

The Correlation between Offshore Vessel Design Trends and Operational Challenges

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In recent years, the offshore industry has been confronted with several operational challenges resulting from vessel deployment in deeper waters and harsher environments as activities for oil exploration and production venture further from shore. Along with these operational progressions comes a significant increase in vessel quantities needed as a direct result of a growing total number of drillings rigs, as well as the necessary replacement of obsolete offshore vessels. The total number of drilling rigs has increased 46% worldwide since 1981 (Figures1/2).¹

First generation Offshore Support Vessels, of which most are about 25 years old, may still have an economic advantage in shallow water operations due to their lower purchase cost but other pressures are quickly replacing these vessels, as they cannot fulfill technical, safety, or comfort requirements.

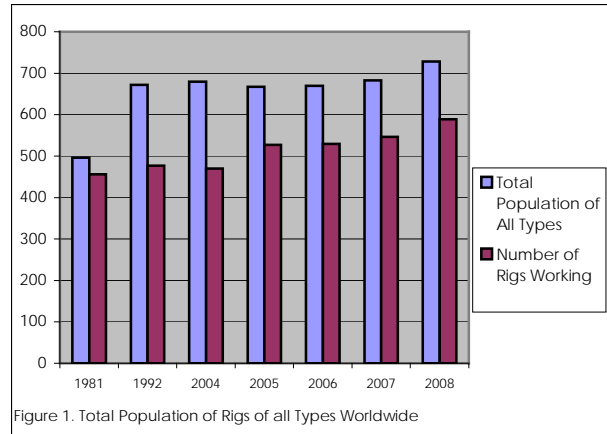


Figure 1. Total Population of Rigs of all Types Worldwide

Modern Offshore Vessels Exceeding Prior Standards

These circumstances have generated design trends producing more advanced, larger, environmentally friendly and safer Platform Support Vessels pushing 100m in length, with some designs in excess of that. Coupled with operations in more difficult conditions is the need for increased cargo capacities and greater product variety to ensure profitable operations. Deck areas in excess of 900m² facilitate increased deadweight capacities of 2,500 – 5,000 mt to meet the requirements for serving deepwater markets by carrying increased amounts of drill pipe, mooring lines and other deck cargo.

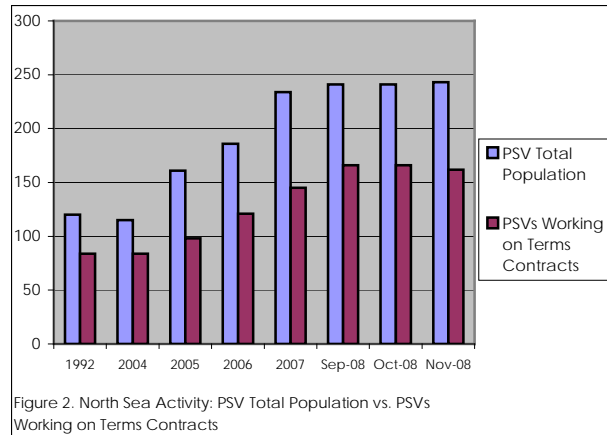


Figure 2. North Sea Activity: PSV Total Population vs. PSVs Working on Terms Contracts

Integral cargo tanks are also pushing the limits of traditional OSV capabilities by allowing a greater variety of products to be transported to offshore installations, providing capacities in excess of 2,400m³ for liquid mud in addition to traditional amounts of bulk mud, fuel oil, excess fuel, drilling brine, rig water, cargo fresh water, as well as special products, such as methanol if required. These increases in vessel size are also accompanied by stringent environmental regulations. To further increase cargo transporting flexibility, advanced multi-purpose tanks capable of carrying either dry bulk, liquid mud, fuel oil or drill cuttings in the same tanks, as well as ORO (Oil Recovery Operation), are currently under development. While the principle of multi-purpose tanks is not a new concept, modern tanks are aimed at simplifying cleaning and the change of cargoes from liquid to dry cargoes and have been incorporated into future GPA designs.

