



MOTOR VEHICLE DIAGNOSIS IN TERMS OF TECHNICAL FACILITIES REQUIREMENTS

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Abstract

This paper presents the importance of motor vehicle diagnostics for proper and safe operation of motor vehicles - safe to drivers, other road users and the natural environment. Other benefits of diagnostic testing, such as a reduction in the vehicle operation costs, a narrower scope of required technical service, a reduction in the purchase costs of spare parts or minimization of service labour intensity are also presented. The paper lists and describes the essential requirements to be met by those who carry out business activity involving diagnostic testing, i.e. the requirements regarding appropriate marking, types and sizes of control stands, adjustment of the equipment to the needs and scope of the offered services, documentation required to carry out technical inspections, qualifications of inspection station staff and training courses for inspection staff. The paper further presents the regulations regarding deadlines for diagnostic tests, the scope and the method for carrying out vehicle technical inspections, the measurement conditions, the course of testing, the evaluation of test results and, depending on the vehicle type, the required additional tests.

Keyword: *technical facilities, diagnostic tests, regulatory requirements*

1. Introduction

The development of the automotive industry as a result of the growing demand for motor vehicles, both private and corporate ones, contributes to the need for establishing specialist technical facilities to ensure proper, that is, safe operation of transport means. Cars in good working order are also a guarantee that the transport tasks are performed to high standards.

Diagnostic stations are motor transport facilities designed to check the technical condition of vehicles in use. In terms of safety, they are very important [7]. They localize faults in the vehicle assemblies and sub-assemblies without disassembling the vehicle or with disassembling some parts only. Diagnostic stations carry out tests in order to compare the current technical condition of the vehicle with the nominal parameters that correspond to good structural systems, assemblies and subassemblies. On this basis, the vehicle is assessed as roadworthy or unroadworthy. A roadworthy may either be in good or bad technical condition, however, any fault found is to be repaired as soon as possible.

In order to ensure high quality services, diagnostic stations must meet many applicable requirements, including those related to suitably qualified staff. Stations should carry out diagnostic tests using specialist equipment. The instruments used for diagnostic purposes can be very simple or advanced, as are, for example, universal sets for diagnostic testing of electronics. Also becoming more and more popular are on-board diagnostic systems. The integrated vehicle diagnostic systems monitor the sensors installed in the vehicle at the manufacture stage and some

of the actuators, which enables the execution of the self-diagnosis process, thus detecting faults as early as possible.

2. The importance of diagnostics for proper vehicle operation

Diagnostic tests carried out in Vehicle Inspection Stations have a fundamental influence on safe operation of transport means. They enhance the availability of cards and increase the efficiency of the transport process due to reduced downtime of and the reduced number of repairs on the vehicles. Vehicle diagnosis also contributes to reduction of vehicle operation costs. The scope of technical services is narrowed, the purchase costs of spare parts are reduced. It is often the case that the staffing levels are subject to review and the service labour intensity is minimized. Diagnostics help keep the vehicle in good working order for an extended time and improve road safety.

Diagnostics is a fundamental operating tool that helps keep the vehicle in good technical condition. It is assumed that, as a result of diagnostic testing, the car utilization ratio is increased by ca. 15-20%, the fuel consumption is reduced by ca. 15%, the wear of spare parts is reduced by ca. 20%, and the car's mileage is 1.3 to 1.5 times higher before it undergoes a major repair [5]. Diagnostic tests allow for:

- evaluation of the current condition of the car, thus providing the user with basic information,
- prediction of future conditions of the car, creating bases for proper scheduling of diagnostic tests and services,
- designation of worn out vehicles as end-of-life vehicles.

The examination, assessment and determination of the causes of the bad technical condition of a vehicle is possible using diagnostic methods (diagnosis), suitable diagnostic instruments and algorithms for condition control and damage localization. Diagnostic methods are an effective procedure to achieve these goals. During the diagnostic process, it is to determine the condition of the technical facility. This process is an action algorithm including diagnostic testing and concluding. The diagnostic process can be carried out through:

- periodical of constant tests and technical condition assessments by use the vehicle's diagnostic instruments (on-board diagnostic systems),
- periodical tests and assessments by use of diagnostic instruments (external diagnostic systems) that are connected to the vehicle,
- a combination of the above.

