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Procedure for the Evaluation of Generation Engines Under Local Environmental Conditions

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During the use of generator sets batteries, the operational evaluation of these to verify their behavior during the operation to which they are subjected is important. For the development of the procedure, theoretical and empirical expressions related to the methods of selection and adjustment of internal combustion engines were considered in specific environmental conditions, obtained from the consultation carried out in the existing bibliographies, mainly ISO 3604- 1 and 15550v. We established the procedure of analysis of consumption index and the service power of the battery under the climatological conditions of the site. It is determined that under normal atmospheric conditions the climate variables do not have a great influence on the variation of the service power and the fuel consumption index, although this is not the case in high humidity and reference altitude conditions above sea level. The objective is based on standard reference conditions and method of declaration of power and fuel consumption.
Keywords: Internal combustion engines, fuel consumption, environmental parameters, power.

1. Introduction

In oil facilities worldwide, electric energy is the main resource for the operation of extraction, separation, pumping and transportation of oil. The importance of controlling the operating parameters of generator sets is essential in the efficient operation of electricity generation.

Ecuador's oil fields have centralized electricity generation plants, with Wartsila 18V32 motor generators; From the literature on diesel cycle combustion engines, it is known that approximately 30% of the energy lost corresponds to exhaust gases, exacerbated by changes in local environmental conditions different from their design conditions. By analyzing operating and maintenance costs, it leads to the determination of the main operating parameters, related to fuel quality, work regime and maintenance cycles.

By not carrying out the evaluation of the operating parameters based on the quality of the fuel and climatological parameters, an inefficient operation is obtained in relation to the operation of the equipment.

For the reasons stated above, a procedure for efficient operation related to the fuel characteristics and nominal operating parameters of the Wartsila 18V32 engines must be implemented.

Introduction to the problem

Taking into account the aforementioned problematic situation, the following scientific problems were declared to be solved in this research:

How does the lack of procedures for the evaluation of the main operating parameters of internal combustion engines affect the operation and performance of the Wartsila 18V32 generator equipment used for electricity generation in Block 12 of the Petroamazonas EP company?

In this case, the general objective is:

To propose a procedure for the evaluation of the operating parameters and their impact on the operation and performance of the Wartsila 18V32 internal combustion engines at different loads, depending on the quality of the fuel.

The lack of evaluation of the operating parameters of the Wartsila 18V32 internal combustion engines based on fuel properties and taking into account local environmental conditions, is an impediment to establishing the efficient operating and life cycle parameters of the equipment.

Importance of the problem

Industrial plants that have implemented quality standards or are managed under the good practices of the industry, usually carry a baseline of the behavior of the equipment in terms of maintenance, currently this is associated with the PAS 55 standard that refers to asset management in the different stages of the life cycle. which goes from the conception of an asset, engineering (design and construction), operation, maintenance and improvement to the divestiture of the asset.

Petroamazonas EP being a benchmark company in the oil sector, in which standards in terms of quality, compliance with legal regulations, social responsibility, and responsibility with the environment are high priorities, this forces to develop and permanently implement better controls for the optimization of resources, therefore it is considered very practical and timely to establish an operational baseline. on the behavior of the operation and performance of the W18V32 internal combustion engines in the power generation plant.

2. Methodology

Determining the behavior of the main parameters of the generator set battery, taking into account the local atmospheric conditions and the effective parameters that characterize the work of the engines, contributes significantly to the continuous improvement of operational efficiency (Martínez, 2007); (ISO Standard, 2012). The proposed procedure is aimed at determining results based on the following methodologies:

1. Methodology for calculating the indicated and effective parameters.
2. Battery Generation Index.
3. Test method on engines according to ISO 3604-1.
4. Methodology for the analysis of climatological conditions.
5. Recalculation of the fuel consumption index under test or adjusted site environmental conditions for engines.

- Methodology for calculating the indicated and effective parameters

To elaborate the calculation methodology, the expressions contained in (Reyes, 1987); (Salinas, 2008).

