# Analysis of the Effect of Radiator Performance on Power Production of Diesel Generator 1 at PLTMG Batamindo

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***Abstract*— Gas Engine Power Plants (PLTMG) are widely used in Batam City due to their relatively small land requirements and economical operational costs. The reliability of a PLTMG is heavily influenced by its cooling system, particularly the radiator, which maintains the engine operating temperature at an optimal level to ensure power stability. This study uses a quantitative approach based on operational data from the Diesel Generator (DG) 1 radiator at PT Batamindo Investment Cakrawala for the period of January–March 2026. Measured parameters include coolant inlet and outlet temperatures, heat transfer surface area, and generator load. The analysis results show that the highest average heat transfer rate occurred in March 2026 at 2,533.2 kW (with an effectiveness of 38.0%), while the lowest occurred in January 2026 at 2,295.0 kW (with an effectiveness of 35.1%). The increase in radiator effectiveness has a positive correlation with the increase in generator load from 3.41 MW to 3.60 MW.**

**Keywords: Effevtivness, Heat Transfer Rate, Maintenace, PLTMG, Radiator.**

## I. Introduction

Electrical energy plays a crucial role in supporting community activities and the continuity of the industrial sector [1]. In Batam City, there are several power plant management entities utilizing various energy sources, one of which is the Gas Engine Power Plant (PLTMG) [2]. This type of power plant is frequently chosen because of its compact installation footprint compared to other types, making it ideal for Batam's limited spatial planning [3].

PT Batamindo Investment Cakrawala acts as an Independent Power Producer (IPP) in the Batamindo Industrial Park, operating 16 units of the 18V32DFC type PLTMG. The stability of these engines' performance relies heavily on the reliability of the cooling system, whose primary component is the radiator [4]. The radiator works to reduce excess thermal energy from the coolant to the ambient air to prevent the engine from overheating [5].

Load conditions directly influence the amount of heat generated from compression and internal engine component friction [6]. Building upon the gap in information regarding detailed actual radiator performance monitoring in DG 1 at PLTMG Batamindo, this study aims to quantitatively evaluate the rate of heat transfer, the effectiveness level of the heat exchanger device, and analyze its relationship

with production load [7]. The expected output is a comprehensive maintenance recommendation methode This research was implemented using direct quantitative observation on the DG 1 PLTMG installation at PT Batamindo Investment Cakrawala. Data recording was conducted from January to March 2026. Sample data was extracted with a frequency of twice a day for five working days per week [8].

The variables studied include the coolant fluid temperatures at the inlet ($T_{in}$) and outlet ($T_{out}$) sides, the volumetric water flow rate (discharge), and the active power output delivered by the generator (MW) [9]. The technical analysis begins by determining the specific heat capacities of air and water fluids. Thermodynamic calculations are then employed to obtain the actual radiator thermal absorption capacity, the maximum limit of heat absorption, and the effectiveness ratio ($\varepsilon$) of the heat exchanger [10].

## II. Methode

The processing stages are described by taking representative measurement formula below. The ambient air mass flow rate ($m_c$) with a density of 1.225 kg/m$^3$ is calculated using equation [3].

$$m_c = \rho \times v \times A \tag{1}$$

Based on this mass, the heat capacity of the ambient air ($C_c$) is evaluated using equation (2) with a specific heat capacity of air of 1.0129 kJ/kg · K.

$$C_c = m_c \times Cp_c \tag{2}$$

On the other hand, the water fluid mass flow rate ($m_h$) as a coolant with a density of 1000 kg/m$^3$ and a discharge rate of 0.06 m$^3$/s is calculated in equation [3].

$$m_h = \rho_w \times Q \tag{3}$$

The thermal capacity of the cooling fluid ($C_h$) with the specific heat of water of 4.184 kJ/kg · K is formulated in equation [3].

