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Impacts of Application Light-Emitting Diode (LED) Lamps in Reducing Generator Power on Ro-Ro Passenger Ship 300 GT KMP Bambit

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Abstract

KMP Bambit is an Indonesian Ro-Ro ship that carries passengers. It is public transportation from Merauke Regency to Asmat Regency and vice versa. The ship is still using fluorescent lamps as its main lighting source. This study presents a comparative study of the efficiency level between the use of fluorescent lamps and LED lamps in the room aboard the ship. The method used is the zonal cavity (lumen) method by dividing each room into three parts, namely the height ceiling cavity (hcc), height room cavity (hrc), and height floor cavity (hfc). The illumination value was determined according to the standards set for each room. The principal results for comparing lighting power on KMP Bambit showed that the total lighting electrical load accumulated using the fluorescent lighting type was 24.31 kW. In contrast, LED lighting had a total lighting electrical load of 16.51 kW. This reduced the generator power from 68 kW to 60 kW, which could improve the efficiency of ship fuel operational costs. This study can evaluate the existing Ro-Ro ship fleet and be a good option in the process of building Ro-Ro ships in the future.

Keywords: KMP Bambit, lighting, zonal cavity (lumen) method, LED, power

1. Introduction

The Passenger Motor Ship (KMP) Bambit is one of the many Ro-Ro Ferry boats operated by PT ASDP Indonesia Ferry (Persero) transports passengers and public transportation from the Merauke district to the Asmat district and vice versa [1]. This ship was built at the PT Dumas Tanjung Perak Shipyard Surabaya in 2014 and is classed at the Indonesian Classification Bureau (BKI) with IMO number 9767302 [2, 3]. Ro-Ro ship is one type of ship that is considered the most successful in terms of world shipping because, besides being fast, this ship has flexible operating characteristics, making it more popular, especially for short routes [4, 5]. Like land buildings such as houses and buildings, ships must also be equipped with lighting sources at night. The lighting system on board ships must keep up with technological developments. So far, the lights used for the main lighting on ships are mostly still using fluorescent lamps compared to energy-saving lamps such as LED (Light Emitting Diode). LEDs provide radiation with low wattage, are cost-effective, and have a longer lifetime [6]. Other research mentions the advantages of LED compared to other lights, such as an analysis of replacing lighting fuel with LED lights for fishermen, which can provide savings of up to 50% for fishermen in Tanzania [7]. A similar study was also carried out at Victoria Lake, which tested the saving level of LED lights on fishing boats after changing the lights to LED lights [8]. Currently, the lamps on ships are still dominantly using fluorescent-type lamps. A fluorescent lamp is a tube-shaped lamp in which a certain gas is charged to produce light through a chemical reaction [9]. These lamps are more economical when compared to incandescent lamps but are still more wasteful than LED lamps [10]. It has a drawback in the form of high mercury waste for environmental pollution compared to LEDs [11].

Energy saving is a concept that must be applied in the planning process of lighting installations on ships because it involves the amount of generator power installed on the ship. Many studies on engine performance provide data that the greater the engine power, the greater the engine's fuel consumption [12, 13]. This impacts the ship's operating costs related to fuel. Considering that currently, in Indonesia, the price of fuel, especially diesel oil, is experiencing an increase in price trend [14]. For the lighting system itself, it is necessary to study the replacement of fluorescent lamps with LED lamps because if fluorescent lamps are better than incandescent lamps, then LED lamps are even better than fluorescent lamps, especially when applied to ships [15, 16].

A good lighting system must be fulfilled in every room on the ship. The American Bureau of Shipping (ABS) class has issued regulations related to lighting criteria for

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each accommodation space on board. The main purpose of this regulation is to regulate the lighting system on board the ship according to minimum standards. In addition, the regulation makes it easier for the crew to work, provides convenience in mobilizing the crew and passengers, as well as ensures safety on board [17]. The zonal cavity method is generally used to determine the amount of lighting in a room. With this method, the number of lights needed in each room on the ship can be known. This method is also used to calculate the lighting in buildings on land [18]. Based on the background above, the hypothesis in this research is to prove whether these LED lamps are more economical than fluorescent-type lamps when applied on passenger ship 300 GT KMP Bambit.

