2020 Applying New Technology in Green Buildings (ATiGB)

Application of air drying technology for helicopter protection in tropical conditions of Vietnam

Hong Phong Nguyen
Vietnam – Russia Tropical Centre
Hanoi, Vietnam
phong.mipt@gmail.com

Vladimir Nikolavich Sereda
A.N. Severtsov Institute of Ecology and Evolution
Moscow, Russia
seredavn@mail.ru

Duy Nam Pham
Vietnam – Russia Tropical Centre
Hanoi, Vietnam
phamnam.ndvn@gmail.com

Chi Chinh Vo
University of Science and Technology
University of Da Nang
Danang, Vietnam
vochichinhdhbk@gmail.com

***Abstract*—This paper presents the experimental results in applying air drying technology developed by the Vietnam-Russia Tropical Centre for protecting EC-155 helicopter against the adverse effects of high humidity in the tropical climate. The essence of this technology is using an ITM- OY7 air dryer, that is placed outside the helicopter, to force dry air into helicopter compartments through an air duct. The ITM-OY7 was fabricated by the Vietnam-Russia Tropical Centre. The test was conducted for 14 months (from April 2019 to June 2020) at an Air force unit in Hanoi. The results showed that air drying technology application helped reduce and maintain relative humidity in the EC-155 helicopter cabin at an average of 60%, while average humidity in the shelter ranges from 70% to 92%. These results are the basis for expanding application of the air drying technology in other Air and Air Defense Force units in protecting helicopters from harmful effects of the tropical climate.**

Keywords— tropical climate, dry air technology, air dryer; humidity; EC-155 helicopters

I. INTRODUCTION

In modern Vietnam army, helicopters play a critical role. In addition to their combat functions, helicopters also participate in search, rescue, and transport activities. Operating in Vietnam, helicopters are negatively affected by tropical climate factors, especially high humidity, which increases frequency of failures, negatively influences their technical features, and increases annual maintenance costs.

Relative humidity parameter in different helicopter storage locations has been researched by Russian and Vietnamese specialists of the Vietnam-Russia Tropical Centre for a long time. Analyzing the research results shows that relative humidity in a day was quite low, while it was high at night and early morning [1,2].

Fig. 1 and 2 present the relative humidity parameter in one military unit, which is located in Thanh Hoa. The measurement was carried out for one month in July 2016 (summer) and January 2017 (winter). The relative humidity values were recorded every 15 minutes by Hobo Temperature/Humidity sensors (model UX-103), which were mounted under the helicopter shelters.

Fig. 1 shows that during daytime in summer, relative humidity in the helicopter shelter was lowest during 11:30-14:00 with values ranging from 28% to 70%. The period of time when average relative humidity was greater than 80% was from 20:00 to 7:00 next morning, and its highest value (80% ÷ 98%) was reached from 4:00 am to 6:00 am.

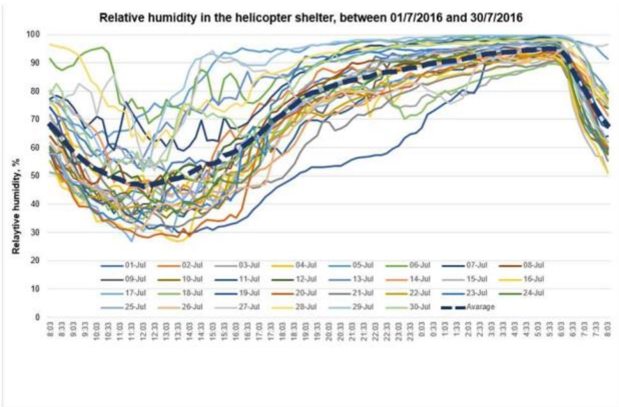

Fig.1. Relative humidity in the helicopter shelter in a day, from 01/7/2016 to. 30/7/2016 (summer)