Indicated and effective parameters

The average pressure indicated pmi is calculated by:

$$pmi = \frac{N_i}{Z \cdot V \cdot \frac{n}{60} \cdot \frac{1}{2}}; \left(N/m^2\right) \quad (1)$$

Being:

N_i: Indicated engine power; (kW). Z: Number of engine cylinders. V: displacement in $\left(m^3\right)$. n: Crankshaft speed; $(rev/\min)$.

For the calculation of the average effective pressure pme, it is proposed:

$$pme = \frac{N_e}{Z \cdot V \cdot \frac{n}{60} \cdot \frac{1}{2}}; \left(N/m^2\right) \quad (2)$$

Where:

N_e: Effective engine power; (kW).

You can get the right job Wi:

$$Wi = \frac{\pi \cdot D^2}{4} \cdot C \cdot pmi; (J) \quad (3)$$

Where:

D A: Cylinder diameter; (m). C A: Piston stroke; (m).

The equation for effective work We is:

$$We = \frac{\pi \cdot D^2}{4} \cdot C \cdot pme; (J) \tag{4}$$

The indicated g_i and effective fuel consumption g_e is determined by the following expressions:

$$g_i = \frac{G_t}{N_i} \cdot 10^3; \left(g / kW \cdot h \right) \tag{5}$$

Where:

G_t: Hourly fuel expenditure; $\left(kg / h \right)$.

$$g_e = \frac{G_t}{N_e} \cdot 10^3; \left(g / kW \cdot h \right) \tag{6}$$

The indicated Yield η_i is obtained:

$$\eta_e = \frac{3600}{H_u \cdot g_i} \cdot 100; (\%) \tag{7}$$

Where:

H_u: Low caloric value of fuel; $\left(kJ / kg \right)$.

Mechanical performance η_m:

$$\eta_m = \frac{N_e}{N_i} \cdot 100 \tag{8}$$

Effective performance η_e:

$$\eta_e = \frac{\eta_i \cdot \eta_m}{100} \tag{9}$$

Determining the Battery Fuel Consumption Index

The consumption index or specific consumption of energy is understood as the amount of energy per unit of production or services, measured in physical terms (products or services provided) (Córdova, 2013).

In a consumption index, the numerator will be the primary or secondary energy carrier, which is consumed at the station in a given period, expressed in a unit of energy measurement, (kW, Ton Fuel Oil, Ton of Steam, TEP.). The denominator shall reflect the level of production carried out or service provided at the post in the given period, expressed in the corresponding unit of measurement (units, tonnes).

$$Indice.Consumo = \frac{Consumo.Portador}{\Pr oducción.\text{Re}\, alizada.(servicio\ prestado)} \tag{10}$$

For the case under study, the consumption index is calculated by:

$$Ic = \frac{C}{G} \cdot \rho \, ; \left(g / kW \cdot h \right) \tag{11}$$

Where:

C : Fuel consumption; $\left(kg/h \right)$. G : Power generation; $\left(kW \cdot h \right)$. ρ : Fuel density; $\left(g/cm^3 \right)$.

- Methodology for the analysis of climatological conditions

Power adjustment for ambient conditions

When the engine is required to be operated under conditions other than the given standard reference conditions, and the output power is required to be adjusted up to or from standard reference conditions, the following equations may be used if no other method is established by the manufacturer.

$$P_x = \alpha \cdot P_r \tag{12}$$

Where:

P_x : Standard power service; (kW). P_r : ISO standard reference power; (kW).

Where the power adjustment factor is given by:

$$\alpha = k - 0{,}7 \cdot (1 - k) \cdot \left(\frac{1}{\eta_m} - 1\right) \tag{13}$$

Where:

k : Indicated power ratio.

$$k = \left(\frac{P_x - a\phi_x \cdot p_{sx}}{P_r - a\phi_r \cdot p_{sr}} \right)^{0{,}7} \cdot \left(\frac{T_r}{T_x} \right)^{1{,}2} \cdot \left(\frac{T_{cr}}{T_{cx}} \right) \tag{14}$$

Being:

$\left(\frac{P_x - a\phi_x . p_{sx}}{P_r - a\phi_r . p_{sr}}\right)$ Dry air pressure ratio. Tr : National average temperature; (º C). Tx : Site temperature; (º C). Tcr : ISO standard reference temperature; (º C). Tcx : Air inlet temperature; (º C).