2. Method

2.1. Ship Description (KMP Bambit)

This ship is a Ro-Ro type ship powered by a 3-phase generator Perkins 6TG2AM Marine Auxiliary Engine with a power of 68 kW [19]. This ship was built in Surabaya in 2014 at PT. Dumas Tanjung Perak Shipyard. This ship could carry 16 crew members, 185 passengers, 6 large trucks, and 11 medium trucks. The main specifications of the ship can be seen in Table 1. The picture of the ship as a whole can be seen in Figure 1.

2.2. Electrical Installation (KMP Bambit)

Like buildings on land, ships also needed an electricity supply to support activities on board [20]. KMP Bambit's power source was two main generators with a total power of 110 kW. In addition, there was a harbor generator and an emergency generator with 12 kW and 24 kW, respectively. This generator provided electricity to lighting installations in the engine room (JL1), vehicle deck (JL2), intermediate deck (JL3), passenger deck (JL4), navigation deck (JL5), power systems that required a voltage of 380 volts (JP), Junction Monitoring (JM), Junction Communication (JC), and Junction Emergency (JE). Installation of the wiring diagram on the KMP Bambit ship can be seen in Figure 2.

Table 1. Main specifications of KMP Bambit.

KMP Bambit Specification	Value
Length Overall (LOA)	39.38 meters
Molded Breadth (BMLD)	11.00 meters
Designed Draft (TMLD)	2.30 meters
Molded Depth (HMLD)	3.30 meters
Speed Service (Vs)	12.00 knots
Vehicle Load Capacity	Large Truck 6 units, Medium Truck 11 units
Passenger Capacity	185 Persons
Main Engine	Yanmar 2 x 829 hp, 5249 series [21]
Generator	Perkins 6TG2AM Marine Aux Engine 2 x 68 kW [19]

Source: PT Dumas Tanjung Perak Shipyard and BKI Ship Register [2, 3]

Figure 1. Ro-Ro KMP Bambit ship.

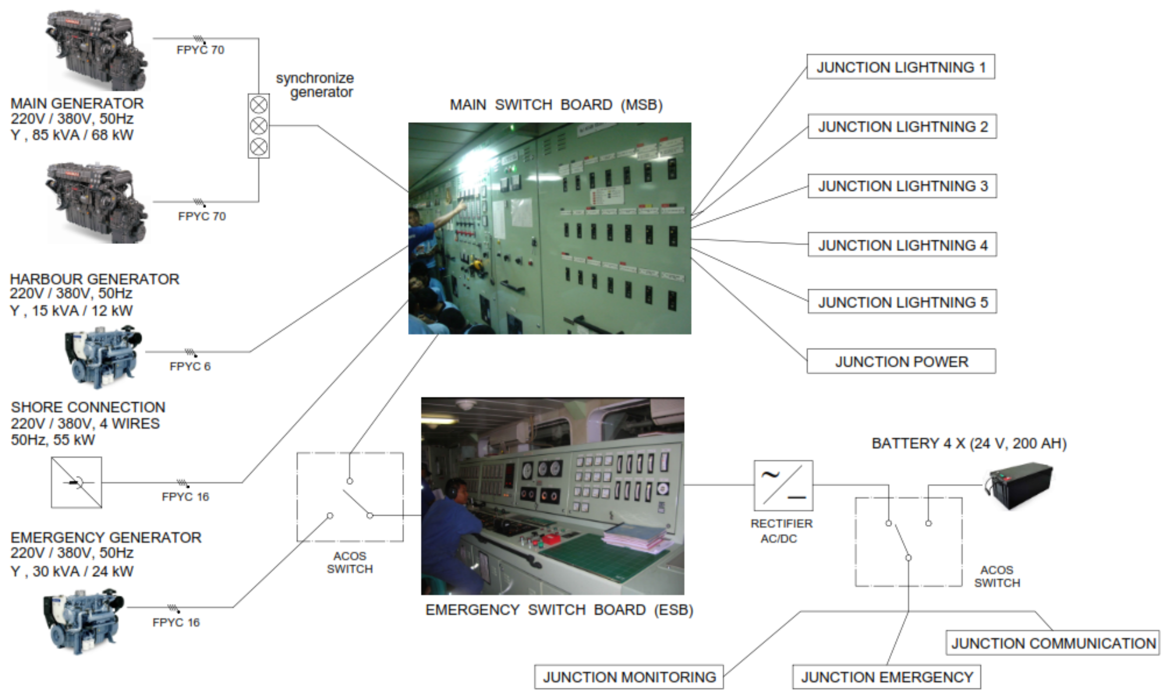

Figure 2. Wiring diagram on (KMP) Bambit.