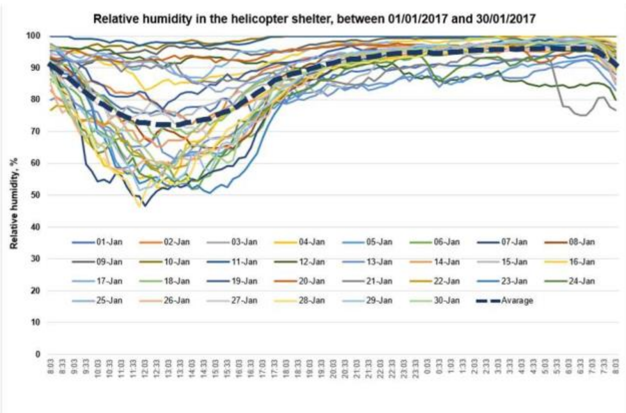

Fig.2. Relative humidity in the helicopter shelter for a day, from 01/01/2016 to 30/01/2017 (winter)

In addition, it can be seen that the amplitude of relative humidity fluctuations during a day was considerable, which could reach 70 %. In summer, the amplitude of relative humidity fluctuations in a day was larger than that in winter.

Night and dawn are a period of time when helicopters are located in the shelter in inactive state, which is easy for relative humidity to penetrate into their compartments. The long-term penetration process causes moisture accumulation inside helicopter's device blocks, which reduces their stability and causes their malfunctions and damages [2].

High humidity also negatively affects polymer materials, as relative humidity can be adsorbed on the material surface and penetrated into inner layers. Due to wide fluctuation of relative humidity in a day, moisture absorption and desorption occur continuously daily, that leads to a deterioration of structural layers bonding in polymer materials [2,3].

In addition, high relative humidity inside relatively closed volumes with little air circulation is favorable condition for molds, microorganisms to grow on surfaces of materials, parts, and assemblies. During their growth, microorganisms release acidic substances, which accelerate corrosion process on material surfaces [2].

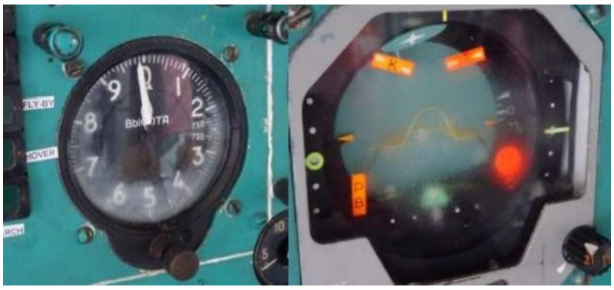

Fig. 3. Vapor condensation inside the helicopter's indicators

Studies [4,5] showed, that metallic parts were most seriously corroded during humid season (in the Northern climate) when aircrafts were in a shelter.

According to the studies [6-8], the relative humidity of 60% is the ideal threshold that prevents metal corrosion or lets it occur at a low rate.

Nowadays, the solution applied in air force units to protect helicopters against negative effects of high relative humidity is quite simple. When it is sunny, the technical team moves helicopters to the landing strip, open their windows and doors to dry them. This is only a temporary solution depending entirely on the weather conditions. In addition, according to aviation regulations, it is not allowed to place an extraneous electrical equipment inside the helicopter. Therefore, it is necessary to develop an effective solution to protect helicopters against the negative effects of high relative humidity in the tropical climate conditions of Vietnam.

Due to that practical need, authors of this article have studied and for the first time successfully developed an air drying technology that allows to dehumidify the helicopter compartments from the outside. The essence of this technology is using an ITM-OY7 air dryer equipment, which was fabricated by the Vietnam-Russia Tropical Centre, to produce and force dry air into helicopter's cabin and cargo compartment through a 15m long pipeline connected to the helicopter through "fake" windows (Fig. 5). In addition, the ITM-OY7 was placed outside, on a distance of 15 m from the helicopter, so the aviation regulations are not violated.

The air drying technology was tested in an air regiment for six months [9] on a Mi-171 helicopter and in another air force unit on a Su-C aircraft for two months [10], both showed positive results.

