

ENVIRONMENTAL PROTECTION AND TECHNICAL TESTS OF MILITARY OFF-ROAD TRUCKS

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Abstract

This paper presents the most vital parts of technical tests of military vehicles in relation to environmental protection. The presented method is based on the most popular military off-road truck of the Star 1466 type. It includes a diagram showing the parts of the test of this vehicle from the perspective of environmental protection whose sequence is not imposed. What is solely required is that all these parts are executed - in accordance with the applicable provisions. For this purpose, the paper presents the methodology (whose major parts are described) of testing the vehicle complying with the requirements of environmental protection. Furthermore, it outlines the process of checking leakages of exploitation fluids, smoke opacity, measurement of external noise of this vehicle and the measurement of the level of an acoustic signal. The description of particular checks is based on the applicable provisions and regulations, as well as on typical and commonly available measuring instruments. It is stressed how important it is to maintain and follow the technical parameters - concerning the systems (units) responsible for polluting the environment - which are required by particular provisions and regulations. In the conclusions, the most crucial documents governing the organization of stations used for testing military vehicles, as well as methods and necessary equipment, have been presented.

Keywords: *diagnostics of military vehicles, systems responsible for polluting the environment.*

1. Introduction

Technical testing of military vehicles is as important as in the case of civil cars. The proper evaluation of the technical condition, in particular its impact on driving safety and environmental protection [10-16], requires the development of suitable methodologies. In this paper, the methodology of technical testing of an off-road truck, in relation to environmental protection for the vehicle of the Star 1466 type, is presented. It is a structure with an armoured cockpit from 2003 assigned for operating in the zone of war threat.



Fig. 1. Star 1466 with transport and loading system [2]

A standard cockpit of Star 1466 has the possibility of installing the armour from armoured plates with the gauge of 5 mm which protect the cockpit against firing with standard bullets – calibre up to 7.62 mm from the distance of 30 m, and splinters of artillery missiles – calibre up to 155 mm from the distance of 100 m. Floor covers provide protection against explosions of hand grenades and antipersonnel mines. The mass of the armour together with bulletproof panes (thickness of 30 mm) and anti-blast liners is over 450 kg. The armour is installed on a vehicle

within 4-6 hours. The cockpit is equipped with the systems of air filtration and air-conditioning. Moreover, it is adjusted for specialist equipment (radio stations, observation devices, telecommunications equipment and anti-chemical apparatuses, etc.). These vehicles are adjusted for exploitation in difficult terrain with the dust discharge up to 1.5 g/cm^3 , ambient temperature from -40° to $+50^{\circ}$ and humidity up to 98 %. Thus, it is a typical military off-road truck in the driving system of 6 x 6. The vehicle is driven by a six-cylinder turbodiesel engine Star 359M with air charge cooling, liquid-cooled, with the capacity 6842 cm^3 and power of 110 kW at 2800 RPM. The maximum torque is 820 Nm at 1500 RPM.

Star 1466 has the mechanism of sealing the driving units when wading. A Dual-circuit braking system of the barrel-cliper type is started pneumatically and equipped with ABS. Emergency and parking brakes working on the middle and rear wheels. Electrical installation 24 V, waterproof. Winch with the towed weight of 60 kN. Cab-over-engine – steel, with hydraulic forward folding platform, MAN type, flat windshields. It is equipped with a roof hatchway, heating, ventilation and insulation. The cockpit has 2 versions: short (2 seats with a couch) for rigid and container variations and long (4-6 seats) in specialist variations. Metal loading box – dimensions: 4440 x 2440 mm, the possibility to install it behind the cabin of crane with the arm of 6 m and lifting capacity of 3.4 t (in this version, the loading box has the dimensions of 3440 x 2440 mm).

2. Procedure algorithm

The methodology of technical testing of the military off-road truck of the Star 1466 type generally requires a similar approach as in the case of a typical vehicle inspection described, among others, in the Regulation of the Minister of Infrastructure dated 16th December 2003 (Journal of Laws, No. 227, item 2250) complying with the requirements imposed by the Regulation of the Ministry of Internal Affairs and Administration and Ministry of National Defence dated 23rd February 2009 on technical testing of vehicles of the Armed Forces of the Republic of Poland, Police and other vehicles used for special purposes (Journal of Laws, No. 39, item 0319). The completion dates of such testing on military off-road trucks are described in chapter 2 of this paper.