¹ *Offshore Industry Market Report*. Kennedy Marr, 2008, p. 3-4.

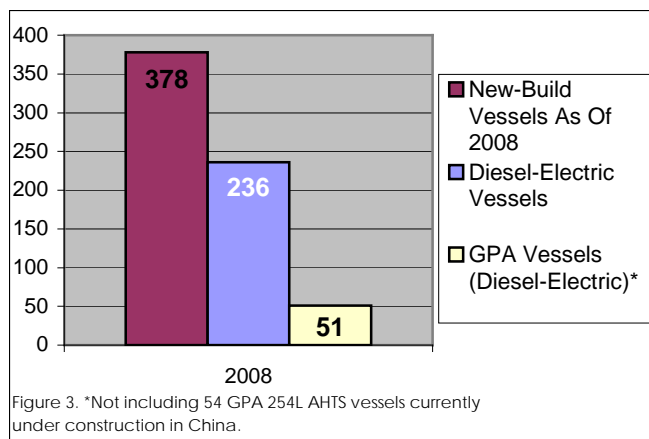
Diesel-Electric Propulsion Systems

Incorporating diesel-electric propulsion systems into offshore designs allows vessels to fulfill the increased cargo space demands. Vessels equipped with a diesel-electric system benefit from the elimination of the drive shaft and therefore the potential for increased tank volumes. GPA designs, such as the 64-meter GPA 640 PSV and the 70-meter GPA 670 PSV, are equipped with diesel-electric systems and have been proven to be very efficient solutions for their owners and operators.

Diesel-Electric Propulsion - Exploiting the System

Diesel-electric Propulsion systems can even surpass the increased cargo space demands if the design exploits the system's advantages and flexibility by locating the engine room above the main deck, a concept pioneered by Guido Perla & Associates, Inc., several years ago. The first vessels worldwide outfitted with and benefiting from this concept are ten of the 54-meter GPA 654 PSV vessels delivered in 2008. This innovative concept, which has been applied in other GPA designs, allows cargo capacities below deck to be increased by 30%,

akin to capacities found in much larger vessels.



For 2008, the number of new-build PSVs/OSVs, delivered or under contract, reached 378 vessels, of which 236 vessels are designed to be equipped with diesel-electric propulsion systems. 51 of these diesel-electric vessels are of GPA design, not including the 54-vessel GPA 254L AHTS series currently under construction in China (Figure 3).²

The industry-wide acceptance of and tendency towards employing diesel-electric systems demonstrates evidence of the improved efficiency and flexibility of the system compared to direct-drive systems.

Growing Construction Capacities

To support the increasing production capacities, existing shipyards have taken measures to expand their facilities while new shipyards solely focused on offshore vessel construction have been established. For example, Sino Pacific Group in China invested in two new shipyards, Zhejiang Shipyard and Dayang City Shipyard, and has become a key player in offshore vessel construction.

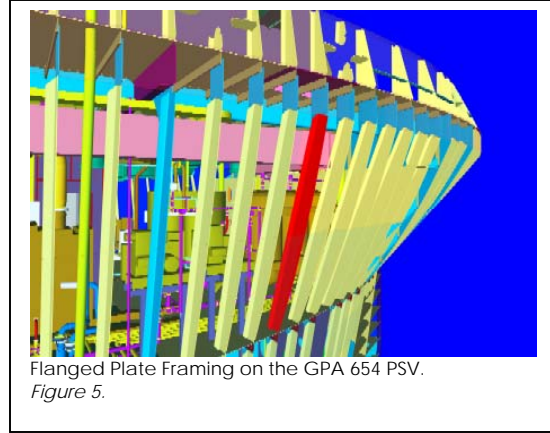
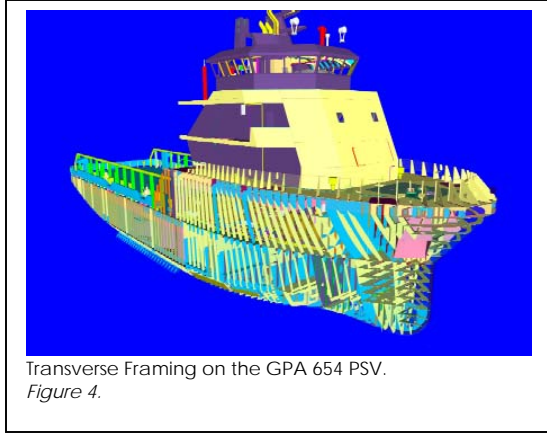
The maritime industry has not encountered such a multitude of construction projects since the Liberty Ships of World War II. With immense efforts, 18 shipyards in the United States built 2,751 cargo ships of identical design in the years of 1941 – 1945.³ The vessels, referred to as the Liberties, served as an inspiration in the designation of the Bourbon Liberty series totaling 76 vessels, which are of GPA 654M PSV and GPA 254L AHTS design, and are currently under construction at Zhejiang and Dayang City Shipyard.