The fundamental task in the vehicle diagnosis is to determine its overall condition, without distinguishing the conditions of the vehicle's separate components. The aim of the testing called a vehicle condition check is to establish whether the vehicle as a whole is roadworthy or not. Obtaining at least one negative result during the check means that the car is unroadworthy and should be subject to further testing and evaluation of malfunctions, that is, to determination of the condition of the vehicle components in order to adjust, repair or replace them. Such testing is called damage localization [6].

All technical inspections carried out at diagnostic stations should be made to the highest possible standards, in accordance with relevant guidelines, at appropriately prepared and equipped control stands and by duly authorized employees.

2.1. Specification of modern internal-combustion engine diagnostics

Special attention is to be paid in the motor vehicle diagnosis to the technical assessment of the internal-combustion engine that is the vehicle's drive. Engine designs have been subject to deep changes particularly in the recent years. This is primarily due to the legislation relating to relevant standards and environmental barriers in transport means. Moreover, the distinct trends to replace

conventional fuels (such as petrol, diesel fuel) with alternative energy sources involve introduction of previously unknown solutions including new generation assemblies, sub-assemblies and control systems to piston engine designs. All that requires a use of new testing methodologies, diagnostic equipment with high performance parameters and diagnostic personnel with knowledge appropriate to the modern solutions in order to ensure an effective and reliable assessment of the technical condition.

Meeting the requirements regarding the correct course of the diagnostic process is determined by possessing of suitable technical facilities with specialist equipment that fulfil the contemporary criteria. Before setting about any activity involving diagnostics of vehicles and internal-combustion engines, one should organize appropriate potential, which, in most cases, would be determined by [2]:

- creative personnel managing the diagnostic tests and having knowledge that allow them to formulate conclusions,
- executive personnel preparing the apparatus and devices for the tests, carrying out the tests and treating the results,
- support personnel responsible for the technological and administrative aspects of the diagnosis,
- test stands (for engines, accessories etc.),
- specialist measuring and recording apparatus,
- applied testing and measuring methods,
- diagnosticians' testing qualifications as required by law.

In the testing of engines, the assessment of their current technical condition is the overriding aim, however, their recorded parameters may not change during the extensive diagnosis or during the diagnosis of separate assemblies and sub-assemblies. If this was the case, it would be significantly difficult to formulate a correct assessment. Then, this would indicate such a degree of wear and tear of the engine that it engine should be subject to repair.

The majority of tests carried out as part of the diagnosis are performed on engines, the condition of which meets the technical requirements that define an engine in good working order. Achieving the so called allowable or limit parameters for the technical condition is referred to a specified run rate of the engine that may be in good or bad working order but yet not non-operational [2].

In the literature, there is no information on specific requirements regarding solely engine diagnosis in regard to technical facilities. It is assumed that an internal combustion engine is an element of the car design, and the relevant requirements should be worked into the construction concept for the whole facility designed for diagnostic testing. However, during diagnosis with the engine running, special attention is to be paid to safe exhaust gas offtake and noise emission. Therefore, a test stand should be separated (shielded) from other stands where other car systems, which do not need to be assessed with the engine running (like the steering and suspension systems), are diagnosed. Exhaust gas must be taken through an offtake system to the outside of the facility, taking into account the immediate vicinity of the diagnostic station to ensure the environment is not in danger (residential buildings, amenity areas etc.). The noise emission should be taken into account when designing the facility's walls that are to dampen the emission to the outside.

The diagnostics of modern internal-combustion engines is essentially based on verification of the operational data recorded in the on-board diagnostic (OBD) system. Since the creation of the OBD system, its development is divided into three periods [4]:

- OBD I - legal and technical regulations concerning car diagnostics and signalling of damages in the injection/ignition system components (date of introduction – 1984r.),
- OBD II - active diagnostics of the emission assemblies and the elements of the power transmission system (date of introduction – 1996r.),

- OBD III - active diagnostics of the other functional systems of the motor vehicle's body and chassis (no fixed date of introduction).