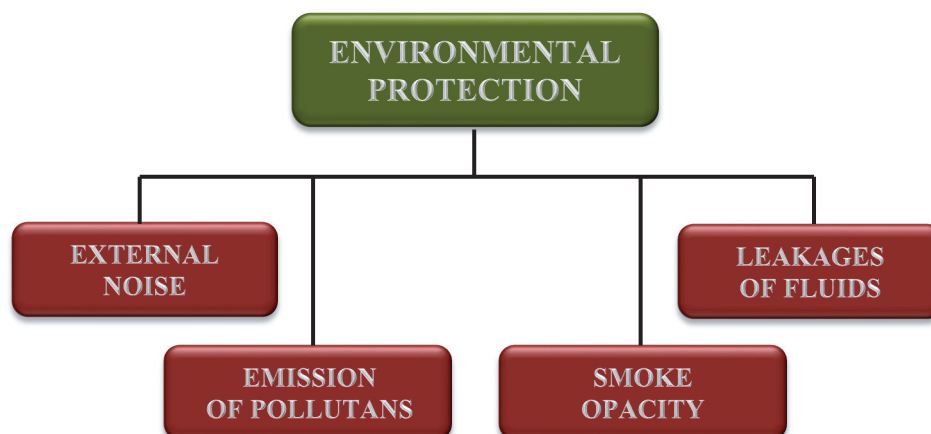


Fig. 2. Parts of technical of a vehicle in relation to environmental protection

Fig. 2 presents the parts necessary to be followed when executing the technical testing of the off-road truck of the Star 1466 type in relation to environmental protection. Executing particular parts of this technical inspection is in principle arbitrary. Moreover, the presented parts should be checked when executing technical tests of other types of military vehicles, including special ones.

3. Methodology of testing a vehicle in relations to environmental protection

Testing a vehicle in relation to environmental protection includes the check of:

- leakages of exploitation fluid of a vehicle (fuel, oils, brake fluids, coolant fluids and others),

- smoke opacity (vehicles with compression-ignition engines),
- exhaust toxicity (vehicles with spark-ignition engines),
- noise on the external station.

4. Checking the leakages of exploitation fluids

Checking the presence of leakages of exploitation fluids is made visually.

For this purpose, it is necessary to:

- 1) place the vehicle over the inspection pit,
- 2) remove the skid plates, move the cabin forward using the hydraulic system,
- 3) check the condition of:
 - fuel lines in the engine cavity,
 - oil lines in the engine cavity,
 - wires of the engine/expansion tank cooling system,
- 4) check the level of:
 - fluids in the expansion tank,
 - brake fluid in the tank of the braking system,
 - fluid in the tank of the washer installation,
 - oil in the tank of the installation supporting the steering system,
- 5) check the tightness of the following installations:
 - hydraulic installation, servo-motors and accumulators of the hydraulic installation for lifting the cabin and the crane (if installed),
 - air-conditioning,
 - fuel system and tanks,
- 6) lower the cabin,
- 7) (staying in the inspection pit) inspect the wires and lines of:
 - braking installation,
 - fuel installation,
 - oil installation,
- 8) inspect the technical condition:
 - oil sump,
 - gearbox,
 - transfer case,
 - drive axles,
- 9) record the result of the inspection.

5. Smoke checking of the Star 1466 vehicle engine

The measurement of the smoke opacity of vehicles with compression-ignition engines consists in determining the absorption coefficient k (m^{-1}). The methodology makes use of an opacimeter with a manual control panel (type: MDO 2) assigned for measuring the opacity of engines with compression ignition. It was chosen as typical and commonly available on the domestic market. Basic components of this opacimeter are shown in the Fig. 3.

5.1. Measurement conditions:

Before taking the measurement of the smoke opacity concerning the off-road truck of the Star 1466 type with the compression-ignition engine, it is necessary to maintain definite conditions, i.e.

- the measurement should be taken with an optical opacimeter using the phenomenon of absorption of visible radiation (light) in gases;
- the measurement should not be taken in unfavourable atmospheric conditions if they may affect the result of the measurement. The ambient temperature should be over 5°C ;

- when taking the measurement in a confined area, it is necessary to ensure effective ventilation of the measuring station or use individual waste gas exhaust of the adequate efficiency.