² *OSV Newbuilding Report*. December, 2008

³ *American Merchant Marine at War*. Retrieved December 19, 2008 from <http://www.usmm.org/libertyships.html>

Growing Construction Capacities / Measures to Support the Large Construction Volumes

To facilitate the rapid building of large numbers of vessels at comparably low capital costs, designs based on constructability have a significant role in these projects. Simplified construction methods, such as single-curvature hulls, transverse framing and flanged plate framing, a combination that is the standard for GPA offshore designs, contribute to decreased construction time and cost (Figures 4/5).



Single-curvature hulls, while not fully accepted yet by some, have proven to be more efficient not just during construction but also during operations. In a variety of applications, but typically for medium to large displacement vessels, a well-designed chined hull form has approximately the same resistance characteristics of an equivalent round bilge hull form. Furthermore, locating the engine room above main deck contributes to simplified construction, as well as improved and safer maintenance, as the engine room can be reached more easily.

Some modern designs include further developments to simplify and expedite construction by creating chronological flexibility of the installment of certain equipment. A well-proven concept delivering such flexibility is a Modular Electric Propulsion System. Electric Power Design, Inc. (EPD), along with GPA, brought a new development of electric propulsion systems to market by providing the actual ship's Engine Control Room (ECR) in a pre-manufactured container. The ECR, completely tested and designed as an integral part of the ship's structure, allows for the equipment to be installed and tested in a controlled environment. During installation, the ECR is simply lowered onto the vessel, secured and connected to power and control cables externally, an approach that greatly reduces the possibility of equipment damage while in the shipyard.

Constructability not only facilitates the growing demand for offshore vessels but also results in reduced man-hours, improved cost and shorter build cycles. For example, currently, a GPA offshore vessel designed for production is delivered approximately every two weeks at one of two purpose-built yards in China. Also, during the recent bidding process for the current Petrobras tenders, quotations by shipyards for GPA designs clearly demonstrated a consistent construction cost advantage in comparison with other designs, as a result of these constructability features.

Environmental Concerns

Design trends have also addressed heightened concerns about environmental degradation. Approaches to minimize the environmental impact of offshore operations are primarily regulatory driven but are also becoming corporate image driven and have had a significant impact on the offshore design evolution in recent years. These approaches focus on tank segregation to decrease the risk of oil or other hazardous substances spills, engine emissions, and on obtaining Clean Class notations.

Environmental Concerns / Developments in MARPOL Regulations

MARPOL regulations are the most significant provisions currently affecting offshore designs to improve the effects of vessel operations on the environment. Docket No. USCG-2007-27813 of the Federal Registry informed the industry that the “USCG will enforce new MARPOL ANNEX I regulations for U.S. flagged vessels that are required to hold an International Oil Pollution Prevention (IOPP) Certificate including Regulation 12A of revised ANNEX I (IMO Resolution MEPC.141 (54)) *Oil Fuel Tank Protection*”. Therefore, design requirements are established for protectively located fuel tanks for all ships with an aggregate oil fuel capacity of 600m³ and above with a building contract on or after August 1, 2007 or delivery on or after August 1, 2010.