Currently, the OBD II standard (the European equivalent is EOBD) is in force. As mentioned previously, this standard addresses damages causing increased emission of toxic compounds from the exhaust system and increased fuel consumption in the fuel system. Such damages are called emission damages because they affect the units and components of the power transmission system that are responsible for the emission of toxic compounds.

According to the OBD II standard, a unit of component is considered inefficient if its operation may cause an increase in the emission of toxic compounds from the exhaust or fuel system. An increase in emission by 50% in relation to the maximum allowable value for a given type of car is defined as a limit increase.

The introduction of the OBD system and its further development create a quite new situation in respect to vehicle diagnostics. The assessment of the car's current technical condition during the current operation, which has previously been the sole task of Vehicle Inspection Stations and vehicle users themselves, now becomes also a duty of manufacturers of transport means, which is guaranteed by laws regarding compulsory type-approval tests.

3. Requirements relating to technical facilities enabling diagnostic testing

All motor transport facilities, including diagnostic stations carrying out technical inspections of vehicles are subject to specific regulations relating to their operation. Diagnostic stations should have signboards appropriately marked and prominently displayed outside, i.e. the signboards should be blue with white notices including at least an identification code, a designation of the station type and the opening hours. For proper operation, the stations should also have at least one control stand to carry out technical inspections of vehicles and an outside stand for noise measurement. The requirements for diagnostic station stands are presented in Table 1.

Tab 1. Requirements relating to control stands, test benches and inspection channels

Stands	Requirements
Control stand	<ul style="list-style-type: none"> • Should be situated in a separate room. • Should consist of: <ul style="list-style-type: none"> - a flat horizontal surface, the so called "test bench", - an inspection channel and a device to elevate the vehicle axle, - measuring and control devices and instruments, - technological equipment, - a noise measuring stand, • The length of a control stand should be more than that of the inspection channel (not less than 3 m). • The width of a control stand should not be less than 6 m (widths below 5 m are allowed). • The sizes of the entry and exit gates should be: height 4.2 m (3.2 m is allowed with regard to inspection of a vehicle with a weight of 3.5 t). • The ratio of the windowpane surface to the floor surface is to be at least 0.15. • A control stand should be equipped with: <ul style="list-style-type: none"> - device operating manuals, - data concerning the criteria for assessing the inspected vehicles, - a set of relevant regulations.
Test benches	<ul style="list-style-type: none"> • Should provide a possibility to put any vehicle with all its wheels on the bench. • Should enable placing the inspected vehicle before the lighting lamps of the device designed for the inspection. • The edge spacing should not be less than: <ul style="list-style-type: none"> - 2.4 m for vehicles with a maximum allowable total weight of 3.5 t, - 2.8 m for all other vehicles. • The maximum allowable irregularity for test benches should be: <ul style="list-style-type: none"> - 2 mm for vehicles with a maximum allowable total weight of 3.5 t,

	<ul style="list-style-type: none"> - 3 mm for all other vehicles. • The maximum allowable deviation from the level should be: <ul style="list-style-type: none"> - 2 mm/lm for vehicles with a maximum allowable total weight of 3.5 t, - 3 mm/lm for all other vehicles.
Inspection channel	<ul style="list-style-type: none"> • The channel width should be within the following limits: <ul style="list-style-type: none"> - 0.65 to 0.60 m for vehicles with a maximum allowable total weight of 3.5 t, - 0.70 to 0.90 m for all other vehicles. • The depth should be within the range of 1.40 to 1.70 m. • Must have drainage and ventilation systems. • There should be lighting and tool/key shelves in the channel. • There should be device installed in the channel to elevate the vehicle.