$$C_h = m_h \times Cp_h \tag{4}$$

For the actual heat rate ($Q_{actual}$) released to the environment, the equation is described through [3].

$$Q_{actual} = m_h \times Cp_h \times (T_{in} - T_{out}) \tag{5}$$

Furthermore, the maximum radiator capacity ($Q_{max}$), limited by the fluid with the minimum heat capacity ($C_c$), calculated using equation. Determining the maximum heat transfer rate involves two conditions. $Cmin = Cc$ if $Cc < Ch$, $Cmin = Ch$ if $Ch < Cc$ [3].

$$Q_{max} = Cmin \times \Delta T \tag{6}$$

The effectiveness level of the radiator performance ($\varepsilon$) is determined from the ratio of the heat transfer that occurs based on equation [7].

$$\varepsilon = (Q_{actual} / Q_{max}) \times 100\% \qquad (7)$$

## III. Result and Discussion

Having obtained the formula to determine the required variable, we now use the following field data to calculate the necessary value. In this instance, due to the large volume of data, we are using the monthly averages for the period of January through March 2026.

*Table 1 Average Data of Radiator DG 1*

| Month | Load | T Inlet | T Outlet | T Embient | T Surface |
|---|---|---|---|---|---|
| January | 3.41 | 353.4 | 344.3 | 304.1 | 325.3 |
| February | 3.52 | 354.6 | 333.6 | 304.3 | 325.4 |
| March | 3.6 | 354.6 | 333.6 | 304.2 | 325.3 |

Next, we substitute the values into the formula we have obtained using data sample of January.

$$Q_{actual} = m_h \times Cp_h \times (T_{in} - T_{out})$$
$$Q_{actual} = 60\ kg/s \times 4.184\ kj/kg.K \times (354.6 - 344.2)$$
$$Q_{actual} = 2295\ KW \qquad (9)$$

By applying that formula, we can calculate the values for all the averages, as shown in the table below.

*Table 2* ***average heat transfer rate***

| Month (2026) | average heat transfer rate |
|---|---|
| January | 2295.0 |
| February | 2510.4 |
| March | 2533.2 |

Based on Table 2, the average heat transfer rates were 2,295 kW in January, 2,510.4 kW in February, and 2,533.2 kW in March. The highest average heat transfer rate occurred in March, while the lowest was in January.

To determine the effectiveness value, follow the steps below.

$$m_c = \rho \times v \times A$$
$$m_c = 1.225\ kg/m3 \times 5m/s \times 21.225\ m2$$
$$m_c = 130.431\ kg/s \qquad (10)$$

After obtaining the air mass flow rate, the next step is to calculate the heat capacity of the air (Cc) using the specific heat of air, 1.0129 kJ/kg·K.

$$Cc = Mc \times Cpc$$
$$Cc = 130{,}431\ kg/s \times 1{,}0129\ kj/kg$$
$$Cc = 132{,}114 kj\ s\ .\ K \qquad (11)$$

After determining the air heat capacity value, the next step is to perform calculations for the cooling water fluid. To determine the water mass flow rate ($m_h$), two parameters are used: the water density (with a constant value of 1000 kg/m³) and the cooling water flow rate (specified in the manual as 216 m³/h, which is converted to 0.06 m³/s).

$$Mh = 1000\ kg/m3 \times 0{,}06\ m3/s$$
$$mh = 60\ kg/s \qquad (12)$$

After obtaining the mass flow rate of the water, the next step is to determine the heat capacity of the cooling fluid, given that the specific heat of water is 4.184 kJ/kg·K.

$$Ch = mh \times Cph$$
$$Ch = 60\ kg/s \times 4{,}184\ kj/kg$$
$$Ch = 251\ KW \qquad (13)$$

Once all the values have been determined, the next step is to calculate the actual heat that can be transferred by the radiator.

$$Qactual = mh \times Cph \times \Delta T$$
$$Qactual = 251 Kj\ s.K \times (353{,}4 - 344{,}3)K$$
$$Qactual = 2295\ KW \qquad (14)$$

