Marine Fuels and Engines

By Chris Townsend, E.I.
Naval Architect, Guido Perla & Associates, Inc.

Marine propulsion starts at the prime mover and ends at the propeller. In this, the second article in our series of marine propulsion systems, we will discuss the most common types of marine prime movers and the different fuels that they use. Many factors go into deciding which prime mover best fits a given vessel.
These factors include the intended service of the vessel, as well as the weight, size, regulatory compliance, and cost of the prime mover. Cost considerations typically include the initial cost of the engine, lifetime maintenance expenses, and fuel cost.
Optimization of fuel costs can be achieved one of two ways: choosing an engine that burns the cheapest fuel possible, or choosing an engine that is particularly fuel-efficient.
A combination of these factors can also be cost-effective over the life of the engine.One of the flaws in choosing an engine that burns the cheapest fuel available is the unpredictable nature of both global and local marine fuel markets. Prices could go up, prices could go down, or regulations could limit or prohibit the use of certain types of fuel.

Fuels

The selection of a primary fuel can be influenced by other factors, such as storage arrangements and auxiliary systems associated with the chosen fuel type. Consider briefly the major types of marine fuel in use today:

Heavy Fuel Oil (HFO)

-Historically the least expensive of in use marine fuels, heavy fuel oil is used extensively in the low-speed reciprocating engines that power many of the world's largest commercial vessels.
Though the cost of the fuel is low, the use of heavy fuel oil for marine propulsion requires a cleaning system to remove excess impurities, as well as a heating system to lower the viscosity for efficient combustion. The energy required to deliver the fuel to the engine ready for combustion is quite high. The space and weight required for the heating and treatment systems associated with HFO make using this type of fuel impractical for smaller vessels.
Ever growing emissions standards are also making the primary use of HFO

SeaNG Rendering One of three Compressed Natural Gas (CNG) carrier versions designed by Guido Perla & Associates, Inc. This 118-meter vessel carries 50 mmsCF of CNG in 16 coselles and features a dual-fuel mechanical drive propulsion system.

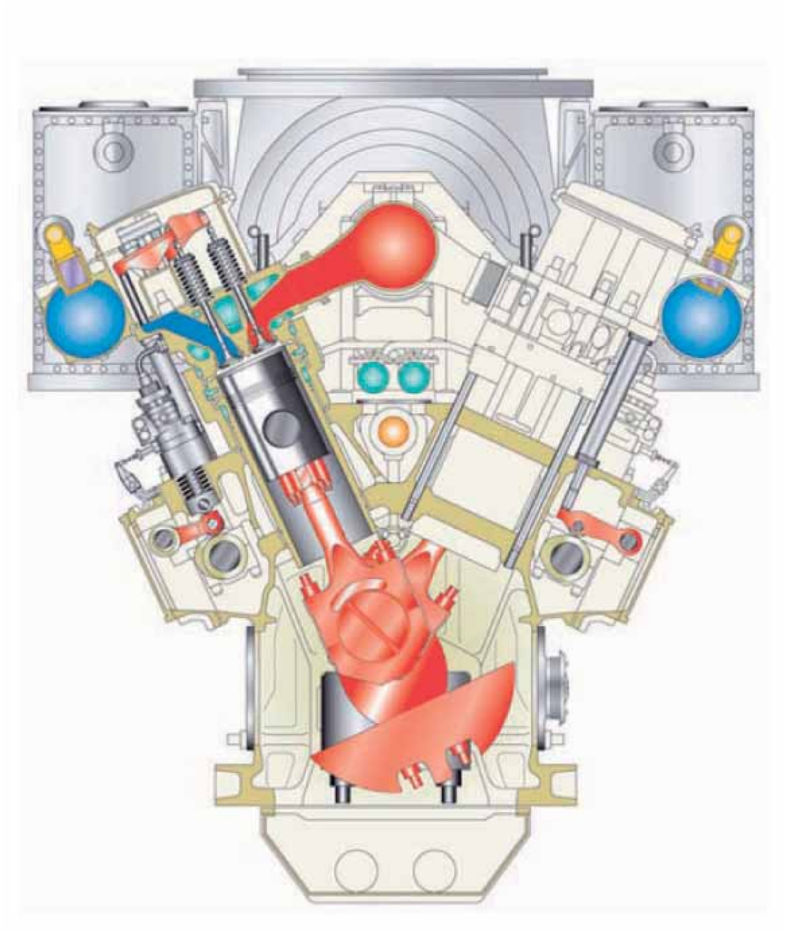
more expensive and less practical.
New regulations allow for the creation of Sulfur Emission Control Areas (SECA), in which levels of sulfur emissions must be below those achievable when burning currently available HFO.
This requires that a vessel be rerouted around the SECA, install a scrubber system to remove sulfur from emissions, or switch to a more expensive low-sulfur distillate fuel while transiting the SECA.
Reports from refiners indicate that there is little interest in developing the technologies necessary to dramatically reduce the sulfur content of HFO.
Instead, the refiners argue money should be spent on increasing the overall refining process, yielding more distillates from residual wastes.