Furthermore, the USCG plans to adopt provisions set forth by MARPOL ANNEX II (IMO Resolution A.673(16)) for “new” OSVs regarding the transportation of Noxious Liquid Substances (NLS) in limited quantities, which already applies to vessels on international voyages with liquid mud and other cargoes classified as NLSs. The requirements for vessels intended to carry limited quantities of over 800m³ of NLSs include tanks segregation and construction requirements.⁴

As a practical result of these double-hull requirements, a 3000dwt PSV of just a few years ago will need to be approximately a 4,500dwt PSV in order to carry the same amount of cargo fuel and liquid mud.

Environmental Concerns / Engine Emissions Regulations – Tier 1, 2 and 3

Vessel designs must follow increasingly stringent engine emissions regulations focused on decreasing the environmental impact of shipping. The Marine Environment Protection Committee (MEPC) of the International Maritime Organization (IMO) continuously works on improving these standards. For offshore design trends, the most relevant regulations introduce a three-tier structure for Nitrogen Oxides (NOx) emission standards for new marine engines, depending on the date of their installation, with significant emission reductions (Tier 3) mandated for ships operated within designated Emission Control Areas:⁵

	rpm < 130	rpm > 130 and < 2,000 *	rpm > 2,000
Tier 1	17.0 g/kWh	45 · n ^(-0.2) g/kWh **	9.8 g/kWh
Tier 2	14.4 g/kWh	44 · n ^(-0.23) g/kWh **	7.7 g/kWh
Tier 3	3.4 g/kWh	9 · n ^(-0.2) g/kWh **	2.0 g/kWh

* PSVs usually fall into this rpm range.

** n = rated engine speed [Crankshaft rpm].

Table 1

- Tier 1 applies to a diesel engine, which is installed on a ship constructed on or after January 1st, 2000 and prior to January 1st, 2011.
- For Tier 2, NOx emission levels for a diesel engine refer to installation from January 1st, 2011.
- For Tier 3, NOx emission levels for a diesel engine refer to installation from January 1st, 2016. Outside a designated Emission Control Area, Tier 2 limits apply.

Environmental Concerns / Clean Class Notations

In addition to complying with mandatory engine emissions standards established by IMO and U.S. EPA and other inevitable regulations in the future, adopting voluntary Clean Class notations from a Classification Society is an increasing trend. Classification societies have incorporated some compulsory regulations, such as the MARPOL ANNEX I and ANNEX II rules as an integral part of their Clean Class notations.

⁴ “Not Your Dad’s PSV”. *Maritime Reporter*, April 2008, p. 29

⁵ ANNEX 13 RESOLUTION MEPC.176(58). MEPC 58/23/Add.1, 2008, p. 14-19.

The American Bureau of Shipping's (ABS) set of Clean Class notations, referred to as ES (Environmental Safety) incorporates the provisions for IMO Resolution A.673(16) in their ABS Rules for Steel Vessels (< 90 meters). Furthermore, ES includes other requirements to address the treatment of black and gray water, ballast water treatment, and the processing of garbage.

To receive the Det Norske Veritas (DNV) Clean Class Notation CLEAN DESIGN, the design also needs to "satisfy the most important environmental aspects, including fuel tanks' protection from grounding damage, handling of sewage, garbage, ballast water and fuel oil, environmentally friendly antifouling, combustion machinery emissions (NOx and SOx), use of refrigerants and Green Passport Inventory for recycling the ship. In addition, the CLEAN-DESIGN notation stipulates defensive design, accident prevention and consequence limitation requirements, thus providing additional environmental protection".⁶

The Bureau Veritas (BV) Clean Class set of notations is referred to as CLEANSHIP and CLEANSHIP SUPER and is "assigned to ships so designed and equipped as to control and limit the emission of polluting substances in the sea and the air".⁷

American Bureau of Shipping (BS)	ES (Environmental Safety)	
Det Norske Veritas (DNV)	CLEAN DESIGN	
Bureau Veritas (BV)	CLEAN SHIP	CLEAN SHIP 7+ *
	CLEAN SHIP SUPER	CLEAN SHIP SUPER 7+ *

Table 2

* The BV notations are followed by the number of consecutive days the ships is able to operate with the full complement of onboard personnel, including crew and passengers, without the need for discharging any substances into the sea. This number cannot be less than one day (24 hours). If this period is longer than seven days, the mention 7+ is appended to the notation CLEANSHIP or CLEANSHIP SUPER.

