MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE NATIONAL AVIATION UNIVERSITY

FACULTY OF AIR NAVIGATION, ELECTRONICS AND TELECOMMUNICATIONS DEPARTMENT OF AVIONICS

APPROVED

Head of department

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GRADUATION WORK

(EXPLANATORY NOTES) FOR THE

DEGREE OF MASTER

SPECIALITY 173 'AVIONICS'

Theme: «Anti-Icing System of Boeing 737»

Done by:________________AV-257Ma, M. D. Makarenko

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Kyiv 2022

МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ

ФАКУЛЬТЕТ АЕРОНАВІГАЦІЇ, ЕЛЕКТРОНІКИ ТА ТЕЛЕКОМУНІКАЦІЙ КАФЕДРА АВІОНІКИ

ДОПУСТИТИ ДО ЗАХИСТУ

Завідувач випускової кафедри

___________Ю. В. Грищенко

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ДИПЛОМНА РОБОТА

Пояснювальна записка

ВИПУСКНИКА ОСВІТНЬОГО СТУПЕНЯ МАГІСТРА ЗА СПЕЦІАЛЬНІСТЮ

173 «АВІОНІКА»

ТЕМА: «Протиобліднювальна система літака Боїнг 737»

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Київ 2022

NATIONAL AVIATION UNIVERSITY

Faculty of Air Navigation, Electronics and Telecommunications Department of avionics

Specialty 173 ‘Avionics’

APPROVED

Head of department

____________Y.V. Hryshchenko ‘____’

____________2022

TASK for execution graduation work

Mark Makarenko

1. Theme: «Anti-Icing System of Boeing 737» approved by order 1413/ст of the Rector of the National Aviation University of 13 September 2022.
2. Duration of which is from 05 September 2022 to 30 November 2022.
3. Input data of graduation work: proposals for establishing and considering the possibilities for improving the anti-aircraft system of the Boeing 737, specifically the tailplane and anti-icing/ de-icing fluids.
4. Content of explanatory notes: List of conditional terms and abbreviations, Introduction, Chapter 1, Chapter 2, Chapter 3, Chapter 4, Chapter 5, Conclusions, References.
5. The list of mandatory graphic material: figures, charts, graphs, tables.

6. Planned schedule

№	Task	Duration	Signature of supervisor
1.	Validate the rationale of graduate work theme	05.09.2022	
2.	Carry out a literature review	06.09.2022 – 20.09.2022	
3.	Develop the first chapter of diploma	21.09.2022 – 05.10.2022	
4.	Develop the second chapter of diploma	06.10.2022 – 20.10.2022	
5.	Develop the third chapter of diploma	21.10.2022 – 03.11.2022	
6.	Develop the fifth and fourth and fifth chapter of diploma	03.11.2022 – 10.11.2022	
7.	Tested for anti-plagiarism and obtaining a review of the diploma	15.11.2022	

Consultants’ individual chapters

Chapter	Consultant (Position, surname, name, patronymic)	Date, signature	
		Task issued	Task accepted
Labor protection	K.I. Kazhan	03.10.2022	07.11.2022
Environmental protection	L.I. Pavlyukh	14.10.2022	09.11.2022

7. Date of assignment: ‘____‘______________2022

Supervisor __________________ V. G. Romanenko

The task took to perform __________________ M. D. Makarenko

ABSTRACT

The explanatory note to the thesis "Boeing 737 Anti-Ice System" contains: 115 pages, 16 figures, 4 tables, 13 sources used.

ANTI-ICING SYSTEM, BOEING 737 CHARACTERISTICS, HEATING ELEMENTS, ANTI-ICING/DE-ICING FLUIDS, AIRCRAFT.

The purpose of the diploma project is to familiarize with the design features of the Boeing 737 aircraft anti-icing system, their analysis of operation and maintenance, and consideration of possible shortcomings of the tail unit.

The subject of the work is proposals for establishing and considering the possibilities for improving the anti-aircraft system of the Boeing 737, specifically the tailplane and anti-icing/ de-icing fluids.