Recalculation of the fuel consumption index in test or ambient conditions of the site for adjusted engines

When the engine is required to be operated under test or environmental site conditions, from the given standard reference conditions, the specific fuel consumption will differ from that declared for the standard reference conditions and could be calculated from the standard reference conditions (Fires, 2002).

The following equation could be used if other methods are not declared by the manufacturer:

$$b_x = \beta \cdot b_r \quad (15)$$

Being:

b_x : Specific service fuel consumption; $(g/kW \cdot h)$. b_x : Specific service fuel consumption; $(g/kW \cdot h)$. β : Consumption adjustment factor.

$$\beta = \frac{k}{\alpha} \quad (16)$$

3. Case Study Results

For the validation of the procedure, a study has been carried out through the practical calculation of the operating parameters of a motor used for the generation of electricity in a generator set battery, where the following results have been obtained:

- Main Engine Parameters

With the application of the methodology described above and taking into account the above data, the results obtained in the calculations are shown in table 1.

Table 1 - Results obtained in the calculations.

Parameter	Unit	Equation	% Engine load			
			75	80	90	100
pme	Mpa	2	1,402	1,48	1,679	1,94
We	Kj	4	5,695	6,021	6,82	7,87
ge	g/kW· h	6	229,14	228,88	226,71	223,14

η_e	%	9	26,7	28,2	32	36,9
η_m	%	8	68,6	72,6	82,2	94,9

- Obtaining the load characteristic curves

After the calculation of the parameters, the characteristic load curves are obtained, which include the hourly consumption curve and effective specific fuel consumption, effective performance and average effective engine pressure. The following data table is used for this purpose:

Table 2. Data for the construction of the load graphs.

Load (%)	Effective power (kW)	Hourly consumption (kg/h)	Specific consumption (g/kW·h)	Effective yield (%)	Average effective pressure (MPa)
75	1366	313,8	229,14	26,7	1,40
80	1444	330,5	228,88	28,2	1,48
90	1636	370,9	226,71	32	1,68
100	1888	421,3	223,14	36,9	1,92

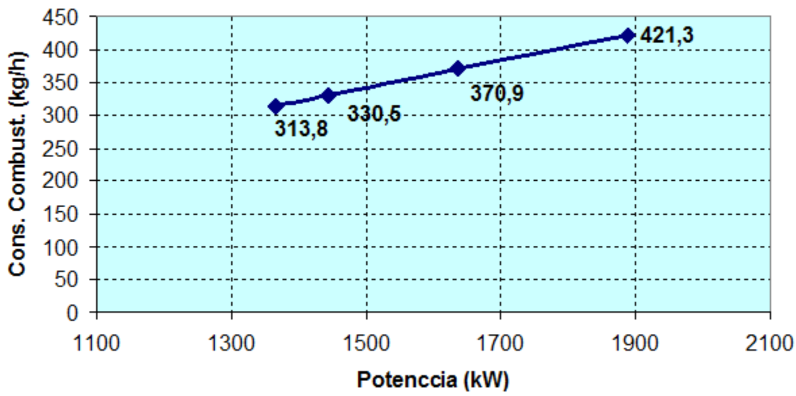

Figure 1. Variation of hourly consumption with respect to effective power. In original language English