Fig. 3. Smokemeter MDO 2: 1 – power connection, 2 – main switch, 3 – lamp indicating that the device is ON/OFF, 4 – connection of the measuring probe, 5 – connection for data transfer, 6 – socket for the wire connecting the manual control panel with the central unit of MDO 2, 7 – wire connecting the probe with the central unit of MDO 2, 8 – alphanumeric keyboard of the manual control panel, 9 – connection of the wire connecting the control panel with the central unit, 10 – LCD display, 11 – paper

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- when taking the measurement in a confined area, it is necessary to ensure effective ventilation of the measuring station or use individual waste gas exhaust of the adequate efficiency.

Preparation of the vehicle:

- 1) place the vehicle over the inspection pit; check (visually and auditorily) the exhaust system up to the place of collecting fumes;
- 2) heat up the engine to the normal working temperature ((min. 70°C for engine oil and min. 80°C for coolant fluid);
- 3) blow out the exhaust system by multiple pressing of the accelerator pedal and then the work of the engine at increased rotational speed in the period of approx. 1 minute;
- 4) move the gear lever to the neutral position;
- 5) apply the parking brake;
- 6) connect the wire with the probe to the exhaust pipe centrally (if possible) to a depth that is (at least) equal to three internal diameters. The wires connecting the probe with the opacimeter should be original, with no sharp bends that could lead to deposition of soot or limitation of the exhaust gas flow.

Preparation of the device:

- 1) put the opacimeter in the place of measurement;
- 2) connect the power supply of the central unit of the opacimeter MDO 2 (1 Fig. 3) to the network;
- 3) connect the wire (7 Fig. 3) connecting the probe with the central unit of the opacimeter (4 Fig. 3);

- 4) connect the manual control panel to the central unit of the opacimeter (6 and 9 Fig. 3);
- 5) start the device (2 Fig. 3);
- 6) press the ENTER key on the alphanumeric keyboard of the manual control panel (8 Fig. 3);
- 7) using the alphanumeric keyboard (8 Fig. 3), enter the data of a vehicle (from the registration card of the vehicle, among others):
 - registration number of the vehicle,
 - name of the producer,
 - type of vehicle,
 - identification number of the vehicle (chassis number),
 - odometer reading;
- 8) press the ENTER key on the alphanumeric keyboard of the manual control panel (8 Fig. 3);
- 9) using the alphanumeric keyboard (8 Fig. 3); enter the required default values (minimal temperature of oil; min. and max. rotations of idle speed, measurement time, max. value of the constant k of the smoke opacity. For the Star 1466 vehicle produced after 30th June 2008, this value is 1.5 m^{-1} , whereas for older versions – 2.5 m^{-1} ;
- 10) press the ENTER key on the alphanumeric keyboard of the manual control panel (8 Fig. 3);

Take the measurement:

1. during the work of the engine at idle speed, quickly (but not violently), press the accelerator pedal so as to achieve full efficiency of the injection pump;
2. the position of full efficiency should be maintained till the engine reaches the maximum rotational speed and the governor is activated – no shorter than for 1.5 sec.;
3. release the accelerator pedal until the engine reaches idle speed;
4. the measurement according the points 1 ÷ 3 should be taken at least three times in the point 7); wait at least 15 sec. after each single measurement.
5. if the measured values, which were achieved from three successive measurements do not differ from each other by more than 0.50 m^{-1} and do not create a decreasing sequence, end the measurement by pressing ENTER on the alphanumeric keyboard (8 Fig. 3); otherwise, repeat the measurements (points 1, 2, 3, 4) or stop the measurement of the smoke opacity (cancelling of measurements: press CLEAR on the alphanumeric keyboard of the control panel);
6. the final result should be an arithmetic mean of the taken measurements with accuracy of 0.01 m^{-1} ;
7. print the result of the measurement together with data that was previously entered – press the “P” key on the alphanumeric keyboard of the manual control panel (8 Fig. 3).

Evaluation of the achieved results of measurements:

- 1) the value of the opacity coefficient achieved from the measurement must be compared to the admissible value:
 - for the Star 1466 vehicle produced after 20th June 2008, the admissible value of k_{dop} is 1.5 m^{-1} ,
 - for the Star 1466 vehicle produced before 2008, the value of k_{dop} is 2.5 m^{-1} ,
- 2) it is admissible to use the measurement of smoke opacity according to the percentage scale of Hartridge (HRT) – the conversion of the achieved values to the coefficient k must be done according to Table 1.

The example results of testing the smoke coefficient k for this vehicle with the 359M engine are presented in Fig. 4.

According to the chart, the value of the smoke coefficient reaches its maximum at the rotational speed of 1500 RPM when the maximum torque is achieved. For this vehicle (production: 2003), it does not exceed the admissible value, i.e. 2.5 m^{-1} . At rotational speed over 1800 RPM, it may be stated that this coefficient is relatively stable.