2.3. Standard Illumination of the Room on the Ship

Illumination was defined as the intensity of the light flux received by the surface area of an area [22]. Illumination was related to the level of illumination. When sunlight shone brightly in summer, the illumination level was highest [23]. On board, the illumination standard for each room must be met so that every activity could be carried out correctly. The lighting criteria for crew accommodation rooms can be seen in Table 2.

2.4. Standard Illumination of the Room on the Ship

The zonal cavity method, commonly called the lumen method, was widely applied to determine the level of lighting in an area in a room. This method was considered accurate for indoor applications, including rooms on ships, because it considered the effect of reflections on lighting levels. The basis of this method was the availability of a cavity in the room. In Figure 3, the division of the cavity dimensions in a room included the ceiling cavity (hcc), floor cavity (hfc), and room cavity (hrc) [24].

Table 2. Lighting criteria for crew accommodation spaces.

Space	Illuminance Level in Lux	Space	Illuminance Level in Lux
	Cabins and Sanitary Spaces		
General Lighting Reading	150		
Reading and Writing		Sanitary Spaces	
Desk	500	Lavatory/Toilet	200
Bunk Light	200	Bath/Shower Area	150
Changing Room	200	Light during Sleep Period	<30
	Dining Room		
Mess Room and Cafeteria	300	Snack or Coffee Area	150
	Recreation Space		
Lounges	200	Gymnasiums	300
Library			
General Lighting	150	Bulletin Board	150
Reading Area	500		
Computer Room	300	Game Rooms	200
TV room/Movie Theater	150	Reception Areas	300

Source: ABS GUIDE for crew habitability on ships [25].

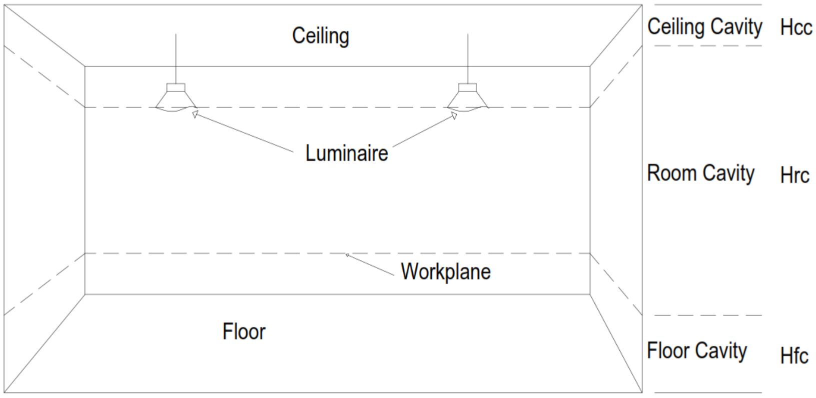

Figure 3. Cavity dimensions of the room.

The calculation stages in finding the lighting level consisted of determining the cavity ratio, the reflectance factor, the coefficient of utilization, and the average illuminance level. The following formula was used to get the Room Cavity Ratio (RCR) ratio value.

$$Room\ Cavity\ Ratio\ (RCR) = 5\ hrc\frac{(L+W)}{(L\cdot W)} \quad (1)$$

where:
hrc = distance from lighting to work plane (m)
L = length of room (m)
W = room width (m)

The amount of light flux required in a room was calculated by the following formula.

$$Room = \frac{(E\ Room\cdot A)}{(CU\cdot LLF)} \quad (2)$$

where:
$N\ Room$ = Number of lights needed in a room
$E\ Room$ = Nominal illumination required in a room (Lux)
A = Area of a room (m^2)
CU = Coefficient of utilization
LLF = Total light loss factor

Meanwhile, the number of lights needed in a room was calculated using the following formula.

$$N\ Room = \frac{Room}{Lamp} \quad (3)$$

where:
$N\ Room$ = Number of lights needed in a room
$Room$ = Flux of light produced in a room (Lumen)
$Lamp$ = Flux of light in the lamp to be selected (Lumen)

3. Results and Discussion

The intensity of lighting in each room on board the ship was measured by referring to room conditions such as room width, height, length, and area. The illumination value was determined following the standards set for each room. As previously explained, the generator on the ship supplied power for all electrical needed on board, including lighting power, power for pumping installations, and power for telecommunications and monitoring. This analysis focused on lighting needed to determine how big the power ratio was between fluorescent lamps and LED lights on the KMP Bambit ship based on the lighting rules issued by ABS. The total power requirement for lighting at KMP Bambit using fluorescent lamps was 24.31 kW, as shown in Table 3.