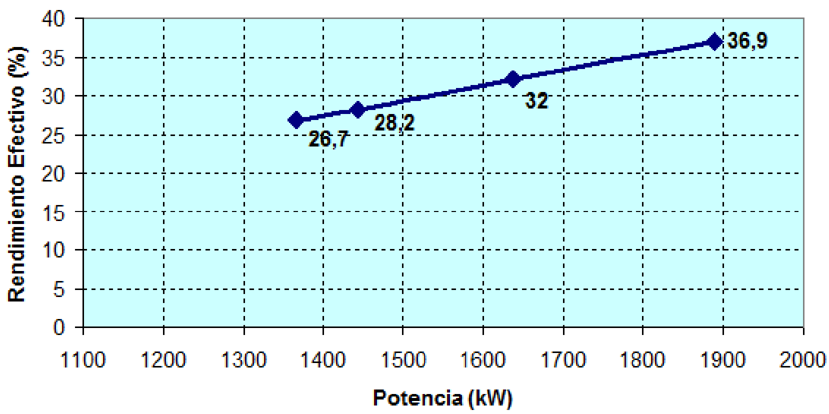

Figure 2. Variation in performance with respect to effective power. In original language English

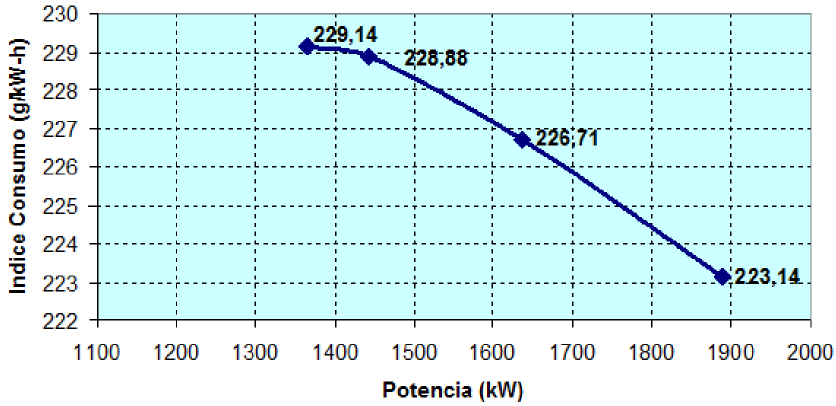

Figure 3. Variation of the fuel consumption index with respect to the effective power. In original language English

4. Discussion

Figures 1 and 2 show an increase in the parameters related in each case (hourly fuel consumption, effective performance) with respect to the increase in engine load. The effective performance increases with respect to the load and the effective specific consumption decreases (Figure 3), (both to approximately 80 – 85 % of the maximum load) at which point they reach their optimal values. For higher charge values, the combustion process is worsened by the imperfection with which the mixture is formed. As a result, the indicated performance decreases sharply and this decrease in your performance is not compensated by the increase in mechanical performance, which causes an increase in specific fuel consumption.

As Figure 1 indicates, hourly fuel consumption is higher as the percentage of charge increases. For the 75% load, the lowest fuel consumption corresponds, 313.8 kg/h; while at 100% load, consumption increases by 421 kg/h. This is conditioned by the fact that in order to increase the percentage of engine load, a greater amount of fuel must be introduced for combustion.

In all of the above, the density of the fuel is present with its influence, this depends, on the crude oil of origin and the refinery treatment. However, in relatively fast engines that consume diesel, density has an impact on power and consumption. A division of the injection pump adjustment corresponds to a certain volume of fuel injected by the cycle, and therefore the higher the density, the energy introduced to the engine with the fuel is higher (the caloric value is expressed in cal/kg of fuel). Density is involved here by its action on caloric value per litre and there may be interest especially when fuel accounting is done on the basis of the unit price per volume of using a sufficiently dense fuel (logically within the permissible limits for the type of fuel used).

In table 1, the increase in the average effective pressure is the result of burning more fuel per cycle, the increase in this parameter is not significant in the case of engines that have a supercharging system, responsible for pumping air to the cylinder head of each cylinder, which implies a lower amount of injected fuel and a growth in the coefficient of excess air (Reyes, 1987); (Palacios, 2007).

