Proceedings IRF2018: 6th International Conference Integrity-Reliability-Failure
Lisbon/Portugal 22-26 July 2018. Editors J.F. Silva Gomes and S.A. Meguid
Publ. INEGI/FEUP (2018); ISBN: 978-989-20-8313-1

PAPER REF: 7157

DEFINITION AND IMPLEMENTATION OF AN INTEGRATED MANAGEMENT PLAN (IMP) APPLIED TO THE EQUIPMENT AT PERIODICAL TECHNICAL INSPECTION (PTI) STATIONS

Julio García-Cordonié, Pablo Izquierdo(*), José A. Vilán, A. Segade, E. Casarejos, M.L. Lago
Department of Mechanical Engineering, University of Vigo, Spain
(*) *Email:* pabloizquierdob@uvigo.es

ABSTRACT

This work is focus on the maintenance management of the equipment at vehicle Periodical Technical Inspection (PTI) stations. PTI is essential to guarantee the appropriate mechanical performance of vehicles related to environmental contamination and traffic safety. That makes necessary that PTI stations implement a comprehensive management plan on the maintenance of all the equipment that check vehicle systems: brakes and wheels-tires, steering, lights and electrical elements, exhaust system, electronic parts, etc. In this paper, a first approach to the definition and implementation of an Integrated Management Plan (IMP) applied to the equipment at PTI stations is studied. Different actions of the IMP are defined: Equipment Inventory, Preventive and Corrective maintenance, Spare part stock at warehouse and Control of maintenance operations. It is study the data base of gas analyzers and opacimeters provided by SYC-APPLUS PTI stations in Galicia and it is calculated the value of several indicators and ratios, such as MTBF (Mean Time Between Failures) and MTTR (Medium Time to Repair), to quantify the most frequent and serious failures in the equipment.

Keywords: Integrated Management Plan (IMP), Periodical Technical Inspection (PTI).

INTRODUCTION

Periodical Technical Inspection (PTI) is essential to guarantee the appropriate mechanical performance of vehicles. The fact is that there is an important correlation between PTI and the accidents decrease and improvement of road safety. According to the study San Román (2007), PTI avoid more than 400 fatalities per year, about 12,000 injured and almost 8,500 accidents during the period 1998-2006. This study was update (San Román, 2012) which demonstrate that vehicle technical failures contribute about a 6% of the total number of car accidents and an 8% of motorcycles accidents, which annually represents 2,000 fatalities in the European Union and a much higher number of injuries. According to this work, PTI stations avoided 11,000 traffic accidents, about 11,000 injured and 170 fatalities, which represents an economic benefit of 300 M€. Other studies (AUTOFORE, 2007) show similar results. Current legislation about “periodic roadworthiness tests for motor vehicles and their trailers” is contained in Directive 2014/45/EU that repealing previously Directive 2009/40/EC.

At PTI stations, the appropriate mechanical performance of vehicles is certificated. A visual inspection of the different mechanical parts is necessary but also the checking of the adequate performance of critical security systems must be done, such as brakes or steering working. These make necessary that PTI station must be equipped with different machines capable to determining the correct mechanical operation of those systems. Two of these testers are showed in following Figure 1: A Roller Brake Testers (left) and a Side Slip Testers (right).

This work is focus on the definition and implementation of an Integrated Management Plan (IMP) applied to PTI stations equipment and the relation between the IMP and the success and reliability of vehicle mechanical performance checking.

Fig. 1 - Roller Brake Testers (left) and a Side Slip Testers (right). Source: SYC-APPLUS

INTEGRATED MANGAMENT PLAN (IMP)

A first approach to the methodology followed to define an Integrated Management Plan (IMP) in the case of study of a PTI station is show in the current paper. A specific case of study will be analyzed and different conclusions will be drawn in order to implement an adequate IMP for any equipment at PTI stations.