Marine Diesel Fuel/Marine Gas Oil
These fuels are blends of distilled fuel combined with small amounts of HFO. They have lower levels of sulfur content than HFO and are cleaner burning.
Though these fuels are more expensive, elimination of heating and extensive treatment systems help justify the higher costs.

Current and future regulation will further restrict the allowable levels of sulphur in distillate fuels, reducing pollution but almost certainly increasing costs as well.

Natural Gas
First commonly used in marine propulsion on LNG vessels, natural gas is now becoming a more popular marine fuel, primarily due to its clean burning charac-teristics, producing signi-ficantly less carbon dioxide than other fossil fuels for the same amount of heat generated. LNG additionally produces less NOx, SOx, and particulate matter than traditional liquid fuels.
Natural gas must be stored as a liquid under pressure, and then warmed to a gas before combustion, creating some challenges in storage and piping arrangements.

Nuclear
Nuclear fuel for marine propulsion, perhaps the most controversial of all propulsion fuels, is typically limited to large capital military vessels. These vessels take advantage of the essentially unlimited cruising range nuclear propulsion provides, without being unduly burdened by the size and weight associated with the nuclear reactor. The high power density and high endurance capability of a nuclear propulsion system also makes it an attractive choice for icebreaking operations. However, there are certain drawbacks to nuclear propulsion that generally limit its use to military vessels.
These constraints include the necessity for specialized (and expensive) manning, high initial cost, the complexities of handling and disposing of nuclear materials, and extremely stringent worldwide regulation.



MAN Diesel Engine Cross Section
A cross sectional view of the vee configuration version of the MAN Diesel 51/60DF dual-fuel gas engine. This versatile prime mover is being installed in LNG carriers, as well as car and passenger ferries. (Image courtesy of MAN Diesel)

Biodiesel
Biodiesel is a clean burning alternative fuel that is gaining traction in the marine industry. As its name suggests, biodiesel is a fuel similar to diesel, but contains no petroleum products. Biodiesel is created through a chemical process called trans esterification, which separates glycerin from fat (such as soybean oil). When done in the presence of alcohol, this process leaves behind methyl esters, more commonly called biodiesel.
This type of fuel can be used in a typical com-pression type reciprocating engine with little or no modification.
Biodiesel burns cleaner than conventional diesel distillates, in addition to being made from renewable sources - these factors make biodiesel very environmentally friendly.

Engines

The generation of power, whether to send down a shaft or an electrical cable, has been at the core of marine propulsion since the application of steam power to ships in the late 19th century. Years of refinement and fine-tuning have resulted in a large array of possible prime movers suited to many different ships in a wide variety of services.

