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THE USAGE OF A THERMOCLIMATIC CHAMBER FOR TECHNOCLIMATIC TESTS OF SPECIAL VEHICLES AND MOBILE MACHINES

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Abstract

Constantly increasing technical and operational demands are set for modern manned and unmanned special vehicles, all − terrain vehicles, and mobile machines. Their producers must comply with very restrictive standards, strict legal regulations, and high customer requirements. They concern not only functionality and efficiency of described objects, but also resistance to the impact of environmental and climatic exposure. Vehicles and mobile machines must be adapted to work in different climatic conditions such as low and high temperature, variable humidity, wind, dustiness, rainfall, variable atmospheric pressure, solar radiation. Verification of the correctness of operation of all these systems installed in machines, vehicles and engineering units requires experimental research in specified and stable climatic conditions. These special conditions can only be implemented in a thermoclimatic chamber. Thanks to these researches, it is possible to confirm the effectiveness of solutions that allow machines to work in extreme climatic conditions, as well as to detect a number of defects and imperfections of the structure, unpredictable at the design stage. The article describes the research procedure certified by Polish Centre for Accreditation and discusses examples of technoclimatic research carried out recently in the thermoclimatic chamber of Laboratory of Technoclimatic Research and Heavy Duty Machines of Cracow University of Technology.

Keywords: *environmental and climatic exposure, extreme climatic conditions, technoclimatic research, thermoclimatic chamber, accredited test procedure*

1. Introduction

The Laboratory of Techno-Climatic Research and Heavy Duty Machines (LBT&MR) of the Cracow University of Technology was established on January 1, 2017. The Laboratory has been continuing since 1973, started by the Institute of Working Machines, interdisciplinary research of large engineering structures in conditions of extreme climatic and environmental exposures – i.e. in low and high temperatures, at high humidity. These tests serve to increase the reliability and safety of technical devices and materials intended for use in extreme climatic conditions [1-3, 7]. Nowadays, it is a basic requirement for new materials, subassemblies, devices, and systems used in large-scale engineering structures. The effect of these researches is shaping and optimization of functional parameters of devices and energy efficiency of drives [6]. The article presents the description of the thermoclimatic chamber, preparation for test conducting and two exemplary tests that were carried out in the Cracow University of Technology.

2. Thermoclimatic chamber

The Laboratory uses for conducting climatic and environmental tests, a facility called a thermoclimatic chamber. In 2016, a new chamber building was put for use on the campus of the Cracow University of Technology in Czyżyny at 37 Jana Pawła II Street (Fig. 1).

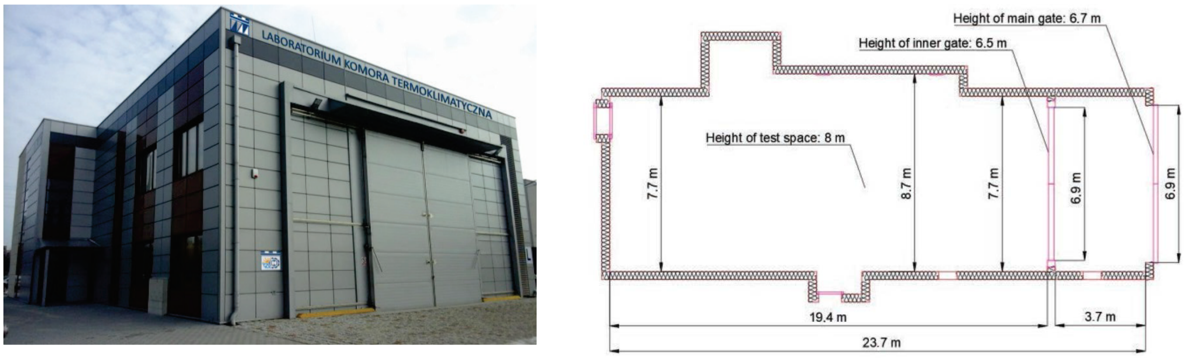

Fig. 1. General view and scheme of the thermoclimatic chamber

The thermoclimatic chamber together with all the equipment and accessories is a research stand. The chamber's equipment is a cold/heating system, which is an integral part of the chamber and a temperature recording system. Additionally, the Laboratory has a set of controlled heaters that can be used to obtain higher temperatures. The chamber is equipped with an automatic control system enabling the realization of various research cycles. The system is based on PLC controllers and connected with them HMI panels. The key element of the measurement set is the acquisition and processing system of measuring data. This data is stored on a computer disk and used to analyse and visualize the results.