By incorporating a Clean Class notation into a vessel design, owners demonstrate an added interest in limiting emissions and operational and accidental pollution. By taking proactive steps and assuming responsibility for the environment, operators improve their corporate image with customers and authorities.

Environmental Concerns – Fuel Economy / The Combination of Dynamic Positioning Systems and Diesel-Electric Propulsion Configurations

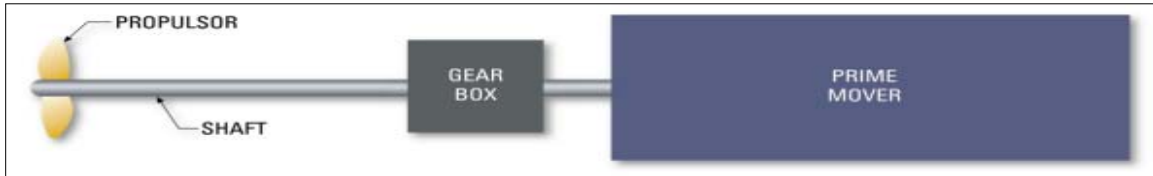
While Engine Emissions regulations, as well as Clean Class notations, address and continuously improve the minimization of measured emissions output, these standards do not enforce limitations on the actual fuel consumption and therefore fuel efficiency of the vessel. Until recently, there was not sufficient motivation to consider overall fuel consumption and efficiency for PSV/OSV operations.

The possibilities in improving fuel economy have grown through the use of diesel-electric propulsion configurations, facilitating improvements in fuel consumption and emissions by 30%. The requirements for Dynamic Positioning (DP) are detrimental to fuel economy due to operating at a reduced engine demand. Diesel-electric systems can considerably improve actual fuel consumption to mitigate this by providing greater flexibility in the use of power, especially during DP operations.

A conventional, purely mechanical system is usually equipped with large engines that are dedicated to propulsion (Figure 6). Small generators for ship's service electric power are installed, thereby limiting the size of other electric consumers, i.e. cargo pumping capacity.

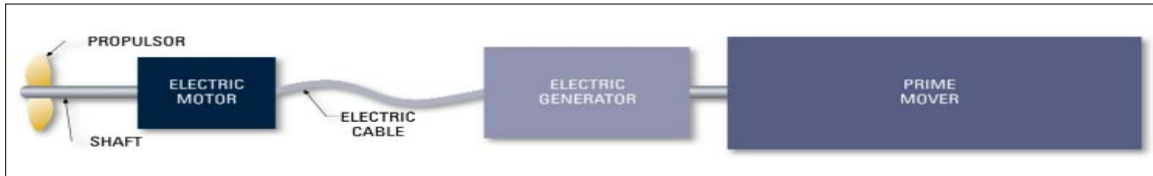
⁶ *Clean-Design*. Retrieved December 29, 2008, from <http://www.dnv.com/industry/maritime/servicessolutions/classification/notations/additional/clean-design.asp>

⁷ *Steel Ships Pt E, Ch 6, Sec 1 Comfort Notation*. Bureau Veritas, April 2007, p. 21



A Purely Mechanical Propulsion System. Figure 6.

Vessels outfitted with a diesel-electric propulsion system on the other hand are equipped with larger gensets providing power to the propulsion, as well as other electric consumers on the vessel (Figure 7). The use of the electricity produced is not limited to one application. Thus, the electric power supply on a diesel-electric vessel has greater flexibility.



An Electric Propulsion System. Figure 7.