As is well known in literature (Liening and Bruemmer, 2017), any equipment in use is susceptible to failure. It is defined a failure rate (λ) as the number of units of that kind of equipment that will fail on average in a time-period. This function is called colloquially 'bathtub curve' (Figure 2) with decreasing, constant, and increasing failure rate sections throughout equipment life-cycle.

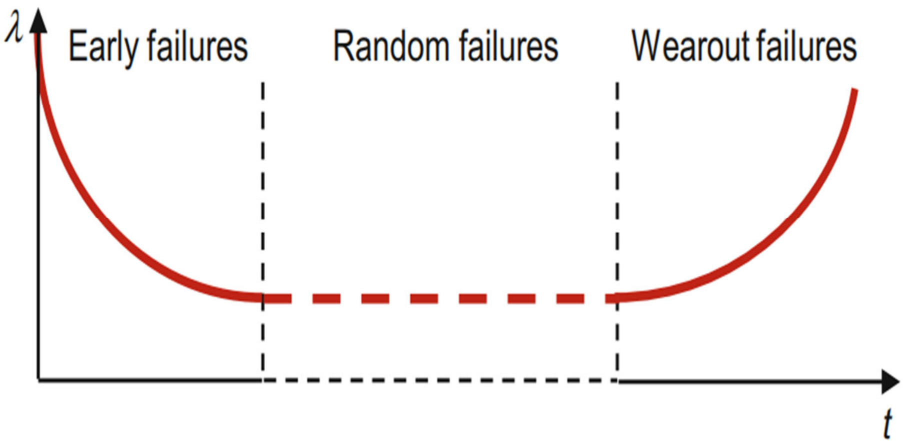


Fig. 2 - Typical plot of the failure rate λ over time t. Source: Liening and Bruemmer, 2017

As in other production installation, PTI equipment at stations requires an adequate, preventive and corrective maintenance to minimize the impact of breakdowns in operation. Its objective is, therefore, to ensure that the equipment used during vehicles' PTI will be in suitable conditions of use. In addition, since these are equipment whose results are used to qualify defects in vehicles, they must be also property calibrated by an accredited official laboratory, in order to ensure the reliability of their measurements. The calibration consists of obtaining the measurement uncertainty of the equipment. This information is included, together with the corrections that must be made, in the equipment calibration certificate issued provided by the laboratory that carries out the calibration.

In this paper, a specific case of study, relative to gas analyzers and opacimeters, is done. For this equipment, there is legal metrology involved, which requires to carry out periodic checks of metrological control (PCMC), also by an official laboratory authorized. The purpose of the PCMC role is to guarantee compliance with the technical requirements and metrological tests legally established by the Administration for certain equipment, since its measures affect the safety, health and economic interests of consumers. This is also reflected in the verification certificate issued by the laboratory and, both certificates (calibration and PCMC) must be indicated with a label placed on the equipment.

To address the maintenance management of the existing equipment at the PTI stations, establishing a system that allows achieving the objectives indicated above, it is convenient to develop an integrated maintenance plan (IMP) which summarizes in the following sections: Inventory and historical archive of equipment, Preventive and Corrective Maintenance Plan, Execution and control of maintenance, Analysis of maintenance activity and Spare parts management.

In fact, the inventory of equipment should allow the identification, location, coding and classification of the equipment to be maintained and the registration of its data. It must be accompanied by a historical archive of equipment with the register of all the interventions carried out on them throughout their useful life, including information regarding additions, removals and changes of location, interventions (preventive or corrective maintenance, calibration or periodic metrological control), personnel that has intervened in them, time required and materials and manpower costs.

In relation to maintenance, preventive maintenance, calibration and PCMC must be planned. To prepare an adequate Preventive Maintenance Plan (PMP) it is necessary to define the preventive maintenance sheets for each equipment, detailing the different operations and the intervention frequencies (daily, weekly, monthly, annual, etc.) as well as the maintenance step to which they correspond (for example: 1st station, 2nd internal maintenance team, 3rd supplier) and the personnel and materials necessary to carry them out.