This article presents the experimental results in applying the air drying technology for protecting an EC-155 helicopter against the adverse effects of high humidity in the tropical climate.

II. TEST OBJECT, PURPOSE AND METHOD

A. *Test object*

The test object was an EC-155 helicopter [11], which is exploited in an air force unit located in Northern Vietnam.

B. *Test purpose*

Maintaining the average relative humidity inside the compartments of the EC-155 helicopter at a level of less than 60% during inactive periods when the helicopter is stored in the shelter.

C. *Test method*

According to the method of temporary protection for military equipment and weapons stored in a closed volume VZ-11 in the standard GOST 9.014 -78 [12], a dehumidifier is used to suck damp air from the closed volume, dehumidify it to obtain dry air and then return the dry air back to that closed volume. Applying this method to helicopters is not feasible due to the difficulty of connecting the air inlet and outlet.

Our method is a modified version of the one described above. We used the ITM-OY7 air dryer (Fig. 4 and 5) to produce dry air, that had relative humidity of 40-60% and temperature leveled the outside one. When the dry air was blew into the helicopter compartments, it pushed the humid air inside out, thereby providing favorable conditions for moisture concentrated in different parts to evaporate and exit.

Fig. 4. Overview of the experiment (left) and ITM-OY7 air dryer (right)

Fig. 5. Connecting dry air pipeline to the cabin and the cargo compartment of the helicopter through «fake» windows

Hobo Temperature/Humidity sensors (model UX-103) are mounted at various positions inside the helicopter cabin and cargo compartment and in the helicopter shelter to record values of temperature and relative humidity to assess effect of drying process in helicopter compartments compared to relative humidity in the shelter. The positions of these sensors are presented in Table I.

TABLE 1. POSITIONS OF HOBO TEMPERATURE/HUMIDITY SENSORS

No.	Sensors	Sensor placement
1	VT-1	In the cabin, below the first row of seats
2	VT-2	In the cabin, above the third row of seats
3	VT-3	In the cargo compartment
4	VT-5	In the shelter, outside of the helicopter, 3 m above the ground

The test was conducted over a period of 14 months (from 04/2019 to 06/2020) at an Air Force unit located in Northern Vietnam. During test time, the helicopter was operated according to daily, weekly regimes as usual. When the helicopter was active or technical team worked on the helicopter, the The ITM-OY7 was disconnected from the helicopter.

D. Construction, specifications and advantages of the ITM-OY7 air dryer

The ITM-OY7 consists of 03 main parts: a dehumidifier with a capacity of 25 l/24h, an automatic controller, a housing frame for moving/transporting. ITM-OY7's specifications are given in Table II.

TABLE II. THE SPECIFICATIONS OF THE ITM-OY7

No.	Specifications	Unit	Value
1	The relative humidity of the inlet air	%	40-100
2	Relative humidity of the outlet air	%	30-80
3	Inlet air's temperature	° C	5-45
4	Airflow at maximum static pressure	m^3/h	250
5	Dehumidification capacity (at 30°C and 80% RH)	l/ 24h	25
6	Power supply	V/Hz	1 Phase, 220/50
7	Power consumption	W	480
8	Weight	kg	60
9	Size L × W × H	cm	42×26×80

The ITM-OY7 works as a condensation dehumidifier. However, it has numerous advantages over similar commercial dehumidifiers:

Firstly, it is possible to control operation of the ITM-OY7 by a sensor that is located in the helicopter compartment where dehumidification is needed.

Secondly, there are two restrictions in operating mode of the ITM-OY7, which are set by the user. The first is a restriction on the relative humidity value: when the relative humidity in the helicopter compartment is greater than the set value (in our experiment - 55 %), the ITM-OY7 turns on and works until the relative humidity inside the compartment drops below the set value (in our experiment - 45 %). The second is the time limit. For example, if the user sets the time mode to 40 - 20, the ITM-OY7 runs for 40 minutes and shuts down for 20 minutes. If the relative humidity inside the helicopter compartment falls below 50 % within 40 minutes, the ITM-OY7 is turned off and turned on again only when the relative humidity is more than 55 %. If the relative humidity inside the helicopter compartment does not fall below 45 % within 40 minutes, the ITM-OY7 will still be turned off for 20 minutes, after that it will only turn on again. This allows to increase the durability of the ITM-OY7 itself.