The applicable laws also specify the technical conditions to be met by diagnostic stations, i.e. requirements relating to [8,11]:

- the station's equipment that must be adjusted to the needs and scope of the offered services,
- documentation required to carry out technical inspections of vehicles,
- types of control stands,
- diagnosticians and training courses offered to them.

The applicable laws relating to the operation of diagnostic stations also regulate the deadlines for diagnostic tests, provide information on the vehicle inspection scope and methods, define the measurement conditions, the course of testing, evaluation of results and, depending on the vehicle type, additional tests to be made. The applicable laws distinguish the following types of diagnostic station:

- Basic Vehicle Inspection Stations that cover basic technical inspections including checks and assessments of the operation of particular vehicle systems, especially in terms of driving safety and environmental protection (exceptionally, the scope of services can be extended to include some tests that are not covered by BVISs),
- Regional Vehicle Inspection Stations that cover an extended scope of technical inspection, including:
 - basic scope of inspection,
 - inspection of buses for which the speed limit on the highway and expressway is 100 km/h,
 - inspection of vehicles designed for transport of hazardous materials,
 - inspection of gas-powered vehicles,
 - inspection of vehicles referred by the traffic control authorities or the starost,
 - periodical inspection of vehicles designated as "self-constructed",
 - inspection of vintage vehicles and vehicles designated as "self-constructed" as to their compatibility with technical specifications,
 - granting and stamping numbers on the vehicle bodies (chassis) and engines, making substitute plates,
 - giving opinions in regard to individual applications for permission for derogation from the technical conditions to be met by vehicles,
 - clarifying doubts and settling disputes arising between the basic inspection station and the vehicle user.

The relevant regulations also address the types of diagnostic devices that are subject to compulsory assessment by an accredited body. All instruments and devices making up the equipment of a diagnostic station are subject to certification carried out by the Motor Transport Institute. The basis for certification is accreditation from the Polish Centre for Accreditation, confirming the competence of the certifying body (the Motor Transport Institute) to carry out this kind of activity. The formulated technical requirements are a basis for assessment of usefulness of devices and for issuing compliance certificates in accordance with the European standards.

3.1. Requirements relating to periodic operational inspections and diagnostic equipment

A diagnostic station performing technical inspections of motor vehicles must possess a statement of conformity for the equipment and instruments with reference to its requirements prepared in Polish. It is permitted to have a declaration of conformity issued in another language along with a translation into Polish. Additionally, the measuring and inspection equipment of diagnostic stations are subject to periodic operational inspections, which do not apply to devices and instruments that are subject to periodic metrological controls (e.g. exhaust analysers, sound level meters and manometers) or to periodic tests by the technical inspection authorities (i.e. jacks). The operational inspection includes:

- organoleptic examinations, if the device or appliance is whole and mechanically undamaged,
- an inspection of the operations and indications made in accordance with the manufacturer's instructions provided in the operation and maintenance manual (user manual),
- other monitoring activities stipulated by the manufacturer carried out in accordance with its recommendations.

The periodic operational inspections are carried out on the dates specified by the manufacturer. They are performed by an authorised station employee. Inspection results shall be entered in the periodic operational inspection card. The station's managing director should also have the documents from the periodic operational, metrological and technical inspections of the equipment and instruments constituting the measuring and inspection equipment of the Motor Vehicle Inspection Station.

The control stand equipment at a Motor Vehicle Inspection Station includes at minimum the following devices and instruments [10]:

- a roller device or overrun device for inspecting brake operation,
- a mechanism to assess the correct wheel settings,
- an instrument to measure and regulate air pressure in tyres,
- an instrument to measure the settings and brightness of the vehicle's lights,
- an instrument to measure the light transmission coefficient on the vehicle's windows,
- a sound level meter,
- a smokemeter,
- an instrument to inspect the electric connector between the vehicle and the trailer,
- an instrument that puts a defined amount of pressure on the mechanism controlling the trailer's overrunning brakes,
- an instrument to force jolting on the vehicle's wheels while in motion,
- a microreader for diagnostic information for the OBD-II/EOBD system,
- a multicomponent exhaust gas analyser for spark ignition engines,
- a decelerometer for inspecting the operation of the brakes,
- a set of assembler's tools,
- a basic set of general-purpose measuring instruments.