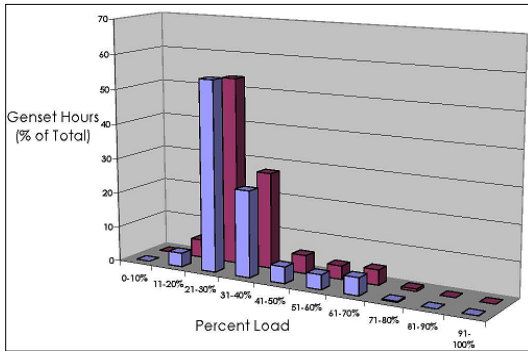
While in DP-mode for instance, a vessel only demands a fraction of the total installed power. Cargo offloading capacities can be increased to improve offloading times. Furthermore, other additional electric consumers can be added to the design, such as additional thrusters or Fi-Fi pumps without adding dedicated diesel engines to drive them.

Modern offshore vessel designs are generally equipped with advanced DP-Systems of at least Class 2 to ensure safer and more efficient operations in increasingly difficult conditions, especially while venturing further from shore for deepwater assignments (See Table 3).

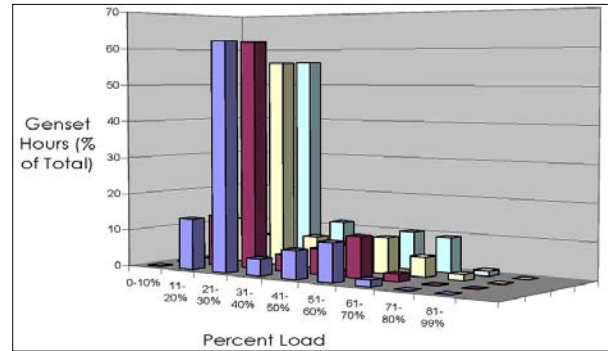
DP 0	Not considered by IMO.
DP 1	Loss of Position may occur in the event of a single fault
DP 2	Loss of position should not occur from a single fault of an active component or system such as generators, thruster, switchboards remote controlled valves etc. but may occur after failure of a static component such as cables, pipes, manual valves etc.
DP 3	Loss of position should not occur from any single failure including a completely burnt fire sub division or flooded watertight compartment.
Table 3	

Recent comparisons of fuel consumption of traditional OSVs and diesel-electric PSVs in service since 2005 demonstrate the efficiency of diesel-electric systems while at sea. The diesel-electric PSV consumed on average 16% less fuel than a direct-drive OSV. A traditional OSV tends to consume less fuel while at quay due to the smaller diesel generator. Therefore, as at-sea utilization increases, the total fuel consumption improves for the diesel-electric PSVs. Diesel-electric PSVs could therefore benefit from either installing a harbor generator, utilization of the emergency generator as a harbor generator, or by installing additional gensets as part of the diesel-electric propulsion system, thereby providing smaller increments of power.

While at sea, diesel-electric PSVs exhibit greater fuel economy due largely to the amount of time spent in DP operations, or in stand-by. However, to fulfill redundancy requirements for a DP-2 classification, the vessel must have spinning reserves of power generation in order to maintain position in the event of loss of a single prime mover. For instance, a DP-2 classified vessel equipped with two main gensets and one smaller "son" genset must have both main gensets running to meet redundancy requirements. This can result in an inefficient engine loading that is far less than the optimum of 80%. With over 50% of vessel deployment time being spent at 30% load, the most efficient solution in terms of fuel savings has not yet been reached with diesel-electric propulsion systems.



Diesel-electric PSV – Engine Hours vs. Engine Load
Figure 8.



Diesel-electric PSV (Seismic Service) – Engine Hours vs. Engine Load
Figure 9.

A potential solution to further improve fuel economy in a diesel-electric PSV could be to better configure the electric plant by installing more gensets with smaller output ratings, thus providing smaller power increments, which is especially useful during DP-mode or other reduced load operations. The smaller gensets, while providing the same total required output, would be running closer to the optimum load. This concept of matching the operational profile more efficiently is not fully embraced as it brings with it a higher capital cost, as well as higher service and maintenance costs.

Crew Safety

Though crew safety has long been a priority, modern offshore vessel designs are substantially safer than those of only a few years ago. Some safety improvements are regulatory driven, but most are voluntary, implemented by operators who have a vested interest in attracting and retaining highly skilled crews.