Tab. 1. Table of conversion of the units in the percentage scale by Hartridge [hrt] to the units of the coefficient k [m^{-1}] [7]

k	% (HRT)	k	% (HRT)	k	% (HRT)	k	% (HRT)	k	% (HRT)
0.02	1	0.55	21	1.23	41	2.19	61	3.86	81
0.05	2	0.58	22	1.27	42	2.25	62	3.99	82
0.07	3	0.61	23	1.31	43	2.31	63	4.12	83
0.09	4	0.64	24	1.35	44	2.38	64	4.26	84
0.12	5	0.67	25	1.39	45	2.44	65	4.41	85
0.14	6	0.70	26	1.43	46	2.51	66	4.57	86
0.17	7	0.73	27	1.48	47	2.58	67	4.74	87
0.19	8	0.76	28	1.52	48	2.65	68	4.93	88
0.22	9	0.80	29	1.57	49	2.72	69	5.13	89
0.25	10	0.83	30	1.61	50	2.80	70	5.35	90
0.27	11	0.88	31	1.66	51	2.88	71	5.60	91
0.30	12	0.90	32	1.71	52	2.96	72	5.87	92
0.32	13	0.95	33	1.76	53	3.04	73	6.18	93
0.35	14	0.97	34	1.81	54	3.13	74	6.54	94
0.38	15	1.00	35	1.86	55	3.22	75	6.97	95
0.41	16	1.04	36	1.91	56	3.32	76	7.49	96
0.43	17	1.07	37	1.96	57	3.42	77	8.15	97
0.46	18	1.11	38	2.02	58	3.52	78	9.10	98
0.49	19	1.15	39	2.07	59	3.63	79	10.71	99
0.52	20	1.19	40	2.13	60	3.74	80		

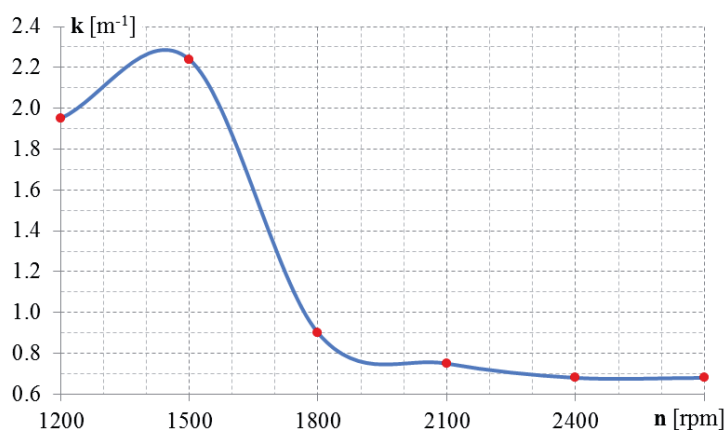


Fig. 4. Conversion of the coefficient k in the function of the rotational speed of the engine n

5.3. Methodology of taking the measurement of external noise of the vehicle: Star 1466

The methodology has been developed by using a standard sound-level meter - type: AS-200 (Fig. 4). The meter is intended for measuring sounds emitted by motor vehicles on the stop. It is also used for evaluating a sound signal of a vehicle.

Measurement conditions:

The measurements of the noise produced by the vehicle must be taken on an external station

- 1) which is separated specially for this purpose;
- 2) During the measurement, there may be solely the owner (driver) of a vehicle and the person taking the measurement. The manner of their behaviour cannot affect the meter reading;
- 3) The measurement of the external noise of a vehicle should not be taken in unfavourable atmospheric conditions if they may affect the result of the measurement. To reduce the noise resulting from the flow of wind and protect the meter against dust and fumes, it is advised to use the windscreen of the microphone;
- 4) The noise level of the environment, when taking into consideration the influence of wind and other acoustic disturbances on the microphone, should be lower by at least 10 dB than the

measured level of external noise produced outside a vehicle. The noise level of the environment should be measured before starting the measurements and checked when they are being taken with the engine running.