The object of the research - process of formation and determination of the best anti-icing protection and analysis of existing systems, comparative analysis.

Research methods are analytical, systemic, dialectical-materialistic, comparative, and general in the field of analysis of aircraft systems.

The anti-icing system of the Boeing 737 aircraft and its functional elements as well as subsystems are considered in the work, a general overview of technical operation, maintenance technology of these subsystems is considered and carried out.

An analysis of the shortcomings of anti-icing of the Boeing 737 tail system was carried out, research work on possible additions was carried out. The material of the diploma project is recommended to be used in conducting scientific research, in

the educational process and in the practical activities of specialists in flight and technical operation of aircraft.

CONTENT

LIST OF ABBREVIATIONS AND DEFINITIONS

A/C - Aircraft.

A/D - Aerodrome.

A/R - Aviation rules.

EASA – European Union Aviation Safety Agency.

OTD - Operational and Technical Documentation.

AVSEC - Aviation Security.

GA - General aviation.

RW - Runway.

SA - State Aviation.

AEA Association of European Airlines

APU Auxiliary power-unit

ATC Air traffic control

DIN Deutsches Institut für Normung

FP Freezing point

FPD Freezing point depressant

ISO International Organization for Standardization

OAT Outside air temperature

SAE Society of Automotive Engineers

INTRODUCTION

Icing is an extreme threat to aircraft flight safety. The study of the state of the atmosphere is necessary to prevent the aircraft from entering the icing zones, but it is not always possible to correctly predict and avoid icing. An anti-ice system is used to prevent and remove ice from aircraft surfaces. When the aircraft enters the icing zones, the anti-ice system is turned on and the flight is built in such a way as to get out of this zone as soon as possible, usually to the side or up, less often down.

The danger of icing in aircraft operating conditions is judged by the degree of icing. The degree of icing shows the amount of ice buildup as the aircraft spawns a unit of path. The degree of icing is influenced by the ambient temperature.

In the event of icing, ice is deposited on all frontal parts of the aircraft: the leading edges of the bearing surfaces and rudders, full pressure receivers, air intakes, guide vanes and engine spinners, cockpit windows, angle of attack sensors, antennas, propellers.

A serious threat to flight safety is not so much an increase in the weight of the aircraft as the deterioration of aerodynamics, as well as possible loss of stability and controllability, destruction of engines or propellers.

Icing of bearing surfaces leads to a decrease in the value of the critical angle of attack, a sharp increase in resistance, which in some cases can increase by 510 times. The decisive influence on the characteristics of an aircraft is provided by icing of the bearing surfaces of the wing, elements of its mechanization, horizontal and vertical tail. This effect manifests itself in a change in the physical picture of the flow around the bearing surfaces due to an increase in the thickness of the boundary layer and turbulence in it, leading to an earlier local separation of the flow and its stall with an increase in the angles of attack and slip.

The greatest influence on the flight characteristics, stability and controllability of the aircraft is exerted by ice formed on the wing and horizontal tail.

Wing icing causes an increase in stall speed, a decrease in level flight speed and, as a result, a narrowing of the aircraft flight speed range. Ice on the leading edge of the wing can cause deterioration in the lateral controllability of the aircraft due to the so-called aileron pickup. Manifestation of aileron drag when turning the yoke, which can provoke the pilot to deflect the ailerons at angles greater than those required for normal piloting. Involuntary errors in the actions of the crew (the desire to take the aircraft out of one roll and into another) can lead to the aircraft swaying. The phenomenon of aircraft swaying when the wing is iced is typical for aircraft with direct-acting control systems. In booster systems, the pick-up phenomenon will not be observed, since the hinge moment of the ailerons is perceived by the power rod.

Ice on the leading edge of the horizontal tail reduces its critical angle of attack. Therefore, with heavy icing, the angles of attack of the stabilizer implemented in the practice of aircraft flight operation can approach a critical value in the transitional flight mode, and this can lead to stall on the horizontal tail. Stall during transient flight conditions on the stabilizer can be facilitated by diving.