DP systems are perhaps one of the most prominent safety features of modern vessels. The automated station-keeping capabilities of DP systems have significantly reduced the burden on the operator while unloading at the rig, lowering the risk of crew fatigue and allisions.

Safety innovation is also playing a key role in minimizing crew exposure to hazards on deck, particularly during anchor handling operations. Work that was previously done manually while on the exposed deck can now be completed using remote-control equipment, operated by the crew from a safe distance. New techniques and equipment have also been developed for retrieving anchors, including the use of a hydraulic stern ramp to reduce the high winch loads typically encountered while decking an anchor.

Crew Comfort

Crew comfort, characterized by noise, vibration, indoor climate and lighting levels, has been acknowledged as an increasing requisite in attracting and maintaining a satisfied, efficient crew and is of prime importance in modern offshore designs. Developments in stabilizing systems and a high level of outfitting are evolving, while significantly reduced noise and vibration levels from current standards are being achieved by a combination of vessel layout, material selection and structural design. For instance, locating the engine room above the main deck creates an additional deck between the bow thrusters, a notorious contributor of noise, and the accommodation spaces, which can further decrease the noise and vibration levels. Vessel designs can adopt comfort notations from different classification societies to demonstrate improved crew comfort standards (Table 4).

American Bureau of Shipping (BS) ⁸	HAB or HAB+
Bureau Veritas (BV) ⁹	COMF-VIB-Crew x / COMF-NOISE-Crew x
Det Norske Veritas (DNV) ¹⁰	Comf-V(crn) / Comf-C(crn) Comfort Rating Number [crn] from 1-3
Table 4.	

Modern vessels equipped with a diesel-electric propulsion system further benefit from a significant vibration decrease due to the genset vibration isolation, which is not common with direct drive systems.

Design Trends – New Operational Challenges

With modern offshore vessel design trends addressing and overcoming such a variety of operational challenges, vessels have advanced to unprecedented levels of safety, comfort and efficiency. These recent developments have created possibilities to perform offshore operations at highly productive rates while further exploring undiscovered fields. With such advancements, new operational challenges are inevitable.

MARPOL Annex I revisions and the application of MARPOL Annex II to PSVs venturing further from shore has led to the need for larger vessels to maximize cargo capacities in order to keep operations profitable and efficient. With vessels exceeding previous size ranges, designs are possibly subject to stricter regulations. Under Subchapter L (46 CFR 125) for instance, offshore vessels <6,000 GRT can carry an unlimited quantity of excess fuel while vessels exceeding 6,000 GRT are categorized as tankers, which entails the enforcement of stricter regulations and places different limits on designs.

Further issues arising indirectly from increased vessel demand, improved crew safety and enhanced fuel economy are the growing difficulties to provide acceptable crew training with regards to qualitative content, as well as sufficient time dedicated to conveying the technical advances of a modern PSV to crewmembers. The developments resulting from the diverse utilization methods of diesel-electric propulsion systems, the use of more advanced equipment and DP systems exceed basic knowledge most skilled crewmembers currently possess. Not only the need for qualified DP operators and crews familiar with diesel-electric systems but also the pace of new offshore vessel construction has placed an even heavier burden on mariner training programs for operators and institutions. Some operators have established dedicated training facilities, while others use existing vessels and crews to provide training while cascading existing crews to the newly acquired vessels.

Stricter regulatory measures and crew shortages are some of the known challenges for today's offshore vessel designer. It still remains to be seen how uncertainty in the global economy will affect the marine industry. While offshore vessel designs have addressed numerous operational challenges in the past years and are pushing the limits of first generation OSVs, unforeseen challenges will undoubtedly continue to drive future design trends in the years to come.

⁸ *ABS Guide for Crew Habitability on Ships*, December 2001. p. 3

⁹ *Rules for the Classification of Steel Ships*, July 2008, p.4

¹⁰ *Comfort Class*. Retrieved January 10th, 2009, from http://www.dnv.no/maritim/shipclassification/classnotations/ships/comfort_class.asp