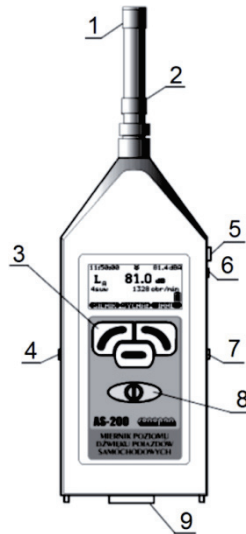


Fig. 5. Sound-level meter AS-200: 1 – speech insert, 2 – microphone follower, 3 – keys, 4 – socket of the probe of a tachometer, 5 – calibration, 6 – AC output, 7 – service socket, 8 – switch, 9 – interface¹

Preparation of the vehicle for testing:

- 1) check if the vehicle is not loaded (it should be detached from the trailer when being tested);
- 2) start the engine of the vehicle and heat it up to a normal working temperature (min. 70°C for engine oil and min. 80°C for coolant fluid);
- 3) place the vehicle in the central part of the appointed measurement area;
- 4) set the engine at idle speed, release the clutch and apply the parking brake.

Preparation of the microphone:

Set the microphone so that:

- 1) its height over the surface of the measurement is equal to the height of the outlet end of the exhaust pipe (but not smaller than 0.2 m);
- 2) it is directed towards the outlet end of the exhaust pipe and distant from it by 0.5+0.01 m;
- 3) the axis of its maximum sensitivity is parallel to the surface of the measurement area and forms the angle of $45 \pm 10^\circ$, with the vertical surface passing through the direction axis of the exhaust outlet (Fig. 6);
- 4) remove the protective plug of the microphone (turning it slightly to the right, which prevents accidental removal of a protective net);
- 5) activate the meter with the button (switch - Fig. 5);
- 6) press the key „SILNIK” [ENGINE] (mode of measuring the external noise).

Taking measurements:

- 1) set the rotational speed of the engine at 75% of the maximum value of the rotational speed (for the vehicle Star 1466: 2100 RPM);
- 2) start the measuring by pressing „POMIAR” [MEASUREMENT];
- 3) reduce the rotational speed of the engine to the value of idle speed by quick release of the accelerator pedal;
- 4) end the measuring by pressing „STOP”;
- 5) take at least three successive measurements according to the instruction specified in the points 1-4;

¹ www.haik.pl/strony/1/i/73.php;

- 6) if the achieved values of the successive three measurements will differ from each other by more than 2 dB, there will be the final result LA displayed on the screen (it is the maximum value from the three measurements rounded to full decibels minus 1 dB - allowance for a possible measurement error). Otherwise, the message „Powtórz!” [Repeat] will be displayed on the screen. Then, it is necessary to repeat the points 1 ÷ 5;

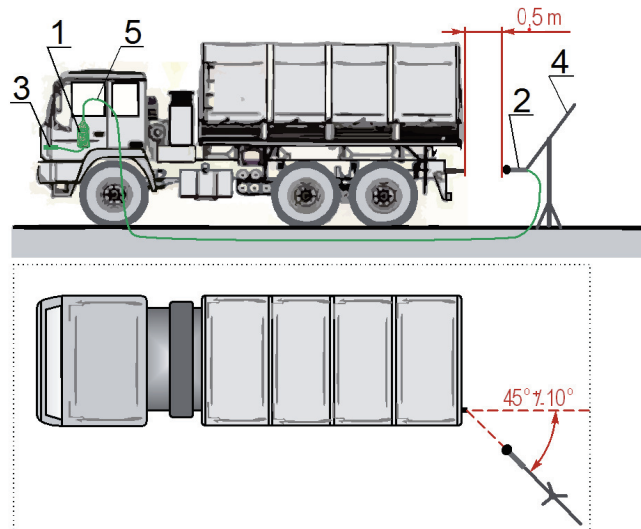


Fig. 6. Position of the meter on the station for measuring the external noise of a vehicle: 1 – sound level meter, 2 – measurement microphone, 3 – probe of the tachometer, 4 – stand, 5 – extension of the microphone [2]

- 7) when the measurement is ended, the meter will display the message asking if you want to save the result in the memory - press the button according to your intention.

Evaluation of the results

- 1) check if the achieved result is not higher than the maximum value for other vehicles (including off-road trucks) which is 108 dB (according to § 9 paragraph 1 point 1, § 45 paragraph 1 point 2, § 53 paragraph 5 of the Regulation of the Minister of Infrastructure dated 31st December 2002 on technical conditions);
- 2) upon the motion of the owner (possessor of the vehicle), the vehicle inspection station should issue a print from the device confirming the result of measurements or provide them in the certificate proving that a technical test of the vehicle was conducted.

The measurement taken for the analysed vehicle Star 1466 showed the noise level equal to approx. 93 dB.

