FEATURES OF CONDUCTING CLIMATE TESTS IN CABINS AND CAR INTERIORS

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Abstract: *Analyzing the results of climate tests in the cabins of habitable compartments of cars that were conducted by the author for several decades and evaluating the research work of other authors done in this direction the features of the tests were determined and errors were identified. It was also found that other researchers did not objectively reflect the temperature and humidity characteristics when studying the climate in the cabins and interiors of cars. There was a replication of the research results with the mistakes made during them. The author conducted a thorough study and obtained objective data on the flow of heat flows into the cabins and salons of cars. In the course of research, it became clear that the main heat load of the cabins and the inhabited compartments is caused by solar radiation entering the interior through transparent fencing. Based on the results of numerous field studies, recommendations were made for climate testing of full-size cabins and their models.*

Keywords: *climate; temperature; humidity; solar radiation; cabin; interior; habitable compartment; cabin layout*

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1. INTRODUCTION

Over the course of twenty-seven years, the author has carried out various climatic tests in order to identify the temperature and humidity characteristics in the cabins and habitable compartments of special wheeled and tracked vehicles at high temperatures. In the course of the research, it was found that the researchers conducting the research had previously made a number of methodological errors, and some of them, apparently due to commercial interest, hid the real picture of temperature and humidity characteristics. During the climatic tests, a number of problems appeared that had to be promptly resolved. This work is devoted to ways of solving these problems.

2. PROBLEMS OF CLIMATE CONTROL IN CABINS AND HABITABLE COMPARTMENTS

The author and his colleagues began to deal with the problem of ensuring the climate in the cabins and inhabited compartments from the beginning of the 90s of the XX century. This period coincided with a reduction in the production of new models of cars, but at the same time, serially produced in small series and operated vehicles underwent modernization, they were given new qualities, and they were very often converted to perform functions that were not intended at all during the initial design.

Very often, customers of a new modification of the machine demanded an improvement in the climatic characteristics inside the cabins and habitable compartments. Moreover, the requirements were sometimes very strict: at an outside temperature of –50 °C to +50 °C, a stable temperature of +18 °C should have been inside the inhabited compartment in all modes of movement and when parked.

An analysis of the vehicles' structures showed that they were completely unprepared to meet the stringent climatic requirements for cabins and habitable compartments. This was especially evident when taking measures to ensure acceptable temperature conditions for the driver and crew at high temperatures. When analyzing machine designs, in order to ensure the required climatic conditions in hot conditions, the following disadvantages were identified:

– when designing cabins and habitable compartments, no measures are taken at all to protect the driver and passengers from the effects of direct solar radiation;

– the habitable compartments and the engine compartment are not adapted to accommodate air conditioning units;

– the requirements of the designers who design the exterior of the car and the technologists who embody the ideas of the designers contradict the requirements of thermal protection of cabins, saloons and habitable compartments.

Many experts in the design of cars mistakenly imagine that to create working conditions for the driver and passengers in high temperatures, you can take an ordinary household refrigerator, cut holes in it by inserting windows into them, install a chair inside them, control elements and connect the whole structure to a compact mobile power plan , and the issue of ensuring the climate will be resolved. Of course, the climate issue can be solved in a similar way, but how much will the solution of this issue cost? According to statistics, the cost of providing cold in the cabin is 5...7 times more expensive than providing heat [1]. But this applies to serial machines adapted for the installation of an air conditioning system. If we consider the installation of an air conditioning system in a car that was not originally intended for the installation of such a system, the costs can be safely increased by 5...10 times. At the same time, the units and parts used for the manufacture of air conditioning units require an order of magnitude greater precision and quality of manufacture than other units. In addition, intense vibration and shock effects very quickly lead to component damage and refrigerant leakage.

Having experience in ensuring climatic conditions at high temperatures, we can say that even an excess of solar radiation entering the inhabited compartment by only 15...20% can radically complicate technically and increase the cost of constructive measures, and in some cases can eliminate them altogether, since they will require units of larger capacity. In the case of ensuring the operation of an air-conditioning unit with a direct mechanical drive from the engine, the units, in terms of mass-dimensional indicators, in many cases cannot be installed. If the compressor of the vapor compression (freon) installation is electrically driven, then the power of the vehicle's on-board network may not ensure the operation of such a system, the generator will overload and the batteries will discharge.

The correct design of cabins and habitable compartments can be facilitated by an objective assessment of the heat fluxes entering them. In numerous methods for calculating the thermal balance of cabins and habitable compartments, it is assumed that the thermal energy entering through the roof panel and side opaque panels is equal to or greater than the thermal energy entering through the transparent glazing. This leads to incorrect calculations of the heat balance and requires, in practice, the use of air conditioning units of greater capacity.