Ice that forms on propeller blades not only reduces their efficiency, but disrupts its balance and can cause dangerous shaking of the engine in flight, with possible destruction of the shaft support bearings and failure of the power plant. Ice grows most intensively on the propeller hub fairing, while the profile resistance of the blades increases sharply. With an ice thickness of 5–7 mm, centrifugal forces prevail over the forces of adhesion of ice to the surface of the blades, and spontaneous ejection occurs. At the same time, pieces of ice, hitting the fuselage, can pierce the skin of the pressurized cabin, damage the plumage.

Purpose of the work: Relevance of the topic: impact and assessment of Boeing 737 aircraft icing and recommendations for anti-icing system and its improvement for further development. To achieve the goal, the following tasks were set and solved:

- a comparative analysis of the most well-known aircrafts and their types of systems was carried out.

- the basic and the best system for de-icing has been determined.

- substantiate the problems and evaluate the prospects for the development of these systems.

- The Boeing Company and its leading qualities are considered.

Object of work: process of formation and determination of the best anti-icing protection and analysis of existing systems, comparative analysis.

Subject of work: proposals for development and consideration of possibilities for improvement of aviation anti-icing systems and improvement of their quality. To fulfill the task of this work, several basic research methods were used. The main ones are comparative and statistical analysis (when analyzing the main types of systems), systematization and generalization (when studying problems that hinder the development of the industry). Critical analysis, which is used in evaluating world leaders, was also used.

The theoretical and methodological basis is made up of systematic and analytical approaches to understanding and studying the object of study. Empirical and theoretical methods were used to solve the problem and achieve the goal. In scientific practice, these are logical analysis, comparative, statistical methods, as well as methods of deduction and induction, abstraction and aggregation.

The practical results obtained, as well as research, practical conclusions and recommendations, can be used:

- in the legal sphere: the creation of a process in accordance with the current standards of Ukrainian legislation in the field of aircraft manufacturing and air transport.

- Research activities: in the study and creation of a more effective or improvement of the existing systems.

The structure of the work is reflected in the task, which forms the sequence and logic of the study.

The work consists of an introduction, 5 chapters, a conclusion and a list of used literature. The total amount of text is 115 pages, and the list of sources has used 13 items.

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CHAPTER 1

AIRCRAFT ANTI-ICING SYSTEM

1.1 Requirements for the aircraft anti-icing systems.

The performance and design of the aircraft must ensure flight safety in icing conditions at all operating altitudes and speeds. The aircraft must be protected from icing in the outdoor air temperature range from 0 to minus 30°C with a water content of 0.8 to 0.2 g/m^3 at altitudes of 5000–9500 m.

During the operation of the anti-icing system, the airworthiness standards provide for the possibility of retaining residual ice formations on individual elements of the airframe, however, such formations should not adversely affect the flight performance of the aircraft and engines. Aircraft components, the icing of which can lead to a dangerous situation, must be protected from icing in the event of a power plant failure.

To warn the crew about icing and for timely activation of the anti-icing system, the aircraft must be equipped with an engine icing warning device and an airframe icing warning device or rate indicator. Icing warning devices or warning devices-intensity meters must give a signal of the presence of icing simultaneously with the visual detection of ice on the surface of the airplane and provide an indication of icing (or intensity) during the entire flight time in icing conditions.

The automatic control of the anti-icing system is presented by the signal of the icing alarm. Be sure to get used to the possibility of manually turning the anti-icing system into operation.

The design of the anti-icing system should allow to check its performance on the ground, as well as to control its operation in flight. It must be possible for crew members day and night to have control on the most critical parts sensitive to excitability.

The operation of the anti-icing system in icing conditions must not cause changes in the flight characteristics of the aircraft, create interference in the operation of navigation and radio equipment exceeding the permissible level, and also cause failure of other aircraft systems. The operation of the anti-icing system of the airframe and engines must be ensured in all operating modes of the engines.

Aircraft with unprotected from icing certain sections of the bearing surfaces and other structural elements must undergo flight tests in icing conditions in order to ensure flight safety.