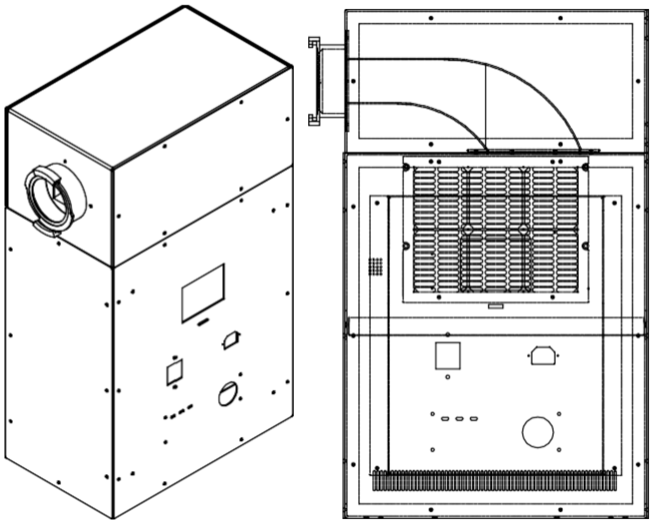

Fig. 6. The engineering drawing of the ITM-OY7 air dryer

III. RESULTS AND DISCUSSIONS

During test period, when the ITM-OY7 operated, average relative humidity values inside the helicopter compartments were maintained at 60%. Table III presented the average daily relative humidity values (some more typical days in months) in helicopter compartments and shelter when the ITM-OY7 was working and when it wasn't working.

TABLE III. AVERAGE DAILY HUMIDITY (%) IN HELICOPTER COMPARTMENTS AND SHELTER

Day	**13/4/2019**	**06/5/2019**	**01/6/2019**	**23/8/2019**	**01/9/2019**	**20/01/2020**	**07/3/2020**
ITM-OY7 was in operation							
Relative humidity in the cabin	58	62	61	55	55	62	56
Relative humidity in the cargo compartment	78 *	51	50	53	50	61	49
Relative humidity in the shelter	83	85	90	80	79	93	92
ITM-OY7 wasn't in operation							
Day	**12/4/2019**	**02/5/2019**	**18/6/2019**	**02/8/2019**	**10/9/2019**	**04/01/2020**	**21/3/2020**
Relative humidity in the cabin	75	81	79	84	77	80	76
Relative humidity in the cargo compartment	77	80	80	80	74	74	70
Relative humidity in the shelter	82	82	86	89	89	89	87

* *In the first day experiment, the ITM-OY7 had not yet connected to the cabin compartment*

From the Table 3, we can see that when the ITM-OY7 was in operation, the average relative humidity in the helicopter compartments remained between 49 % and 62 %. In comparison, the average relative humidity in the helicopter shelter was between 79 % and 93 %. When the ITM-OY7 was not in operation, the average relative humidity in the helicopter compartment ranged from 70 % to 81 %.

In addition, in the first day experiment, the ITM-OY7 had not yet connected to the cabin compartment, so the avarage relative humidity in that cabin was high (78 %). In following days, when the ITM-OY7 was connected to the cabin compartment, the avarage relative humidity in that cabin was held below 61 %.

Fig. 7 shows the relative humidity values inside the helicopter compartments and in the shelter when the ITM-OY7 was in active and inactive states.