In the chamber can be examined in a variety of climatic (from -50ºC to +70ºC) and environmental (to 98% RH) exposures objects with a weight of up to 50 tons and dimensions up to 22 m in length, 7.7 m in width and 8 m in height, such as heavy-duty machines, including building equipment (excavators, loaders, bulldozers, graders), trans-lifting equipment, civil and military wheeled, tracked or rail vehicles, manned and unmanned special units used in conditions of crisis (Fig. 2) [4, 8, 9]. There also can be tested internal combustion engines, hydraulic drive, and control systems, components of aircraft and vessels and train rescue or military personnel to operate in difficult climatic conditions and other devices [2, 5].

The basic forms of research are functional and temperature resistance tests of objects at temperature range: from -50ºC to +70ºC and tests of total resistance to reduced (to -50ºC) and elevated (to +70ºC) ambient temperature. Additionally, tests at elevated temperature can be conducted under at increased humidity up to 98% RH. The Laboratory conducts tests of total resistance on reduced or elevated ambient temperature performs based on the military standard NO-06-A107:2005, points 4.2 and 4.3, and its own testing procedure PB01.

3. Measuring system

Temperature measurements are conducted using sensors, type Pt-100/3 TOPE-361-3-50-0.15-A-L3p-TT and three-lead compensation lines within the measuring range from -50ºC to +150ºC. These sensors use the phenomenon of resistance change during work. The air relative humidity is measured using transducers, type EE 08-PFT3V11E301T22.

The temperature registration system of the thermoclimatic chamber consists of:

- thirty temperature sensors, type Pt100:
  - eight temperature sensors are dedicated to measure the temperature inside the chamber, in the ambience of the tested object; they are permanently attached to four stands,
  - twenty two temperature sensors are dedicated to measure the temperature in the tested object; these sensors are permanently connected to the registration device; location of the sensors in the tested object is determined each time, individually, in accordance with the requirements of the relevant standard and/or according to arrangements with the client.
- a thirty-channel analogue-digital temperature transducer with an accuracy of 0.1% of the measuring range.

Fig. 2. The examples of objects tested in thermo-climatic chamber: car, bus, fire truck, military vehicle

For registration of measurement data, ADAM series modules manufactured by ADVANTECH are used. Modules cooperate with the diagnostic system. The system observes, and registers measured values of temperature and relative humidity of air. The resolution of the temperature measurement system is 0.1°C and the humidity measurement system 1% RH.

4. Preparation to research

Four sets of temperature sensors are placed inside the thermoclimatic chamber. The set consists of two temperature sensors are mounted at two different heights: 0.5 m ± 0.2 m and 2.0 m ± 0.2 m.

If the temperature distribution is examined in the thermoclimatic chamber without the tested object, the sets of sensors are placed in the corners of the chamber at distances of 1 m from the walls. If the temperature distribution is examined in the thermoclimatic chamber with the tested object, the sets of sensors are placed at distance of 1 m from the corner of the object, in the plane at an angle 45° ± 5° from the longitudinal axis of the object. In the case of large-size objects, it is possible to place the sets of sensors at other heights and in other locations but after agreement with the client.

After placing the test object in the thermoclimatic chamber, temperature sensors are mounted in its interior. The sensors are mounted in places specified in the relevant standard or according to requirements of the client. The mounted sensors must not disturb with the operator / driver's work and must not disrupt the natural air movement. During measuring the air temperature inside the tested object and the temperature of fluids in tanks, the measuring part of the sensor cannot touch the solid elements. The sensors are marked with numbers enabling their unequivocal identification. Photo documentation of mounted sensors is made. For object with internal combustion engines, which will be started during tests, an exhaust gas system from the chamber is installed. After organizing the wires connecting the sensors with the data acquisition system, the measurement registration starts, and the research begins.