After the amount of electricity consumption on the KMP Bambit ship was known, as in Table 3, the next step was to calculate the lighting using the zonal cavity (lumen) method by replacing the fluorescent lamps with the LED lamps, which was more efficient.

Tables 4 and 5 show that after a study of the use of LED lamps to replace fluorescent lamps was carried out, the generator power decreased from 24.31 kW to 16.51 kW, as shown in Table 6.

Table 3. Illumination load with fluorescent lamps.

No.	Deck	Power (kW)
1	Engine Room	8.44 kW
2	Car Deck	0.68 kW
3	Deck 1	1.99 kW
4	**Passenger Deck**	**5.27 kW**
5	Navigation Deck	8.8 kW
	Amount	24.31 kW

Table 4. The cavity ratio of rooms on the passenger deck.

Lamps in Various Conditions	Illumination Standard (Lux)	Room Dimension (m)				RCR	CU
		Length	Width	Height	Area (m^2)		
Clinic	150	2.5	2.6	2.3	6.5	4.71	0.42
Pray Room	150	2.5	2.6	2.3	6.5	4.71	0.42
Passenger Deck (130 P)	150	19	11	2.3	173.3	0.86	0.68
Men Toilet (SB)	150	4	2.9	2.3	11.6	3.57	0.49
Women Toilet (PS)	150	4	2.9	2.3	11.6	3.57	0.49
Passenger Deck (130 P) Sleeping Condition	30	19	11	2.3	173.3	0.86	0.68
Back Corridor	150	6	11	2.3	45.2	1.55	0.63
Front Corridor	150	3	11	2.3	28.98	2.55	0.55
Lights that are on when there is an emergency							
Passenger Deck (130 P)	20	19	11	2.3	173.3	0.86	0.68
Back Corridor	20	6	11	2.3	45.2	2.55	0.55

Table 5. Calculation of luminous flux and total lamp requirement on passenger deck.

Lamps in Various Conditions	Minimum Flux Needed (Lumen)	Flux Lamp (Lumen)	Planning	Total Flux (Lumen)	LED Lamp Type	Lamp Power (Watt)	Total Lamp Power (Watt)
Clinic	2693.17	1500	2	3000	Green up Slim Downlight [26]	15	30
Pray Room	2693.17	1500	2	3000	Green up Slim Downlight [27]	15	30
Passenger Deck (130 P)	44587.95	4576	10	45760	Acxent LED L Lighting 8’ [28]	51	510
Men Toilet (SB)	4200.40	1500	3	4500	Green up Slim Downlight [27]	15	45
Women Toilet (PS)	4200.40	1500	3	4500	Green up Slim Downlight [27]	15	45
Passenger Deck (130 P) Sleeping Condition	8917.59	650	14	9100	QB Twins 2L 6+6W [29]	12	168
Back Corridor	12695.73	3000	5	15000	Carn Waterproof LED light [30]	27	135
Front Corridor	9239.50	3000	4	12000	Carn Waterproof LED light [30]	27	108
Lights that are on when there is an emergency							
Passenger Deck (130 P)	5945.06	850	8	6800	IS Series [31]	8.5	68
Back Corridor	1231.93	850	2	1700	IS Series [31]	8.5	17

Table 6. Illumination load with LED lamps.