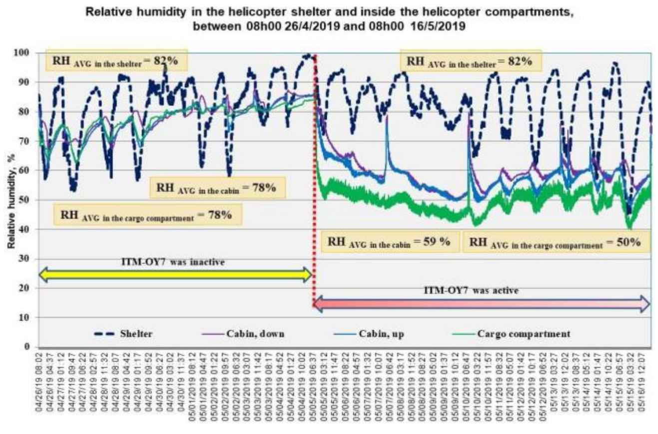

Fig. 7. Relative humidity in the helicopter compartments and in the shelter when the The ITM-OY7 was active and inactive.

From 26/04 to 05/05, the ITM-OY7 was inactive, the average relative humidity inside the helicopter compartments remained at the level of 78 % -79 %, of which there were times when the relative humidity was higher than 85 %. When the ITM-OY7 was in operation (from 05/05 to 16/05), the relative humidity in the helicopter compartments decreased, then fluctuated stably with average values ranging from 50% to 60% throughout the test period later.

The relative humidity in the cargo compartment tended to be about 5 % in average lower than that in the cabin. The reason is that the volume of helicopter cabin is about three times larger than that of the cargo compartment, so drying process in the cargo compartment was faster.

If a shorter time is taken for analysis, we will clearly see effect of air drying technology application using the ITM-OY7 air dryer.

From Fig. 8, we can see that when the ITM-OY7 was inactive, the average relative humidity values in the helicopter compartments were 80 % ÷ 81 %. Most of the time, they were higher than 80 %.

Fig. 9 shows that when the The ITM-OY7 was inactive, the temperature in the helicopter compartments was higher than that in the shelter from 0.5 ºC ÷ 1 ºC at nighttime and at dawn. However, during the day, the shelter's temperature was higher than that in the helicopter compartments from 0.5 ºC ÷ 1 ºC. Therefore, the average temperature values in the helicopter compartments and the shelter were almost no different.

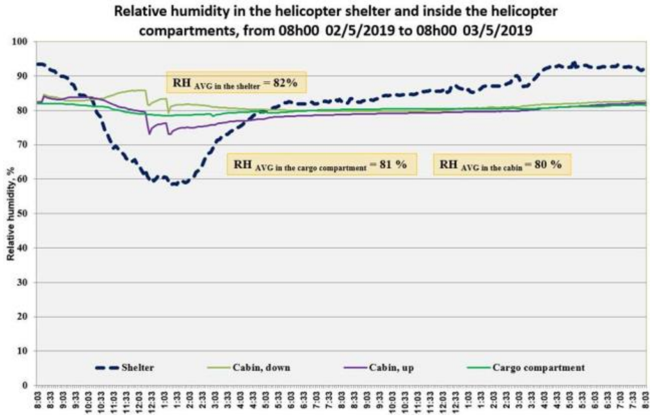

Fig. 8. The relative humidity in the helicopter compartments and in the shelter when the ITM-OY7 was inactive

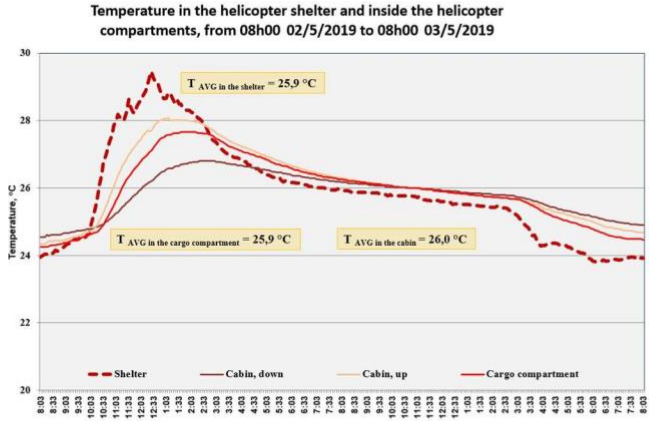

Fig. 9. The temperature in the helicopter compartments and in the shelter when the ITM-OY7 was inactive