In the case of tests, requiring reducing a temperature of the thermoclimatic chamber is started according to the instructions. The reducing begins the process of cooling the research space to the temperature agreed with the client. The air temperatures in the chamber are controlled and recorded continuously. After reaching the set temperature level, the stabilization process takes place. It is controlled by a chamber temperature control system. In the case of tests requiring a temperature up to +45 ° C, the test space of the chamber is heated only by an automatic system. It is a standard equipment of cold/heating system of the chamber. In the case of tests requiring a temperature above +45ºC, additional, controlled heaters are inserted to the test space. Heaters are placed next to sets of temperature sensors and their blowing is directed to the centre of the chamber. Using the chamber control system the process of air heating in the test space is started to the temperature agreed with the client. The air temperature in the test space is controlled and registered continuously. After reaching the set temperature level, the stabilization process takes place. It is controlled by a chamber temperature control system.

5. Ensuring the quality of test results

For many years, the Laboratory of Techno-Climatic Research and Heavy Duty Machines have been cooperating with industrial research centres and the defence industry. Therefore, in order to offer our clients high quality tests, the Laboratory obtained the accreditation certificate No. AB 1678 issued by the Polish Centre for Accreditation meets the requirements of PN-EN ISO/IEC 17025:2005 standards. In addition, this year the Laboratory applied to the Military Centre for Standardization, Quality and Codification in order to obtain the accreditation of defence and security (OiB) for conducting conformity assessment of products intended for the needs of national defence and security [10].

The Laboratory performs tests based on elaborated system and research procedures, such as “Ensuring the quality of results” and “Temperature resistance tests and temperature distribution tests in the thermoclimatic chamber and in the objects tested in it”. All activities are carried out by qualified personnel under the supervision of the Laboratory’s management. Ensuring high quality services is achieved by using calibrated measurement apparatus in state units of measurement or accredited calibration laboratories, participation in internal comparisons, repeating tests using the same methods, strict compliance with the requirements of quality assurance system documents [11, 12].

6. Process and test results – car investigation

The purpose of the first research presented in this article was to check the possibility of starting the diesel engine of a passenger car fuelled with winter-specification fuel in conditions of reduced temperature. The tests were carried out on a car refuelled with one of the two tested diesel oils after the previous cleaning of the fuel system and replacement of the fuel filter. The possibility of starting the car engine during test after cooling the fuel and the fuel filter to -20ºC and to temperature -30ºC was verified. In addition, an attempt was made to start up the engine fuelled with diesel oil No. 2 after lowering the fuel temperature and fuel filter to -35ºC.

Tab.3. List of the temperature transducers used during the tests of a passenger car at a reduced ambient temperature

No. of measuring points	Installation location of the measuring transducers
T1-T8	Ambient, distance of 1 m from the vehicle
T9	At the fuel filter
T10	In coolant reserve tank
T11	In fuel tank – fuel pump basket
T12	At the exhaust pipe of the final silencer
T13	Vehicle interior, on the parking brake lever

In Fig. 3, a few minutes of recorded temperature waveforms are presented, when a successful attempt to start the car engine fuelled by the No. 1 diesel oil was carried out. Starting the engine was preceded by a few failed attempts of start up the car. Restarting the starter machine allowed starting the engine of the tested vehicle. Confirmation of the engine's operation is increases in the temperature of the medium in the coolant reserve tank (T10) and fuel in the tank (T11).