On the other hand, it is necessary to have an adequate control of the spare parts warehouse, recording the inputs and outputs of material and its assignment to the different works carried out, both preventive and corrective maintenance, and managing their stocks, relying on the system of the company's purchases.

Finally, it is necessary to carry out the execution and control of the activity, which is based on the launching of Work Orders (whether they are revision, issued according to those established in the Maintenance Plan, or repair, which are generated when they occur breakdowns) and in the subsequent completion of Work Reports, whose data make it possible to generate structured information about the work carried out and the analysis of the maintenance activity by calculating a series of indicators and ratios, such as, the well-known Mean Time to Failure (MTTF) and the Mean Time to Repair (MTTR) that make possible a quick view of the maintenance status of each equipment and allow, if it is necessary, implement any corrective action for a continuous improvement of the service and, therefore, to increase the operability of the inspection lines. To contribute to this, it is useful to make an analysis of the main failures that have occurred, for example, through the use of methodologies such as FMECA- Failure mode, effects and criticality analysis- in order to incorporate improvements in equipment to reduce them in the future.

A specific case of study will be done in the next section of this paper related to an opacimeter operation in a PTI station. The following diagram (Figure 3) represents the main parts of an integrated maintenance plan (IMP) must include, such as it was explained before, as well as its connection with other management systems of the company (fixed assets, human resources and warehouse).