However, a test stand in the Regional Vehicle Inspection Station should have the following additional equipment [8]:

- an instrument to measure wheel and axel alignment,
- an electronic gas detector to inspect for gas leaks,
- equipment for monitoring the effectiveness of the vehicle's shock absorbers with a maximum allowable total weight of 3.5 t,
- a set of torque wrenches in the range of 20 to 400 Nm.

The measuring and inspection equipment may be shared by several control stands of one station. The measuring and inspection equipment as well as other equipment of the station may be used to carry out technical inspections on vehicles if it has been subject to the conformity assessment and also has the CE marking.

3.2. Qualification requirements for diagnosticians and industrial safety and fire regulations

Technical inspections at Vehicle Inspection Stations should be carried out by authorised diagnosticians who meet the following conditions [9]:

- have completed higher technical education with a speciality in motor vehicles or two years of professional experience at a vehicle service station or at a vehicle repair and service station in a vehicle repair shop,
- have completed secondary technical education with a speciality in motor vehicles and four years of professional experience at a service station or at a vehicle repair and service station in a vehicle repair shop,
- have completed professional training in accordance with the training programme and have received positive results on the qualification exam.

In cases where the diagnostician's technical education is in an area other than automotive, his or her professional experience should be at least twice as long. All candidates who wish to become licensed diagnosticians carrying out technical examinations for motor vehicles must complete all parts of the training presented in Table 2.

Tab. 2. Types of training for diagnosticians [9]

No.	Training type	Features
1.	Part I; Basic training	Deals with the carrying out of periodic vehicle inspections with regard to checking and assessing the operation of particular vehicle assemblies and systems (mainly concerning aspects of traffic safety and environmental protection).
2.	Part II; Specialist training	Deals with technical inspections of busses for which the speed limit on the highway and expressway is 100 km/h.
3.	Part III; Specialist training	Deals with the carrying out of technical inspections of vehicles used in transporting hazardous materials.
4.	Part IV; Specialist training	Deals with the carrying out of technical inspections of gas-powered vehicles.
5.	Part V; Training in technical inspections of:	<ul style="list-style-type: none"> • vehicles registered for the first time abroad - of a new type, produced or imported in the amount of one per year, • vehicles that have been referred by the traffic control authorities or the starosta if they require special inspections and vehicles, the design or structure of which has been altered, which requires a change to be made to the registration data, • vehicles designated as "self-constructed" as to their compatibility with technical specifications.

Diagnosticians who, after receiving positive results on their exam, earn the right and qualifications to carry out technical inspections on vehicles shall retain these qualifications in the scope that they were issued and that they are recognised as meeting the requirements outlined in the instructions. They can also obtain permission to carry out new types of vehicle inspections after completing the relevant parts of the training and pass the qualification exam with positive results.

In addition to possessing the qualifications mentioned above, a diagnostician to be employed at a Vehicle Inspection Station must be familiarized with health and safety regulations and provided with introductory general and stand-specific training as well as basic and recurring training. In accordance with the appropriate requirements, the employee should receive work clothing and footwear as well as personal protective equipment (e.g. work gloves, glasses).

The diagnostic station's building should be constructed of non-flammable materials and be equipped with all necessary fire-fighting equipment in the form of two 6 kg ABC_E dry powder fire extinguishers, three 6 kg carbon dioxide extinguishers and a fire blanket. It is forbidden to store

flammable materials unnecessary for diagnostic tests inside the station. There is also an absolute ban on smoking and open flames in the station. Warning and informational signs should be posted around the area of the station.

The station's control stand is required to have sensors for excessive concentrations of carbon monoxide that will automatically start ventilation. The ventilation system in the station automatically prevents dangerous levels of exhaust gases. To maintain safety at work, additional safeguards shall be applied in the diagnostic stations, including:

- resetting machines and electrically-powered devices,
- installing low-voltage lighting and insulation grates in the channel,
- air injection into the channel,
- floors made of non-slip material.