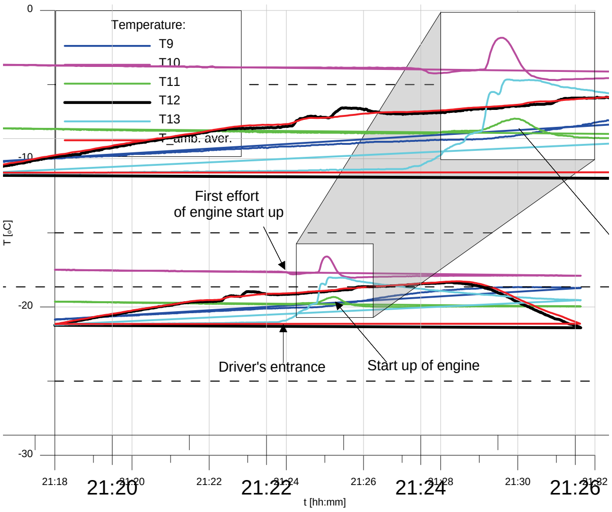

Fig. 3. Test of engine start up for car fuelled by diesel oil No. 1 at temperature -20ºC

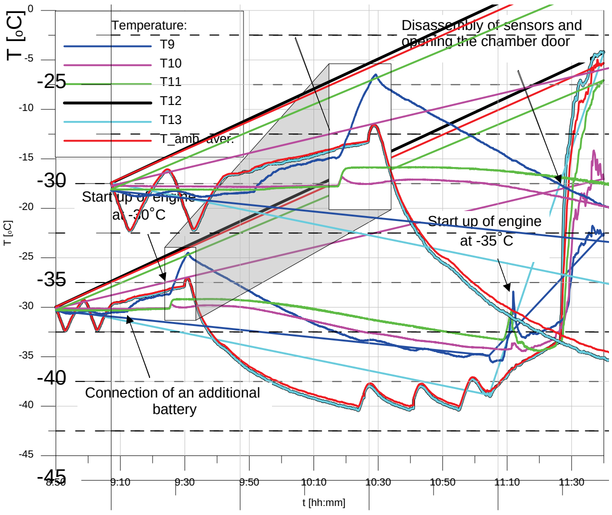

Fig. 4. Test of engine start up for car fuelled by diesel oil No. 2 at temperature -30ºC and -35ºC

Then the vehicle and the diesel oil stored in the fuel tank were cooled down to -30°C. The time required achieving this temperature at the measuring points and temperature stabilization mainly around fuel filter was over twelve hours. Attempts to start the engine even with the use of an additional battery were unsuccessful.

In the second phase of the tests, the car was refuelled with fuel No. 2, and then the vehicle and the diesel oil collected in the fuel tank were cooled down to -30ºC (Fig. 4). The nearly eleven-hour stabilization of temperature in the thermos-climatic chamber, test space allowed reducing the temperature of the car operating fluids to the assumed value. After a successful attempt to start the car engine at -30ºC, it was decided to lower the temperature in the test chamber space to -40ºC. This allowed obtaining a temperature reduction around the fuel filter to -35ºC, thus cooling the fuel accumulated in it to the same temperature and carrying out similar tests. The engine-starting test was successful. Effective engine start up again confirms noticeable increases in recorded temperatures on sensors T9, T10 and T11.

Based on the observations from the tests of car fuelled with winter-specification fuel, it was found that both kind of diesel oil allow for an efficient engine start up at -20ºC. However, the engine of a car fuelled with No. 2 fuel was additionally started at -30ºC as well as -35ºC.

7. The course and results of the military command module tests

Another example of tests carried out in the thermoclimatic chamber of LBT&MR is tests of the military command container of ZAMET – GŁOWNO production. These tests were aimed at checking the fulfilment of ergonomic and climatic requirements specified in the Technical and Tactical Conditions, regarding resistance to changes in ambient temperature, total resistance to a reduced ambient temperature (including checking the efficiency of heating the air inside the container's operating compartment) and total resistance to elevated ambient temperature (including checking the effectiveness of air cooling inside the container's operating compartment).