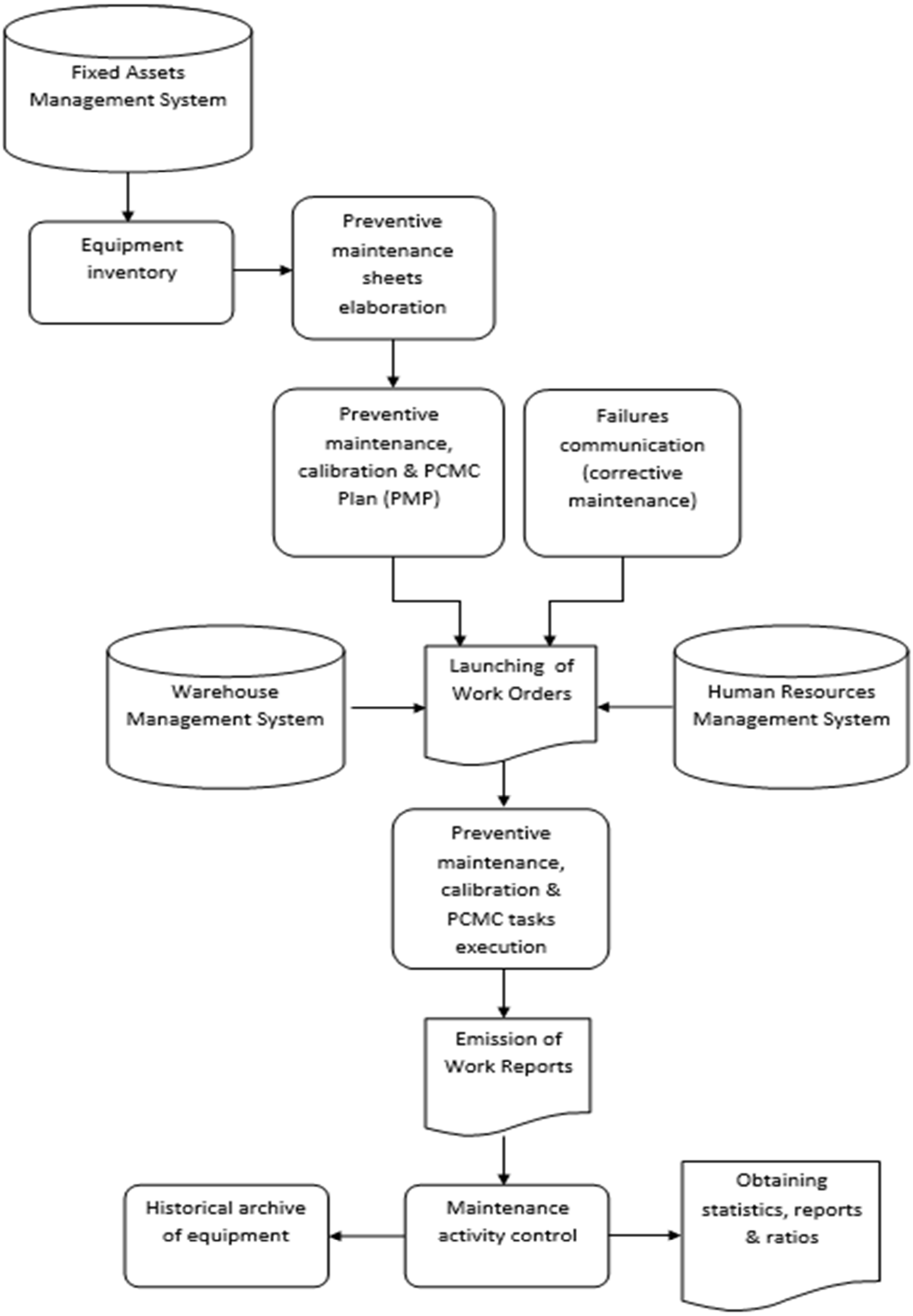


Fig. 3 - Scheme of an Integrated Maintenance Plan (IMP). Source: Own elaboration

CASE OF STUDY

To illustrate what has been described in previous sections, a case of study is done. The impact on the operation of inspection lines due to equipment breakdowns is analyzed for the equipment to vehicles pollutant emission control at PTI stations: gas analyzer and opacimeter.

Equipment description:

- Gas analyzers

Gas analyzers measure the concentrations of components (CO, CO2, O2 and unburned HC) presented in the exhaust gases of a vehicles with spark ignition engines. Based on these concentrations, the Lambda (λ) coefficient (Balance of Oxygen to Fuel) is obtained using the Brettschneider equation (1979) that is the de-facto standard method used to calculate the normalized λ.

Control of emissions is carried out with an equipment that consist on an analyzer that is introduced into the exhaust pipe of the vehicle inspected (Figure 4). This analyzer obtains a sample of the gases emitted using a vacuum pump and eliminating most of the water and solid particles. The analyzer also has a power supply and a control unit for the set-up configuration and calibration of the equipment and to record and present the results and all the information of the gas analyzed.

Fig. 4 - Emission control in a PTI station. Source: SYC-APPLUS

- Opacimeters

The opacimeters measure the fumes turbidity emitted by the vehicles with compression ignition engine. Gases are sent to a measurement chamber in which it is emitted a light signal and it is detected their intensity after pass throw the gasses with a photoelectric cell sensor. As well as analyzers, opacimeters are composed of a unit of measurement, a power source and a control unit.

The presence of these fumes in the chamber produces an absorption of light, which varies the intensity of the light-beam. This variation is detected by the equipment and it is calculated the light absorption coefficient, using Beer-Lambert law, referenced in several papers such as Cha (1988), as a measurement of the diesel particulate emissions. It is defined a K-index as the level of the gas turbidity emitted by the vehicle engine.

ANALYSIS AND RESULTS

From a data base of the corrective maintenance of a gas analyzer and opacimeter equipment, provided by one PTI operator during a period of two years, an analysis is done. The main faults occurred during its operation at the PTI stations, as well as the frequency of interventions in each case, is shown in the following table for each type of equipment.