After determining the actual heat value that can be transferred by the radiator, the next step is to find the maximum heat value that the radiator can transfer.

$$Qmax = Cc \times \Delta T$$
$$Qmax = 132{,}114 kj/s.K \times (353.4 - 304.1)K$$
$$Qmax = 64206513.2\ KW \qquad (15)$$

Once the required parameters are met, the next step is to determine the radiator's heat dissipation efficiency.

$$\varepsilon = Q\ actual / Q\ max \times 100\%$$
$$\varepsilon = 35.1\ \% \qquad (16)$$

Radiator effectiveness is a parameter indicating the cooling system's capacity to dissipate the thermal energy generated during the operation of DG 1 at the PLTMG. Changes in generator loading conditions affect engine operation; consequently, an increase in operating load can lead to a rise in the thermal energy that the cooling system must dissipate. Therefore, analyzing the relationship between the heat transfer rate and generator loading is necessary to understand how load variations impact radiator performance in maintaining engine operation. The average effectiveness values over a three-month period are presented below.

*Table 3 Average Effectiveness Score.*

| Month (2026) | Effectiveness (%) |
|---|---|
| January | 35.1 |
| February | 37.8 |
| March | 38 |

Based on the table above, the highest effectiveness value occurred in March at 38%, while the lowest was in January at 35.1%.

To compare the effectiveness and heat transfer rate values, both values are displayed in the graph below.

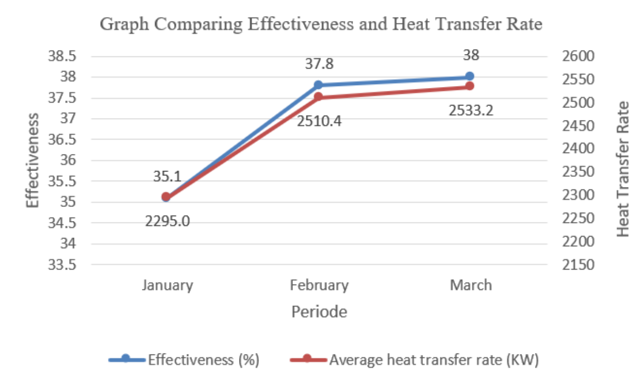


*Figure 1 Average Effectiveness and Heat Transfer Rate.*

The image above illustrates the fluctuations in heat transfer and radiator effectiveness over a three-month period. Observations reveal a strong correlation between the heat transfer rate and the effectiveness value; the highest effectiveness values—observed from January to March 2026—coincided with the highest heat transfer rates, and vice versa.

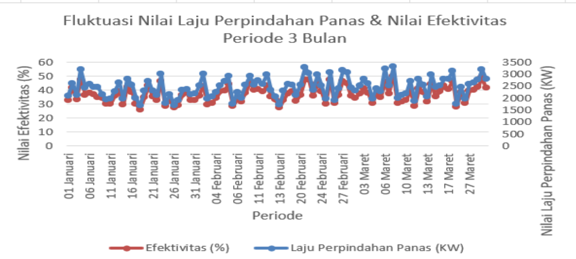


*Figure 2  Fluctuations in Heat Transfer Rate and Effectiveness Values*

To compare the effectiveness value and load value, both values are shown in the table below.

*Table 4 Comparison of the load value and the average value*

| Month (2026) | Load (MW) | Effectiveness (%) |
|---|---|---|
| January | 3.41 | 35.1 |
| February | 3.5 | 37.8 |
| March | 3.6 | 38 |

The table above summarizes the generator's efficiency and average load. In January, efficiency was recorded at 35.5% with an average load of 3.41 MW. Both figures subsequently declined in February—to 37.8% and 3.5 MW, respectively—before rising again in March to 38% and 3.6 MW. This synchronized pattern of fluctuation highlights a positive correlation between efficiency and generator load: the drop in load in February was accompanied by a decrease in efficiency, while the increase in load in March—which slightly exceeded January's levels—pushed efficiency back to its peak. Nevertheless, the magnitude of these fluctuations across the three months was minor, indicating that the generator's performance remained relatively stable throughout the first quarter of 2026.