No.	Deck	Power (kW)	Total
1	Engine Room	5.86 kW	
2	Car Deck	0.44 kW	
3	Deck 1	1.12 kW	16.51 kW
4	**Passenger Deck**	**1.16 kW**	
5	Navigation Deck	7.06 kW	

From Table 3, Table 4, and Figure 4, the results of the power requirements for LED lamps were lower when compared to fluorescent lamps. Therefore, using LED lamps was more efficient. The engine room was the second most power consumptive when using fluorescent lamps, with a total electric power of 8.44 kW. But after analyzing the cavity (lumen) method using LED lights, it reduced to 5.86 kW. Car deck power consumption was reduced from 0.68 kW to 0.44 kW. The deck 1 power consumption was reduced from 1.99 kW to 1.12 kW. The passenger deck power consumption was reduced from 5.27 kW to 1.16. The navigation deck power consumption was reduced from 8.8 kW to 7.06 kW. The total generator power required at KMP Bambit can be seen in Table 7 for fluorescent lamps and Table 8 for LED lamps.

From Table 7 and 8, it can be seen that the saving effect of the LED lamp was proven to reduce the amount of generator power on the ship from 68 kW to 60 kW. This proved to reduce ship operational costs regarding fuel consumption of the generator engine. For port generators and emergency generators, it was also possible to reduce the generator power in anchored conditions from 12 kW to 8 kW and in emergency conditions from 24 kW to 20 kW. This proved the high power saving by using LED lamps compared to Fluorescent lamps.

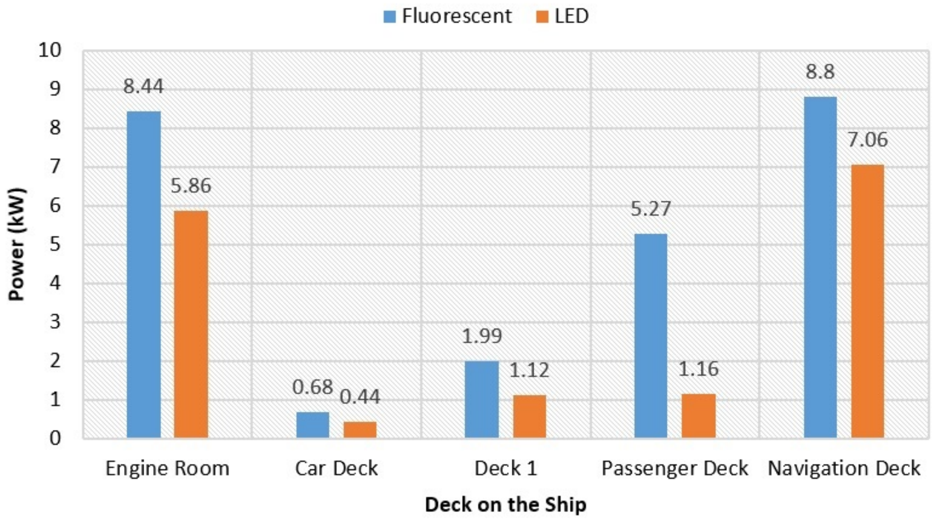

Figure 4. Comparison graph of illumination load with fluorescent lamps and LED lamps.

Table 7. Total generator power required with fluorescent lamps.

Information	Sailing conditions	In and Out of the Port	Loading and Unloading	Anchored	Emergency
Continuous load (kW)	46	44.2	39	-	19.8
Intermittent Load (kW)	18.6	17.7	26.3	10.6	-
Diversity Factor(0.7)	13	12.4	18.4	7.4	-
Total Load (kW)	59	56.6	57.4	7.4	19.8
Total Generator Power (kW)	1 x 68	1 x 68	1 x 68	1 x 12	1 x 24
Available Power Capacity (kW)	**68**	**68**	**68**	**12**	**24**
Generator Load Factor	87%	83%	84%	61.70%	82.60%

Table 8. Total generator power required with LED lamps.

Information	Sailing conditions	In and Out of the Port	Loading and Unloading	Anchored	Emergency
Continuous load (kW)	38.2	38.2	32.5	-	16.6
Intermittent Load (kW)	18.6	17.7	26.3	6.8	-
Diversity Factor(0.7)	13	12.4	18.4	4.8	-
Total Load (kW)	51.2	50.6	50.9	4.8	16.6
Total Generator Power (kW)	1 x 60	1 x 60	1 x 60	1 x 8	1 x 20
Available Power Capacity (kW)	**60**	**60**	**60**	**8 [32]**	**20 [33]**
Generator Load Factor	85%	84%	85%	59.80%	82.80%

In Figure 5, there are three lighting conditions on the passenger deck: normal, emergency, and sleeping. Before this study, KMP Bambit only had two lighting conditions. When the conditions were normal, all the lights in the room were turned on. When it was time to sleep, some of the lights were turned off. While for emergency conditions, it remained the same.