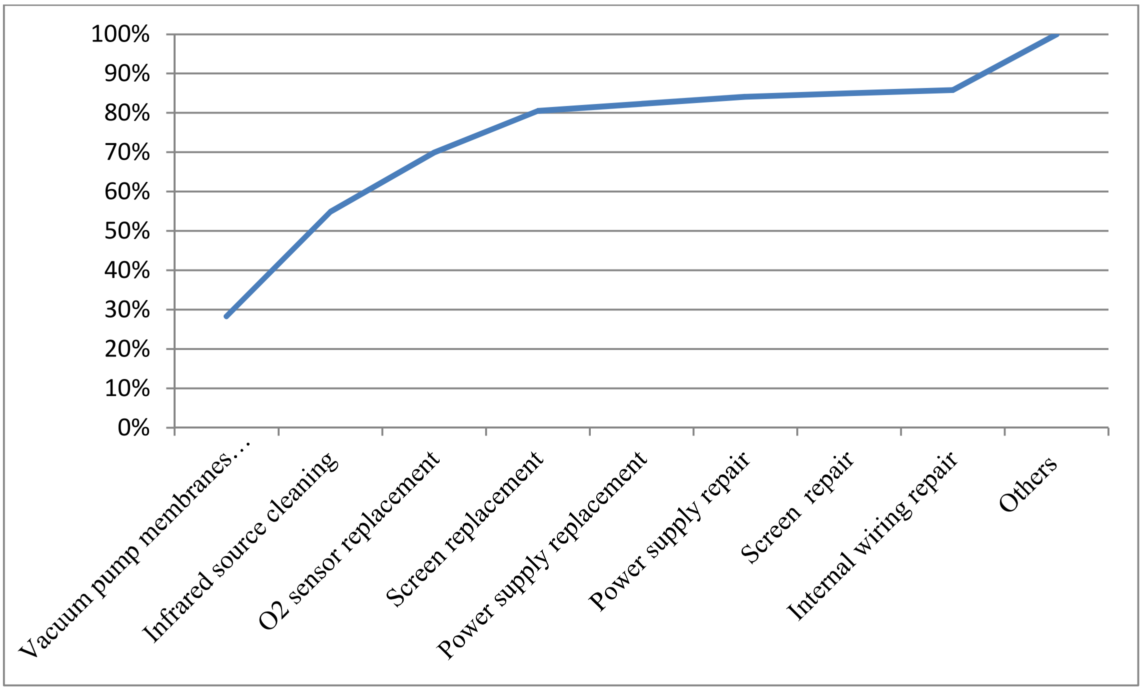
Table 1 - Main operation faults in gas analyzers at PTI stations. Source: SYC-APPLUS

Type of failure (gas analyzers)	% of interventions
Vacuum pump membranes replacement	28%
Infrared source cleaning	27%
O2 sensor replacement	15%
Screen replacement	11%
Power supply replacement	2%
Power supply repair	2%
Screen repair	1%
Internal wiring repair	1%
Others	14%

Table 2 - Main operation faults in opacimeters at PTI stations. Source: SYC-APPLUS

Type of failure (gas analyzers)	% of interventions
Opacity camera cleaning	32%
Temperature transistor replacement	28%
Fan replacement	4%
Fan repair	4%
Power supply replacement	4%
Heating resistance replacement	4%
Power supply repair	3%
Microprocessor replacement	3%
Speed sensor repair	3%
Temperature probe replacement	3%
Screen replacement	2%
Control cable replacement	2%
Emitting source replacement	1%
Internal wiring repair	1%
Internal connector repair	1%
Motherboard replacement	1%
Others	6%

In both installations, most of the failures are due to a reduced number of causes. Following figures (Figure 5) show the cumulative frequencies of the interventions in each case (top: gas analyzer; bottom: opacimeter) using a Pareto analysis of the data.