3. STUDIES OF HEAT FLOWS ENTERING THE CAR INTERIOR

Experiments were carried out to determine the significance of various heat fluxes entering the habitable compartments by shielding individual sections of the outer panels and glazing of the car interior (Fig. 1).

Fig. 1. *Temperature experiments when shielding the roof, the windscreen and rear windows*

Experiments show that the main value for heating the inhabited compartment under conditions of high summer temperatures is carried by solar radiation coming through the glazing of the cockpit or the inhabited compartment (see Table) [2-3].

Table. *Measuring the temperature in the car interior in the driver's seat with various options shielding the roof, the windscreen and rear windows (the car is oriented with the front part facing the sun, the position is adjusted every 15 minutes, outdoor humidity in the shade 45…57 %)*

Temperature measurement area	Driver's head area	Driver's chest area	Driver's abdomen-hip area	Driver's shin-foot area	Outside temperature in the shade
The car is in the shadow	+29,7ºC	+29,8ºC	+30,4ºC	+28,5ºC	+30ºC
The car is in the sun, roof, windscreen and rear windows are shielded	+32,1ºC	+32,5ºC	+32,1ºC	+29,9ºC	+30ºC
The car is in the sun, roof screen removed	+32,8ºC	+32,6ºC	+32,4ºC	+32,4ºC	+30ºC
The car is in the sun, the screen is removed from the roof and glass	+42,3ºC	+39ºC	+61ºC	+31ºC	+31ºC

In the process of static and running climatic tests, sometimes little attention is paid to such an important factor as the natural movement of the sun along the horizon relative to the earth. It should be taken into account during climatic tests that the angular value of displacement is 15º per hour, or in 20 minutes the sun moves along the horizon by 5º. In climatic tests, this is a fairly high angular value. It is clear that the most objective results will be with such an arrangement of the object, when it is in a position in which solar radiation can maximally influence the temperature rise in the cabin.

The testers need to keep in mind that the preparation itself for the climatic tests takes at least an hour. During this time, the sun, as mentioned earlier, will change its angular position by 15º. The best option for organizing tests is when it is possible in the process of research to correct the position of the machine or cabin, which consists in moving or turning the object clockwise in the direction "behind the sun".

4. THERMAL PROTECTION STUDIES ON THE CABIN LAYOUT

When the structural thermal protection tests were carried out on the cockpit mock-up (Fig. 2), the design made it possible to rotate the mock-up on a support leg through 360º.

Fig. 2. *The layout of the cabin with the ability to rotate 360º relative to the sun and the ability to change the design of the thermal protection*

During the tests, studies were carried out on the so-called "thermal breakdown", in which if the thermal protection is designed incorrectly, then at some angular position relative to the sun, the temperature in the cabin would begin to rise. In this case, the cockpit layout rotated counterclockwise (against the direction of the sun's movement along the horizon). The cockpit rotated every 3 minutes by 30º. Since the temperature conditions in hot conditions can be unstable, the time for experiments is very limited. For this type of tests, a revolution of 360º per hour is the optimal mode both for fixing the temperature characteristics and for evaluating the design of the investigated thermal protection during the experiment.

Researchers very often make a mistake when measuring the temperature of the outer panels of the cab. Research experience has shown that the temperature of a "bare" metal panel will differ from the temperature of a panel with thermal insulation installed on it. Thermal insulation plays the role of a thermos and makes it difficult to heat exchange with the interior of the cabin. The temperature of such a panel will always be higher than that of a “bare” panel without thermal insulation, although thermal insulation will play its role and reduce the flow of heat into the habitable compartment [4-5].

Studies have shown that the color of a metal panel can significantly affect its heating. The difference can be 7…14 ºC. This, in contrast to early research, is significant. It should be mentioned that the American Global Energy Prize Laureate Arthur Rosenfeld (USA) proposed using light-colored paints to paint roofs of houses and cars, and they say that after that the energy savings amounted to $10 billion. But at the same time A. Rosenfeld did not answer how much the color of the roofs affects their heating.

5. CONCLUSION

The psychophysiological state of the driver during his work critically depends on the favorable climatic conditions, both external and internal [6-9]. The relevance of this problem is confirmed by the development of systems for monitoring driver fatigue [10-12] or operator fatigue, if we are talking about promising autonomous vehicles [13-15]. Full-scale climatic tests are one of the most difficult of the entire set of tests that automotive equipment can be subjected to, since the complexity of such tests is influenced by a changeable unstable climate that can change both during the day and during the entire test period. But, nevertheless, such tests, unlike others, cannot be replaced by bench experiments or tests in climatic chambers, since under these conditions it is difficult to simulate the complex process of the effect of naturally occurring solar radiation on a car.

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