- Main parameters of the battery in its interaction with the environment

Based on the methodology described above and taking into account the data provided on the climate and the operation of the facility, it is offered in table 2, with results obtained in the calculations.

Table 2. Battery overview according to ISO and SCADA

Month/ Year-2016	G E battery.			
	ISO 3046-1 Standards		SCADA	
months	Power	Ic. Consumption	Power	Ic. Consumption
March	1421	221,22	1413,90	226,00
April	1380	221,97	1377,50	227,00
May	1353	222,49	1369,70	228,04
June	1358	222,40	1362,30	228,80
July	1355	222,45	1348,97	231,20
August	1354	222,46	1341,40	231,80

The power and consumption index according to ISO 3604-1, by equations 11 and 14. In the case of the results obtained from the SCADA system, they were determined in the control panel and equation 10.

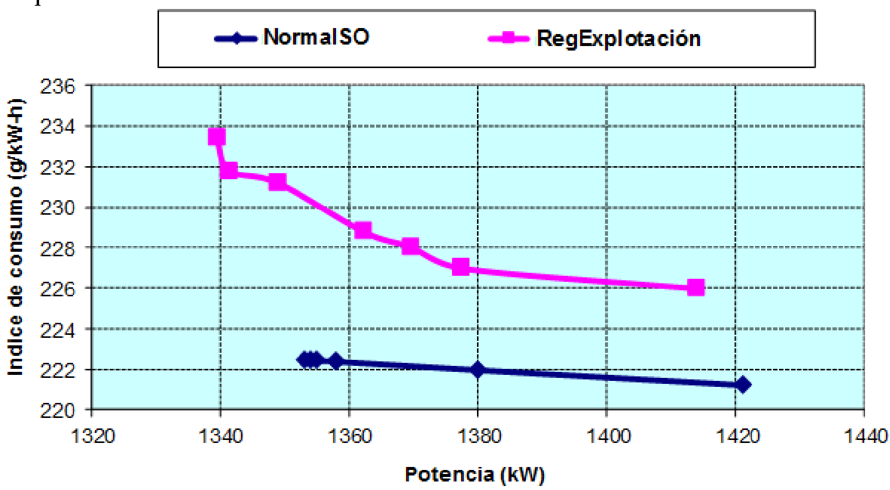

Figure 4. Behaviour of fuel consumption indices in the battery with respect to power. In original language English

Figure 4 shows a tendency of the fuel consumption index to decrease as the engine load (service power) increases, which is a product of the influence of fuel quality, the latter conditioned by its density, and sulfur content that provide better combustion and use of the energy carried by the fuel.

The curve showing the behavior of the consumption index corrected according to the ISO 3604-1 standard, has a slight tendency to decrease between the values of 221.22 and 222.49 g/kW·h, this is because it is under the influence of climatological parameters such as atmospheric pressure (average of 101.556 kPa), relative humidity (average 78.57%) and air temperature (average 26.27 ºC); because there is not a great dispersion of values, it behaves like a line. When the interaction of these parameters with the work of the engine is analyzed, it is shown that they are directly related to the mechanical performance of the engine (η_m); As the % load of the engine increases, the mechanical performance increases, therefore the engine consumption rate decreases, due to the increasing approach of the service power to the declared standard power.

5. Conclusion

The ISO 3604-1 standard establishes the foundations for the analysis of the power and fuel consumption of distributed generation facilities under local atmospheric conditions supported by internal combustion engines; establishing the calculation procedure for the determination of the parameters that characterize the engine. As well as the method of adjusting the power and fuel consumption of these motors in the battery. The analysis of the results, based on the effective parameters of the engine, shows that the effective performance increases (26.7 to 36.9%) with respect to the load due to a greater use of the energy carried by the fuel. The effective specific consumption decreases from 229.14 to 223.14 g/kW·h, increasing the effective power of the engine. In the case of hourly fuel consumption, it increases considerably with the increase in power, because it is necessary to inject a greater amount of fuel into the combustion chamber.

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