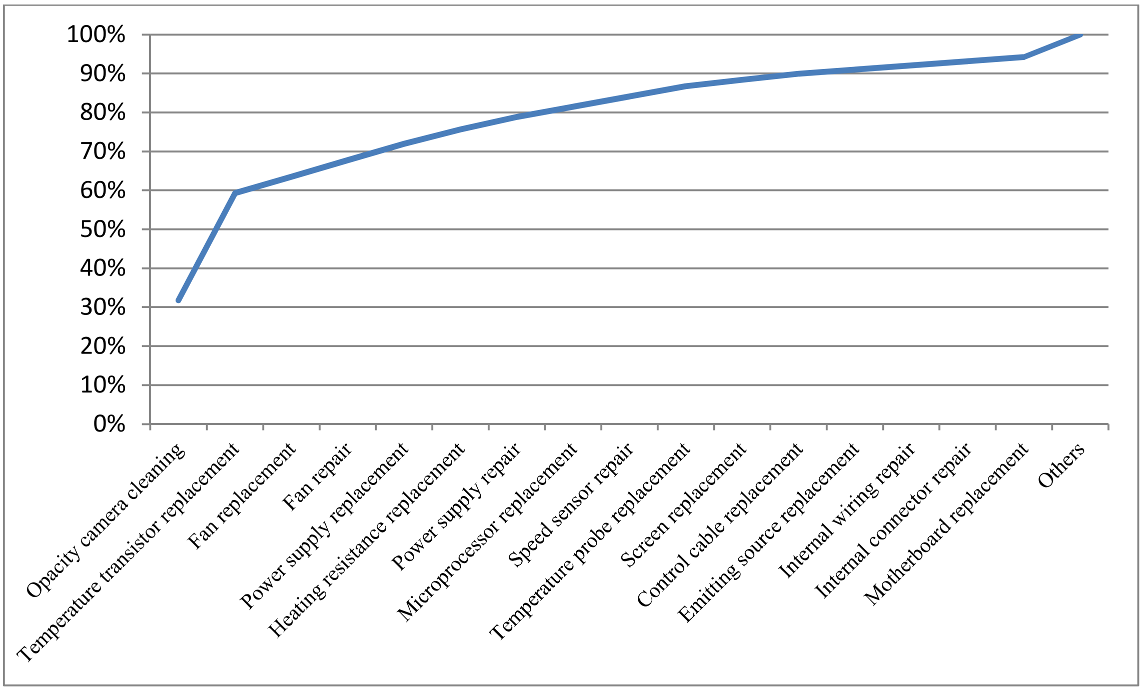


Fig. 5 - Analysis of cumulative frequencies of failure in gas analyzers (top) and opacimeters (bottom). Source: SYC-APPLUS

In both cases, more than the 80% of the corrective maintenance interventions are due to a few types of failures. In the case of gas analyzers, there are only four main causes with more than the 80% of the frequencies, and eight causes in the case of opacimeters. In both case, less than the half of the different causes analyzed are responsible of more than the 80% of failures.

These results allow to defining an accurate integrated management plan (IMP) to those devices which include a preventive maintenance to avoid service failures. Among them, both type of equipment must be cleaned by the maintenance personnel, in a complementary way to inspection personnel, as the first step of preventive maintenance, also the opacity chamber and the infrared bank.

Taking into account the data, it is obtained indicators and ratios, such as MTBF (Mean Time Between Failures) and MTTR (Medium Time to Repair), to quantify the most frequent and serious failures in each equipment. The main goal of this preventive maintenance is avoid non-operational availability of equipment. Such it is showed in figure below (Figure 6), due to repair operations, this equipment could be more than 15 days without operation in a 2-3% of the cases. Fortunately, most of the cases analyzed, only one non-operation day is happened (more than the 50-55% of the cases), and in a 90% of the cases, less than 4-5 days.