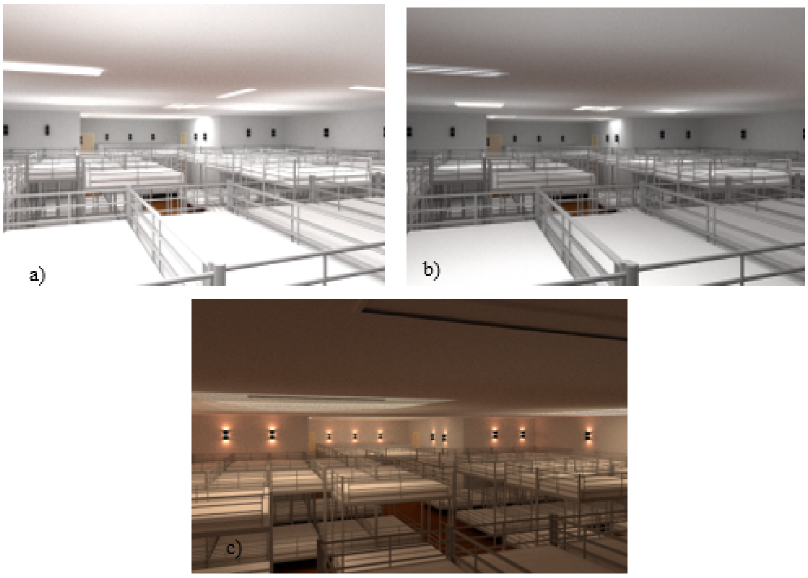

Figure 5. Passenger room lighting in conditions, a) in normal conditions, b) in emergency conditions, c) in sleeping conditions.

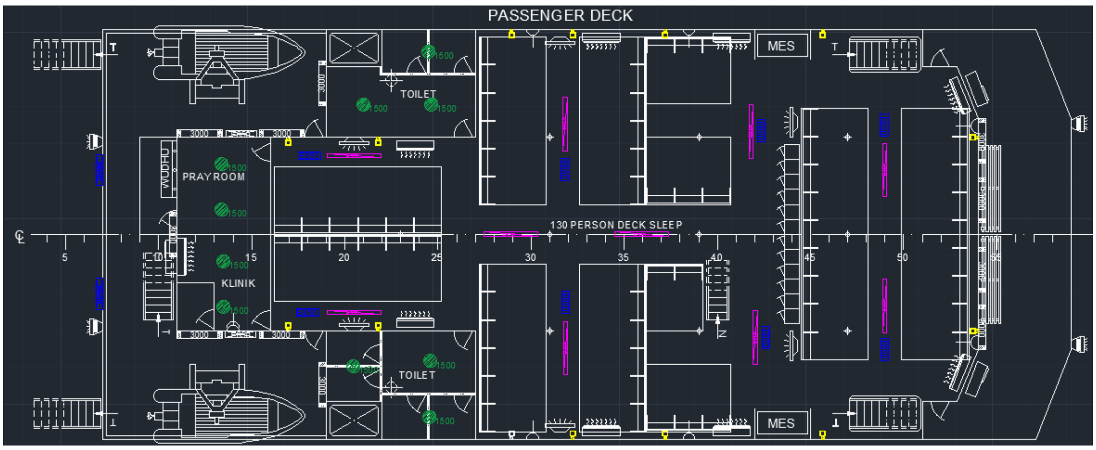

Figure 6. 2D Passenger Deck Floor Plan using LED Lamp.

4. Conclusion

The analysis results for comparing lamp power on KMP Bambit showed that the total lighting electrical load accumulated using the fluorescent lighting type was 24.31 kW. In contrast, LED lighting had a total lighting electrical load of 16.51 kW. Thus, using LED lamps was more efficient, with savings of up to 31% or a power reduction of 7.89 kW. The total power requirement for the ship's electrical system using LED-type lights was 51.2 kW in sailing conditions, 50.6 kW in port entry and exit conditions, 50.9 kW in loading and unloading conditions, 4.8 kW in anchoring conditions and 16.6 kW in emergency conditions.

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