Internal Combustion Reciprocating
The most common type of marine propulsion prime mover is a reciprocating internal combustion engine (such as a diesel engine). This type of engine is characterized by the intermittent rapid burning of air and fuel inside a combustion chamber, releasing energy that moves a piston, yielding linear motion that is converted into rotational motion.
Reciprocating internal combustion en-

gines typically fall into one of three categories describing the speed at which the engine rotates. Low-speed engines typically rotate between 100 and 500 RPM.

Medium-speed engines rotate at speeds of 700-1200 RPM. High-speed engines generally rotate at 1800-4000 RPM. The particular advantages and disadvantages of each of these types of engines must be understood to properly match the engine to the application. Low-speed engines are large, heavy, and expensive, but pay dividends on lower fuel, operating, and maintenance costs when compared to a high-speed engine of the same output. Installation of a low-speed engine can also eliminate the need for a gearbox, saving further cost and weight.

Perhaps one of the primary advantages of a recipro-cating internal combustion engine is the widespread acceptance and use of this type of engine in the marine industry. The high production numbers drive down cost and promote reliability, while allowing for easy access to parts and trained mechanics.

Reciprocating internal com-bustion engines are not without fault. At the larger end of the spectrum, they do not have good power-to-weight ratios, though this is generally offset by greater vessel displacement.

Reciprocating internal com-bustion engines are capable of burning a variety of different fuels. Use of heavy fuel oil is traditionally limited to use in low-speed engines, but marine diesel fuel and natural gas are suited for a wider range of engine speeds. Natural gas can be used in a slightly modified diesel engine in a dual-fuel arrangement. Diesel is injected as pilot fuel to ignite the natural gas, which will not detonate under extreme compression alone. Alternatively, natural gas can be used as a sole fuel source in a spark-ignited reciprocating internal combustion engine. As mentioned previously, diesel engines can also be made to run on biodiesel with little or no modification necessary.

Diesel engines are well suited for a wide variety of marine applications - in fact diesel engines can be found in nearly every type of commercial marine vessel, from passenger vessels to tug boats. Diesel engines have recently gained traction in LNG tanker propulsion, marking a shift away from burning boil-off gas. Though the installation of a reliquefaction plant adds complexity and cost to the vessel, rising market prices of LNG cargo and the greater achievable efficiency of dual-fuel and diesel-electric propulsion systems has made this option attractive and financially viable.

Internal Combustion Rotational

Rotational internal com-bustion engines (such as a gas turbine) are also utilized for marine propulsion. This type of engine is charac-terized by continuous combustion of air and fuel and conversion of this energy directly into rotational motion.

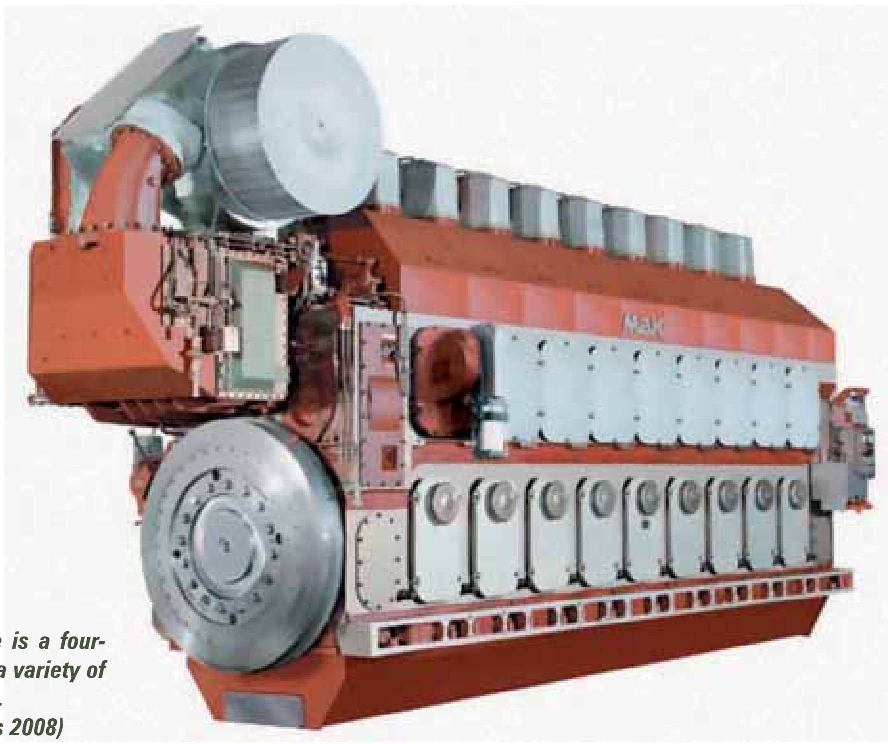
The principle advantage of installing a gas turbine engine is the large power-to-weight ratio this type of prime mover can achieve. The compactness of the engine eases maintenance and downtime - the small size makes it possible to quickly swap out turbines instead of spending time at the dock doing in-place maintenance or repair. The relative simplicity of the engine is another secondary advantage - there are fewer moving parts, none that reciprocate.