5.4. Measurement of the sound level of the acoustic signal

The inspection consists in an organoleptic check of the functioning of the acoustic signal of the vehicle and evaluation of its technical condition. In justified cases (e.g. negative result of the organoleptic control), there is also the measurement of the sound level.

The following things are unacceptable:

1. lack of clearly visible discontinuities of the functioning of the signal;
2. clearly visible changes of signal tones.

According to the point 2, in the case of negative evaluation, the vehicle must be absolutely subjected to the control of the measurement of the sound level on the stop.

The measurement conditions are identical as in the measurement of the external noise.

Preparation of the microphone

- 1) set the measurement microphone: - it should be placed in a longitudinal plane of symmetry of the vehicle at a height of 0.5 m to 1.5 m over the surface of the measurement area, in a distance of 3 m from the front contour of the vehicle (Fig. 6);

- 2) remove the protective plug of the microphone (turning it slightly to the right, which prevents accidental removal of a protective net);
- 3) activate the meter using the button (switch - Fig. 4);
- 4) press the key „SYGNAŁ” [SIGNAL] (mode of measuring the sound of the acoustic signal).

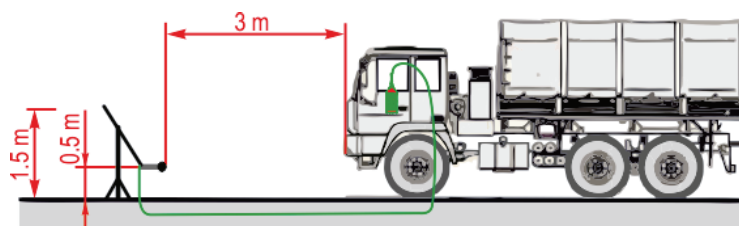


Fig. 7. Position of the sound level meter AS-200 on the station for measuring the sound level of the acoustic signal: 1 – meter, 2 – measurement microphone, 4 – stand, 5 – extension of the microphone [2]

Taking the measurement:

- 1) start the measurement by pressing „START”;
- 2) and the measurement by pressing „STOP” (measuring is on until the key “STOP” is pressed);
- 3) when the measurement is ended, the meter will display the message asking if you want to save the result in the memory - press the appropriate button according to your intention;
- 4) print the result and record in the certificate of the conducted technical test of the vehicle.

Evaluation of the results:

It is impermissible that the measured value of the sound level of the acoustic signal exceeds the admissible value. The limit value for the off-road truck STAR 1466 is 96 dB. The value achieved for the vehicle STAR 1466 is 89 dB.

6. Final conclusions

- 1) The basic document governing the mode of conducting technical tests of military vehicles is the Regulation of the Minister of Internal Affairs and Administration and the Minister of National Defence dated 23rd February 2009 on technical testing of the vehicles belonging to the Armed Forces of the Republic of Poland, Police and other vehicles used for special purposes (Journal of Laws of 2009, No. 39, item 319). Pursuant to this Regulation, all wheeled vehicles are subject to technical testing.
- 2) The document governing the organizational and technical requirements for military vehicle control stations is the Attachment No. 1 to the Regulation of the Minister of Internal Affairs and Administration and the Minister of National Defence dated 23rd February 2009 which includes the requirements concerning the measuring bench, auxiliary surface for equipment and measuring/control devices, inspection pit, technological accessories, external station for acoustic measurements.
- 3) A vehicle control station should be equipped with diagnostic devices allowing for the evaluation of the technical condition of modern motor vehicles, which must meet high requirements concerning the durability and reliability, as well as limitations of emission of toxic exhaust gases and noise. The list of these devices is included in Attachment No. 2 to the Regulation of the Minister of Transport and Construction dated 10th February 2006.
- 4) Performing the evaluation of the technical condition of any system of a motor vehicle requires not only advanced devices, but also adequate specialist knowledge and experience from technical personnel working in the VCS - this refers to the operation of the devices, suitable methods of measuring diagnostic parameters and the ability to interpret the results of measurements. The methodologies of testing the military off-road truck (type: Star 1466) presented in this paper result from the above-mentioned regulations, among others, and should be strictly adhered to. The achieved example results from the test indicate that this vehicle is in a good condition, even though its structure is not that modern.

- 5) As in the range of operations, a military vehicle control station does not differ from a control station assigned for vehicles of national economy, the applicable provisions presented by the Minister of National Defence allow for the possibility of conducting technical tests of military vehicles in civil vehicle control stations.

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