In order to determine the ambient temperature, eight transducers were installed around the tested object, which allowed registering the temperature distribution and determining its average

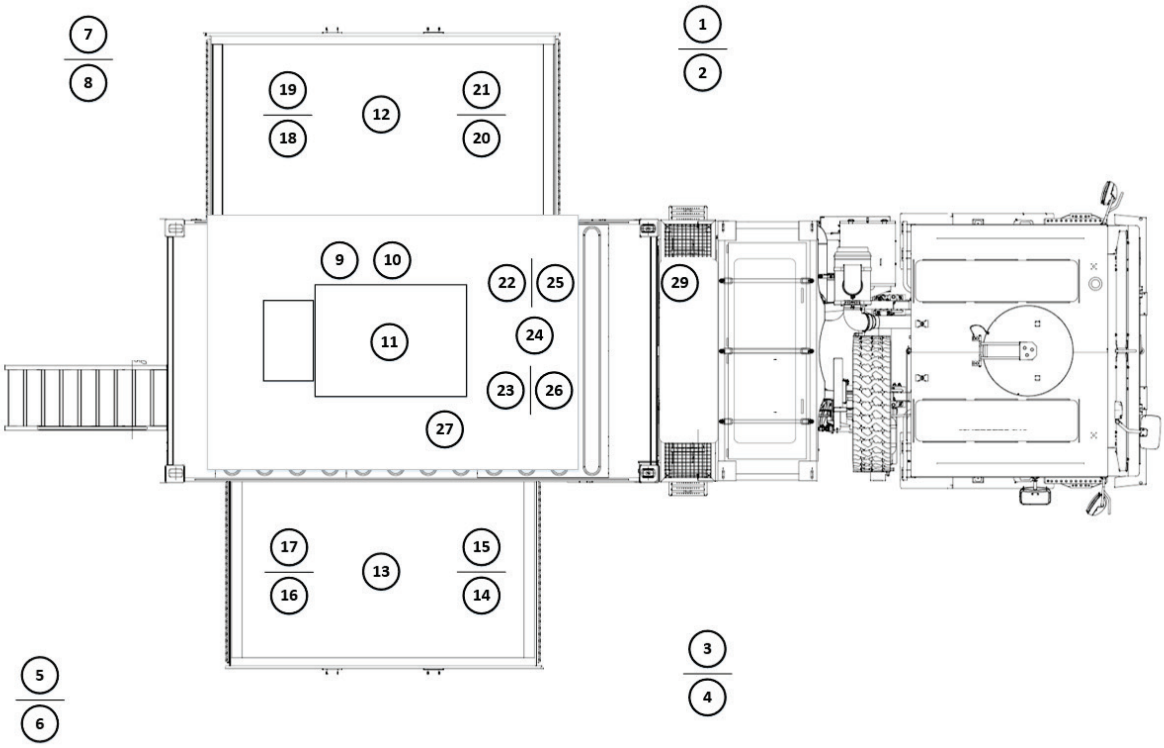

Fig. 5. Scheme of location of temperature sensors used during the tests

value. Inside the container, according to the guidelines of the test program, twenty sensors were installed. Diagram of distribution of temperature measuring transducers is shown in Fig. 5.

After placing the test object in the thermoclimatic chamber, the correctness of operation of all devices installed in the module was checked, among others: checking the function of sliding and inserting of the module moveable parts, checking the functional parameters of the air conditioning system in the heating and cooling function, also checking of the filtering and dynamic drying systems has been done. External examinations were carried out; taking into account the condition of paint coatings, seals, blinds operation. Activities connected with connecting the power supply to the power grid were carried out, the operation of power generators was checked, and exhaust gas piping was installed. The results obtained during the functional tests were considered positive and meeting the standard criteria for normal operating conditions (normal climatic conditions of the tests: according to NO-06-A105 standards point 2.2.2 – air temperature from +15ºC to +35ºC, relative air humidity from 45% to 80%) [10].

One of the tests was to evaluate the performance of A/C systems, both in heating and cooling modes. The effectiveness of the cooling system was evaluated at an ambient temperature of +50ºC and increased humidity, while the heating system was tested at an ambient temperature of -30ºC.