Some of the disadvantages of gas turbines are the strict inlet and exhaust pressure requirements, the need for large, heavy gearboxes - particularly if used in a direct drive configuration, high exhaust gas temperatures, higher initial cost, and lower relative fuel economy - particularly at idle. A gas turbine can burn nearly any grade of refined petroleum such as marine diesel fuel and kerosene, as well as natural gas. Though these fuels are expensive, the gas turbine's fuel flexibility makes it attractive for volatile fuel markets.

A gas turbine works well in high-speed applications, where weight is always a concern. Additionally, there is a growing market for gas turbines in vessels that cannot afford excessive downtime, such as shuttle tankers

External Combustion Rotational

Though internal com-bustion engines (parti-cularly diesel internal combustion engines) are the dominant source of power in the marine industry, a rotational external combustion propulsion plant (such as a nuclear-powered steam plant) still plays an important role in certain services. An external combustion engine heats the working fluid (typically



MaK Diesel
The MaK 9 M 43C propulsion engine shown here is a four-stroke medium-speed diesel engine, well suited to a variety of common applications on intermediate-sized vessels.
(Image Copyright Caterpillar Marine Power Systems 2008)

steam) outside the mechanism (turbine), upon which the working fluid expands, producing rotational motion.
Like their gas turbine counterparts, a steam turbine's advantages include the simplicity of fewer moving parts that rotate, a good power-to-weight ratio, and compact size. The steam boilers, however, which are neither small nor light, are a necessary compromise in this type of system.
A steam system also requires constant upkeep and maintenance. Further disadvantages include a slower response time compared to internal combustion engines, both from a cold start and while underway.
In most modern steam applications, steam is generated one of three ways - burning marine diesel, burning natural gas, or using nuclear fuel.
Large vessels are the most practical platform for a traditional steam power plant, regardless of the heat source. The nature of their size requires a substantial installation of power, but also allows for the installation of a large, heavy propulsion system without an excessive penalty to the vessel's performance.

Conclusion

The real change in marine propulsion in recent times hasn't been the types of engines installed, but the fuels that power them. Regulatory and environ-mental changes are shifting the industry away from the exclusive use of HFO, towards cleaner burning distillates. LNG is undergoing a radical shift as it becomes less popular as a fuel for LNG tankers but more common in environmentally friendly ferry, tug, and PSV operations.
Even nuclear power for commercial ships is an old idea being resurrected. In this day and age, prime mover selection must be a balance of modern environmental consciousness and old world economic savvy.

References:

- "Biodiesel Basics"
  <http://www.biodiesel.org/resources/biodiesel_basics/>

- "Natural Gas and the Environment"
  < http://www.naturalgas.org/environment/ naturalgas.asp>

- Palomares, Miguel. "IMO Takes on the Environmental Challenege." Surveyor. Fall 2008. 2-4.

- Rauta, Dragos. "Towards Cleaner Fuel." Surveyor. Fall 2008. 21-23.

Source: Maritime Reporter & Engineering News November 2008
www.marinelink.com