Compliance of the aircraft with the requirements for the anti-icing system must be confirmed by calculations, bench and pipe tests, as well as flight tests in dry air and under controlled conditions of natural and artificial icing.

Aircraft icing is associated with the presence of supercooled droplet-liquid water in the atmosphere, when aircraft icing develops in a medium containing supercooled water drops and in conditions of heavy cloudiness, rain and sleet.

The entry of a supercooled aircraft into an atmosphere saturated with water vapor is short-term, and the icing of the aircraft is of low intensity, therefore it is less dangerous. But such icing can pose a danger to engines. The icing process can develop on engines at positive air temperatures, for example, at 5°C and even at 10°C. Under these conditions, the carburetors of internal combustion engines freeze up due to the cooling effect of fuel evaporation. In the air intakes of turbojet engines, during the adiabatic expansion of the intake air, the temperature decreases, drops of moisture condense and freeze.

The appearance of droplet-liquid water is associated with the cooling of water vapor that saturates the atmosphere. The mass of condensing water depends on the humidity of the air and the temperature difference during cooling and can be estimated by the formula:

$$\Delta M_{c.w} = 2{,}17 \cdot 10^3 \left(\frac{p_{w.v}}{T_d} - \frac{p_t}{T_d}\right)$$

where $p_{w.v}$ - initial partial pressure of water vapor at temperature before cooling t_0; T_d - dew point temperature; p_t - partial pressure of saturated vapors of water at the temperature before cooling.

The pressure of saturating vapors over ice is less than over water; therefore, the icing that has begun proceeds with increasing heat. Meaning $p_{w.v}$ determined from the ratio:

$$p_{w.v} = \frac{\varphi}{100} p_t$$

Where φ is relative humidity.

Partial pressure p_t determined by the temperature of the vapor-air mixture t (Fig. 1).

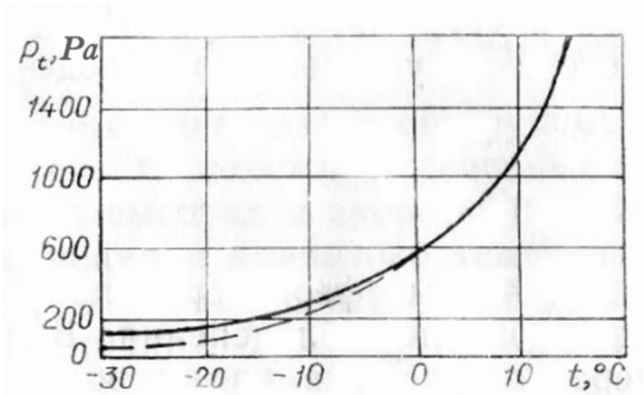

Fig. 1 Partial pressure determined by the temperature of the vapor-air mixture

Even with relatively moderate air humidity, a significant amount of moisture can be released during cooling. For example, the mass of water released from 1 m^3, at air humidity φ = 60% and cooling it from 15°C to 0 will be equal to:

$$\Delta M_{c.w} = 2{,}17 \cdot 10^{-3} \left(\frac{p_{w.v}}{T_d} - \frac{p_t}{T_t} \right)$$

The initial saturation vapor pressure is calculated as follows:

$$p_{w.v} = \frac{60}{100} 1720 = 1032\ Pa$$

The dew point temperature T_d is determined from Fig. 2.

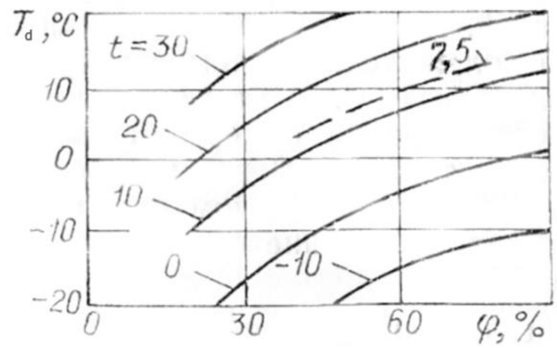

Fig.2 The dew point temperature determination

The transition to degrees Kelvin is carried out according to the formula:

$$T_d = 273 + 7{,}5 = 280{,}5\ K$$

Then the mass of condensed water is equal to:

$$\Delta M_{c.w} = 2{,}17 \cdot 10^{-3}\left(\frac{1032}{280{,}5} - \frac{610}{273}\right) = 3{,}14\ g/m^3$$