Fig. 10 shows relative humidity measurement in the helicopter compartments and the shelter for 24 hours (from 8:00 on 11/5/2019 to 8:00 on 12/5/2019) when the ITM-OY7 was active. From the graph, the relative humidity values in the helicopter compartments ranged from 45 % to 60 %, in which the relative humidity inside the cargo volume was lower than that in the cabin at approximately 5 %. The relative humidity in the compartments of the helicopter varied according to the sawtooth shape, most obviously the relative humidity in the cargo compartment with an amplitude of about 3 %. The reason is that the ITM-OY7 has a stop mode (20 minutes). When the device was active, the relative humidity in the helicopter compartments decreased. When the device stopped functioning, the damp air in the shelter penetrated back to the helicopter compartments (due to the fact that compartments were not fully hermetic) and the relative humidity in the compartment increased. Until the ITM-OY7 was active again, the relative humidity in the compartment was reduced. So the relative humidity values in the compartments fluctuated steadily, increased and then decreased, and so on, but were retained in the average between 50 % and 58 %. At the same time, the relative humidity in the shelter ranged from 70 % to 91 % (average 84 %).

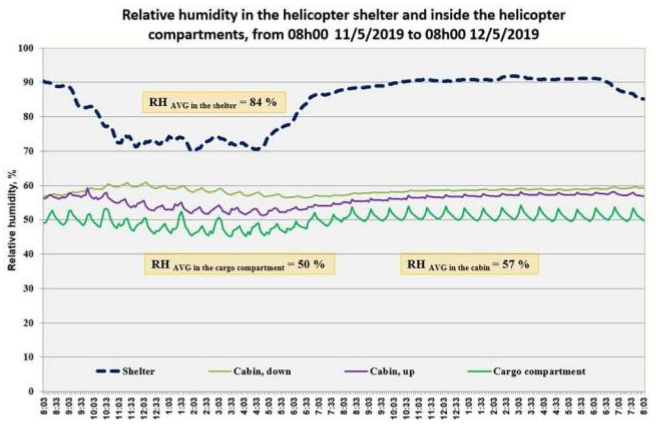

Fig. 10. Relative humidity in the helicopter compartments and in the shelter when the ITM-OY7 was active

Also, during this time, the average temperature in the cabin was 0.3 °C higher than the average in the shelter (Fig.11). The average temperature in the cargo compartment was about 2 °C higher than the average in the shelter. The reason was explained above, beside the small volume of the helicopter cargo compartment, it is quite closed, so the process of heat exchange with the outside air takes place slowly. In addition, the air, that was blew into compartments, was dry and warm, so the process of accumulating the heat caused the cargo compartment temperature to be about 2 °C higher than the shelter's temperature. However, when comparing to the graph in Fig.8, when ITM-OY7 was inactive, at night, and at dawn, the temperature in the cargo compartment was still about 1 °C higher than the temperature in the shelter. Thus, when the The ITM-OY7 operated, it only increased the temperature in the cargo compartment by about 1 °C - which can be considered negligible.

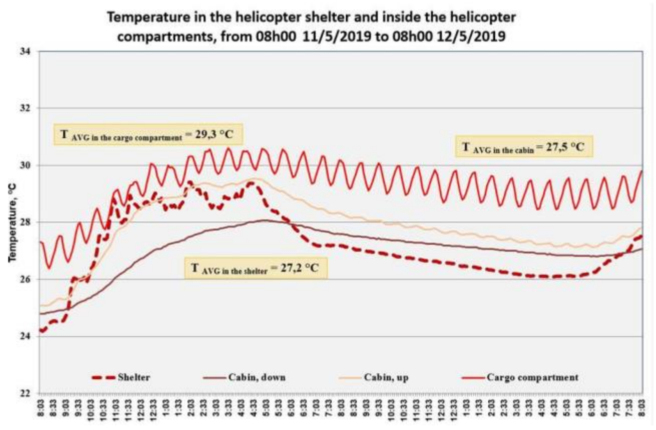

Fig. 11. Temperature in the helicopter compartments and in the shelter when the ITM-OY7 was active

The above results has demonstrated the possibility of using the ITM-OY7 to forcefully blow dry air into the EC-155 helicopter compartments to reduce and maintain the average relative humidity level at less than 60 %, thereby helping to protect electrical, electronic and other components inside the helicopter, enhancing the durability and reliability of the helicopters when operating in tropical conditions of Vietnam. This result is completely consistent with the test results on the Mi-171 helicopter [9].