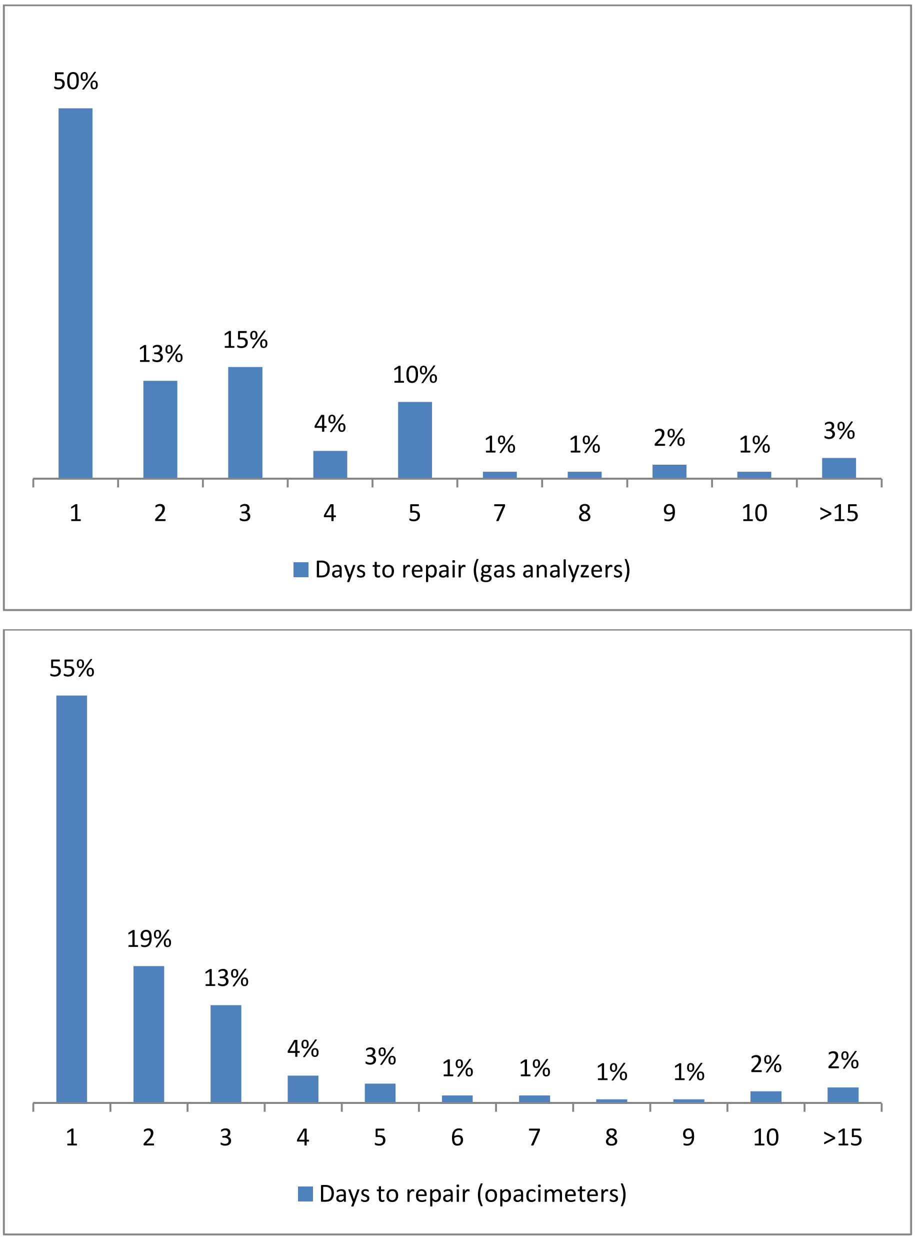


Fig. 6 - Non-operational days for gas analyzers (top) and opacimeters (bottom). Source: SYC-APPLUS

Although these graphs show that a significant number of failures were repaired on the same day, there were others that required more time for various reasons: need to acquire the necessary spare parts, availability of maintenance personnel, etc. These facts cause a decrease in the inspection capacity of the station. As we saw, if we add up the time elapsed until the repair in all the interventions carried out in the opacimeters, the total number of days that result is approximately 80% of those that had been working during the period contemplated, which means that during most of the same time, some equipment was broken in some of the station under study. If we do a similar operation with the times corresponding to the analyzers, the percentage obtained is 50%. As indicative ratios of the status of the equipment in the PTI stations during the period considered, we can obtain the failure rate (λ) in the opacimeters and gas analyzers. It was $\lambda = 3.32$ and 1.89, respectively, which provide values of MTBF of 7.24 and 12.68 months in each case. As regards the MTTR, in the opacimeters, maximum delay was about 15 days with a MTTR value of 7.98 days, while, in the analyzers, the greatest delay was of 10 days with a MTTR value of 5.11 days.