3.3. Requirements for environmental protection in diagnostic stations

The functioning of the technical facilities for motor vehicle diagnostics should do as little as possible to negatively impact the environment. The use of the diagnostic station should have a minimal impact on air quality and the acoustic environment. The manner of conducting services and the range of activities should also not negatively impact the quality of the surrounding water and soil, the inhabitants of nearby areas and the surrounding environment. Direct impacts associated with the emission of noise, dust and gas should only be local in scope and limited to the area on which the facility is located.

A problem associated with the carrying out of diagnostic tests may be noise from the work equipment used in the station. It is important, however, that they are used only during the station's hours of operation in accordance with their intended use. The choice of location for the diagnostic station is in this matter significant, in that it should be away from single-family housing and should have thermal-acoustic insulation in the form of expanded polystyrene and airtight seals on the entry/exit gates and windows.

A good solution that should be taken into account in many technical facilities, including diagnostic stations, is the use of storage tanks to collect rainwater from the roof as well as installations for reusing waste water, which would significantly reduce the amount of water taken from the mains [1,3]. The collection and use of rainwater allows for reduced costs, thereby increasing the profitability of each automotive facility. It is, however, important to remember that rainwater and snowmelt may be contaminated with petroleum derivatives, and therefore must be purified prior to their release into the environment. In accordance with the regulations of the Ministry of Environment, waste of this type should be passed through a petroleum derivative separator to adequately reduce suspensions and pollutants to appropriate levels.

All waste produced by the diagnostic station should be segregated and stored separately in a designated area until it is of the appropriate amount that can be removed by an authorised company, but for not longer than 3 years. Please note that cleaning the separators can be dealt with only specialised companies. Caution should also be exercised in the case of hazardous wastes. Until they are collected by the appropriate firm, they must be stored in sealed containers made of materials resistant to the elements contained in the waste and placed on paved, sealed surfaces in places inaccessible to unauthorised persons.

Among the many activities aimed at eliminating the adverse impacts of diagnostic stations on the environment, the ones carried out in accordance with the regulations from the Ministry of Infrastructure deserve special attention, i.e.:

- control of the technical condition of the exhaust system and control of the level of external noise while the vehicle is stationary,
- control of the gas pollutants from vehicles with petrol engines whose first registration was made after 1 July 1995,

- control of the smoke opacity of vehicles with compression-ignition engines,
- control of the proper adaptation of a vehicle to gas power when performing periodic technical inspections of the vehicle.

4. Conclusions

Ensuring the safe operation of motor vehicles for their owners, other drivers and the environment, is largely dependent on the vehicle's technical condition. Thanks to the compulsory periodic technical inspections that must be performed on every vehicle travelling on the roads, it is possible to maintain their good working order. Technical inspections can detect any defects in a vehicle before they become the cause of a serious breakdown, accident, injury or major environmental pollution. The technical condition of vehicles is checked in diagnostic stations equipped with specialised equipment and highly qualified workers. They need to upgrade their skills due to the dynamic development of the automotive industry as well as the rapidly increasing advances with regards to vehicle design and technology.

All requirements for the operation of diagnostic stations are intended to ensure a high level of service performance. The relevant legislation governs both the sizes of the control stands, the equipment for carrying out the tests, the inspection procedures, as well as the amount and types of training enabling diagnosticians to carry them out. Many of the laws were also created with the goal of eliminating adverse effects on the environment by diagnostic stations. Vehicle Inspection Stations have had an increasingly important role in improving the technical conditions of traffic safety vehicles and environmental protection. Every defective vehicle is a potential threat to people's health and safety. However, while the risks associated with mechanical malfunctions are easier to diagnose even for vehicle owners, failures and deficiencies resulting in increased emissions are harder to notice. In this respect, all of the work carried out in diagnostic stations is a vital element in ensuring the proper functioning of all transport means.

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szczegółowych wymagań w stosunku do stacji przeprowadzających badania techniczne pojazdów.