AIDAprima is also the world's first ever "LNG cruise ship" as it uses LNG fuel supply while berthed in ports.

4.7.7 AIDA's LNG-powered cruise ships

The AIDAprima ship's first successful test run for LNG supply was in Hamburg Germany on May 7, 2016. While berthed, the ship was successfully provided with LNG at all the itinerary's ports of call (Hamburg, Rotterdam, Le Havre, Southampton, Zeebrugge).

- Company's statistics show that the AIDA ship spends about 40% of its operating time in ports. Compared to using conventional marine diesel (0,1% sulfur content), by using LNG the vessel's emissions were considerably reduced even further - Sulfur oxides and soot particles were prevented completely (while in port), nitrogen oxide emission were reduced by up to 80%, CO2 emissions were lowered by 20%.
- The AIDA ships (produced by Meyer shipyard in Papenburg) are 100% LNG-powered.
- AIDA Cruises invested in research and testing of LNG cruise ship technologies since 2015. In 2013, AIDA collaborated on LNG hybrid barges with Becker Marine Systems. The innovative and flexible solution is used on ships moored in Port Hamburg.
- Since May 30, 2015, AIDASol is regularly supplied with low-emission LNG power at Hamburg's Hafencity Cruise Terminal.
- AIDA ships use just 3 liters (0,8 US gallons) of fuel on average per person on board for a 100 km (62 ml) trip. This was confirmed by an independent expert study in 2012.
- Thanks to the use of new technologies and the economical handling of resources, additional progress was made. Company's statistics for 2016 (over 2012) showed 9% less energy used per person on board, reduced water consumption per person on board (by 7,2%) and reduced CO2 emissions (by 7,7%).

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