In addition, the ITM-OY7 operates completely automatically, without affecting the professional activities of technical staff. The connection of dry air pipeline to the aircraft is also carried out quickly and conveniently.

From this result, Vietnam-Russia Tropical Centre will continue to improve and perfect the technology and conduct test to widely apply the air drying technology in the maintenance of other helicopters in the Army.

IV. CONCLUSION

1. Air drying technology developed by the Russian-Vietnam Tropical Centre helped to reduce and maintain the relative humidity inside the compartments of the EC-155 helicopter at an average of less than 60 %, not dependent on climatic conditions and the weather outside.

2. Air drying technology is a highly effective solution for protecting, improving the reliability, minimizing the damage on the EC-155 helicopter exploited in the tropical climatic conditions of Vietnam.

3. Air drying technology should be continuously researched, perfected, and advanced to be widely utilized in the army to protect helicopters against negative impacts of high relative humidity in tropical conditions Vietnam.

REFERENCES

[1] Report of Scientific Research "Study the effect of tropical climate factors on the technical conditions of air and ground equipment in the Air and Air Defense Force ". Code Ecolan T-2.1, Vietnam-Russia Tropical Centre, Hanoi, 2017.

[2] Report of Scientific Research "Study the effect of tropical climate factors on the technical conditions of aircrafts and ground equipment in the Air Defense Force". Code Ecolan T-2.1. Vietnam-Russia Tropical Research and Technology Centre, Hanoi, 2018.

[3] Report on Scientific Research "Study the effect of tropical climate factors on the technical conditions of aircrafts and ground equipment in the Air and Air Defense Force ". Code Ecolan T-2.1, Vietnam-Russia Tropical Centre, Hanoi, 2014.

[4] Авдеев Ю.П., Карпов В.А., Ольшанский В.М., "К вопросу формирования коррозионно-опасных условий в замкнутых объемах технических устройств," - Москва, Коррозия: материалы, защита, №7, 2013.

[5] Karpov V. A, Svitich A. A, Sereda V. N, Pham Duy Nam, "Results of technical conditions analysis of 4th generation aircrafts during 20 years operating in the tropical climate of Vietnam," The Journal of Tropical Science and Technology, No. 12, Ha Noi, 2017.

[6] P. J. Sereda, "Corrosion in Natural Environments," Tech. Publ. no 558, American Society for Testing and Materials, Philadelphia, Pa., 1974.

[7] Улиг Г. Г., Реви Р. У., "Corrosion and protection against it: An Introduction to Corrosion Science and Technology," - L.: Chemistry, 1989.

[8] Essays on the history of technology in Russia. - M.: Science, 1973.

[9] Nguyen Hong Phong, Sereda V.N., Le Ngoc Minh, Pham Duy Nam, "Test results of Mi-helicopter protection in tropical conditions of Vietnam using dry air technology," Journal of Tropical Science and Technology, No. 20. Hanoi, 2020.

[10] Sereda V.N., Nguyen Hong Du, Svitich A. A, Pham Duy Nam, Nguyen Hong Phong, "Additional protection of equipment compartment of Su-C aircraft by air drying technology in tropical conditions of Vietnam," The Journal of Tropical Science and Technology, No. 17, Ha Noi, 2018.

[11] Instruction Manual of EC-155B helicopter. Eurocopter, 2005.

[12] GOST 9.014 -78. Unified system of protection against corrosion and aging. Temporary anti-corrosion protection of products. General requirements.