In the initial phase of the tests in elevated temperature the basic technical efficiency of devices and systems, such as air conditioning, fluid heating, filtering, dynamic drying, alarm and fire protection system was checked. All systems worked correctly. The air conditioning system should ensure air cooling by 10ºC of IT equipment zone and container supply system in less than 15 minutes, and also by 10-15ºC at workstations (T14-T21) in less than 60 minutes. The test took more than 1 hour. Graphs of temperature changes in characteristic measuring zones, inside the tested object are presented in Fig. 6. According to the requirements, the air temperature difference between the bottom and the top part of the container, at staff workstations should not exceed 5.5ºC. The tested air cooling system of the command module fulfils this requirement.

In Fig. 7 transients of temperature in the middle of particular section of tested object, during heating system test in ambient temperature -30ºC are presented. Performed test confirms high effectiveness of heating system installed in military command module.

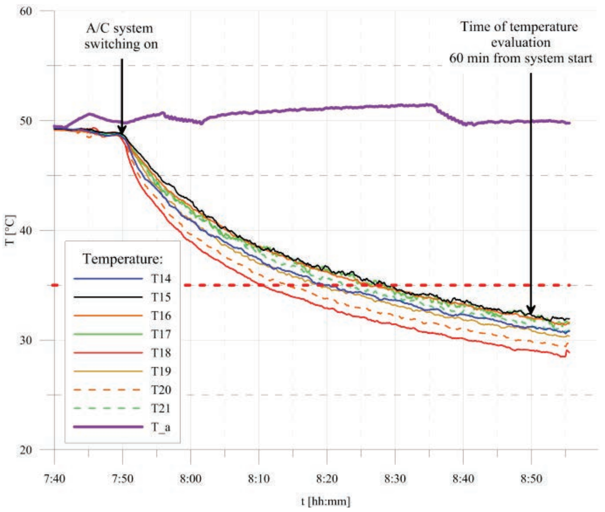

Fig. 6. Temperature distribution inside the module during air cooling system test in conditions of ambient temperature 50ºC and humidity above 50% RH

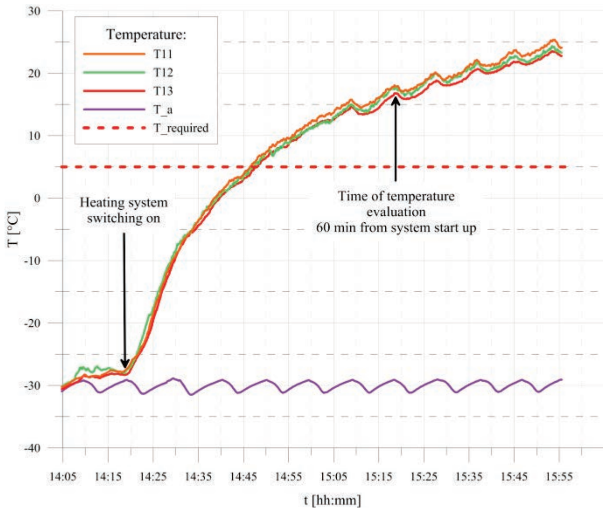

Fig. 7. Temperature distribution inside the module during air heating system test in conditions of ambient temperature -30ºC

8. Summary

Techno-climatic research are carried out in a new facility, characterized by high cooling capacity and the largest, in this part of Europe, dimensions of the test space. Many researches have been carried out on various objects, such as cars and special vehicles, military and civil engineering devices.

These tests were carried out with special care for the quality of performed measurements, which is confirmed by obtaining an accreditation certificate of Polish Centre for Accreditation. Another issue is to obtain the accreditation in Defence and Security, which will confirm the competence of Laboratory to conduct activities related to the assessment of compliance of products for the needs of national defence and security in terms of features related to their resistance for different climatic conditions.

The increasing range of requirements related to the resistance of machines and devices to extreme climatic conditions, forces to further expand the area of research being conducted and to develop and implement further accredited procedures such as the determination of the impact of humidity or light radiation.

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