CONCLUSIONS

An adequate proposal for an IMP applied to the equipment at PTI-stations must contemplate the flowing main activities: Equipment Inventory, Preventive and Corrective maintenance, Spare part stock at warehouse and Control of maintenance operations. These actions must guarantee that the equipment had the reliability and availability expected, and then the data obtained from the equipment was accurate and precise.

As it is known, equipment must be reliable in operation and their availability is in function of the evolution of the number of failures throughout its life cycle. First, and as a preliminary study of the IMP, 'bathtub curve' of different equipment will be done, in order to stablish equipment 'useful life'. Secondly, actions related with preventive and corrective maintenance must be defined to be implemented with the purpose of reduce equipment failures and increase their reliability and availability.

In the other hand, in order to get precise and accurate data from equipment, calibration must be taking into consideration. Also, metrological control and calibration allows to obtaining correct data from the equipment and to avoid a false pass-testing, and a periodic metrological control has to be done to confirm compliance with the legally requirements.

Finally, a Control of maintenance operations will be presented. Taking into account the study, a data analysis will be presented in order to calculate several indicators and ratios, such as MTBF (Mean Time Between Failures) and MTTR (Medium Time to Repair), to quantify the most frequent and serious failures in each equipment.

In the case of study of gas analyzer and opacimeter, two years' data from PTI were done. The main faults occurred during its operation was determined and in both cases, more than the 80% of the corrective maintenance interventions are due to a few types of failures. Due to repair operations, this equipment could be more than 15 days without operation in a 2-3% of the cases. Fortunately, most of the cases analyzed, only one non-operation day is happened (more than the 50-55% of the cases), and in a 90% of the cases, less than 4-5 days. Indicative ratios were obtained. The failure rate (λ) was $\lambda = 3.32$ and 1.89 in the opacimeters and gas analyzers respectively, which provide values of MTBF of 7.24 and 12.68 months in each case. MTTR value was 7.98 days and 5.10 days in each case, with an average maximum of 15 and 10 days, respectively.

ACKNOWLEDGMENTS

The authors gratefully acknowledge SYC-APPLUS for data base used in this paper.

REFERENCES

[1] AUTOFORE: Study on the Future Options for Vehicle Roadworthiness Enforcement in the European Union. International Motor Vehicle Inspection Committee (CITA). http://citainsp.org/wp-content/uploads/2016/01/PressReleaseEN.pdf

[2] Brettschneide J, Bosch Technische Berichte (1979) V. 6. N. 4. pp. 177-186

[3] Cha, S, Black, F., King, F. Continuous measurement of diesel particulate emissions (1988). Journal of the Air Pollution Control Association. Volume 38, Issue 3, pp. 252-257

[4] Directive 2014/45/EU of the European Parliament and of the Council of 3 April 2014 on periodic roadworthiness tests for motor vehicles and their trailers and repealing Directive 2009/40/EC. http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32014L0045

[5] Lienig Jens and Bruemmer Hans. Fundamentals of Electronic Systems Design. Ed. Springer AG. ISBN: 978-3-319-55839-4 (2017). doi.org/10.1007/978-3-319-55840-0

[6] San Román García JL., Gauchía Babé A., Díaz López V. Contribución de la Inspección Técnica de Vehículos a la Seguridad Vial. Fundación Instituto Tecnológico para la Seguridad del Automóvil (FITSA). Instituto de Seguridad de los Vehículos Automóviles (ISVA). Universidad Carlos III, Madrid. (2007)

[7] San Román García JL., Gauchía Babé A., Díaz López V. Contribution of Periodic Motor Vehicle Inspection (PMVI) to vehicle safety. FITSA. ISVA. U. Carlos III, Madrid. (2012).