To clearly visualize the fluctuations in load values and effectiveness, the following graph is presented.

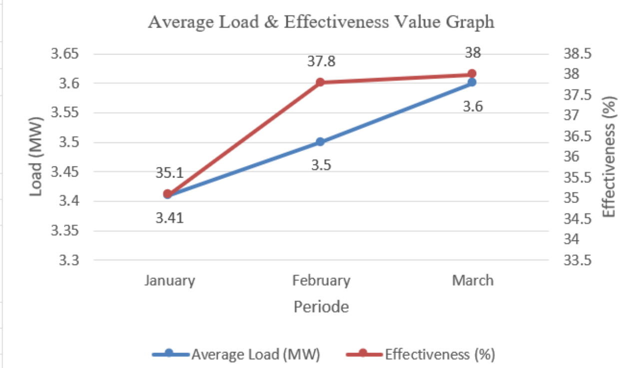


*Figure 3 Average Load & Effectiveness Value Graph*

The graph above illustrates the fluctuations in average effectiveness and load over a three-month period. It shows that the effectiveness value significantly influences the load value; however, unlike the heat transfer rate which tracks closely with effectiveness despite positive fluctuations the load value does not align as tightly with the effectiveness value. While effectiveness reflects the radiator's heat transfer capacity, the load value is ultimately determined by operator settings. The relationship between the two is such that the operator adjusts the radiator's heat transfer capacity (i.e., the effectiveness) to establish a target load range, meaning that effectiveness effectively dictates the load value.

Table 5 Recommendations for Radiator Care and Inspection.

| No. | Activity | Type of Maintenance | Parameters Checked | Examination Method | Implementation Period |
|---|---|---|---|---|---|
| 1 | Monitoring the radiator's inlet and outlet temperatures | Preventive Maintenance | Radiator inlet and outlet temperature, radiator ΔT | Temperature sensor observation and recording of operation data | Everyday |
| 2 | Checking abnormal temperature conditions | Predictive Maintenance | Temperature change compared to normal operating conditions | Temperature data analysis and comparison with historical data | Everyday |
| 3 | Coolant system leak check | Preventive Maintenance | Leaks in the radiator, pipes, seals, and connections | Visual inspection of cooling system components | Weekly |
| 4 | Overall radiator performance evaluation | Predictive Maintenance | Generator load relationship, temperature, and radiator performance | DG 1 PLTMG operation data analysis | 6 months |

## IV. Conclusion

a. The magnitude of the heat transfer rate and radiator effectiveness can be determined through the analysis of operating parameters such as inlet temperature, outlet temperature, radiator surface temperature, and heat transfer area. Over the 3-month research period (January – March 2026), the average heat transfer rate peaked in March 2026 with a value of 2533.2 kW, while the lowest value occurred in January 2026 at 2295 kW, followed by the highest and lowest effectiveness values of 35.1% and 38%.

b. The radiator effectiveness influences the ability of DG 1 to generate electrical power. During the three-month observation period, the highest average radiator effectiveness was recorded in March 2026 at 38%, while the lowest average effectiveness occurred in January 2026 at 35.1%. These values were accompanied by the highest and lowest average generator loads of 3.6 MW and 3.41 MW, respectively.

c. Recommended radiator maintenance includes regular inspection and periodic maintenance by monitoring operating temperature, coolant condition, leakage, radiator fin cleanliness, and cooling fan performance. The implementation of preventive and predictive maintenance can maintain radiator performance and enhance the reliability of the DG 1 PLTMG cooling system.

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