The absolute humidity of the environment is estimated by the mass of water vapor $\Delta M_{w.v}$, contained in a unit volume, according to the expression.

$$\Delta M_{w.v} = \frac{R_{p_{w.v}}}{R_{w.v} pV} = 0{,}662\frac{p_{w.v}}{T}p$$

where V - vapore volume.

Relative humidity φ is defined as the ratio

$$\varphi = \frac{\Delta M_{w.v}}{M_e}100\%$$

where M_e - mass of saturated water vapor at a given temperature.

Mass of water ΔM, condenses when the vapor cools to the dew point, is equal to:

$$\Delta M = 2{,}17 \cdot 10^{-3} \left(\frac{p_{w.v}}{T_p} - \frac{p_t}{T_t} \right)$$

The released water in a drop-liquid state can be stored in a supercooled state up to significant negative temperatures.

Such a state of droplets is especially characteristic of highly dispersed aerosols. For example, droplets with a size of 15 to 20 microns remain in a liquid state up to temperatures of the order of minus 20°C. Larger droplets already at this temperature begin to freeze, with further cooling, the crystallization process accelerates and almost already at t = -40 ° C, the freezing of water in aerosols ends. Therefore, at temperatures below minus 40°C, the icing process is impossible, although under extreme conditions it is sometimes possible to keep single drops of water in a supercooled state up to t=-72°C. Most often, the process of icing development is observed in the temperature range from 0 to minus 15°C. The temperature range of the onset of icing development is affected by the aircraft flight speed, and as the speed increases, the icing process occurs at lower outside air temperatures.

The development of aircraft icing is influenced by the saturation of air with a droplet liquid phase, called water content.

The probability of occurrence of conditions for the existence of aerosols with water content ω depends on the outside air temperature (Fig. 3).

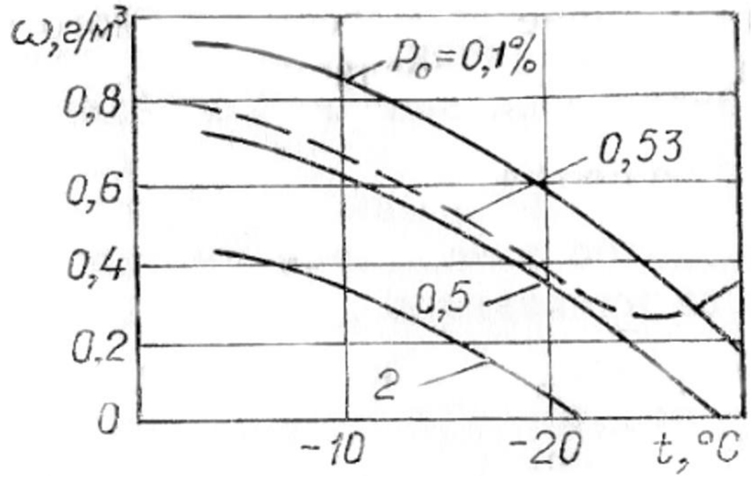

Fig. 3 Probability of occurrence of conditions for the existence of aerosols with water content

With decreasing temperature at a given level of probability, the existence of water conditions decreases. The calculation of the anti-icing system is performed depending on the outside air temperature, normalized water content, flight altitude H, the length of the icing zones L, and the droplet diameter d of the liquid aqueous phase. The size of the droplets of the aqueous phase predetermines the size of the icing zone of the aircraft components, the nature and structure of the ice. For example, large water drops of the order of 1000 microns do not flow well around the wing profile, plumage and form growths near the wing leading edge. Small droplets are carried by the air stream further along the chord, expanding the icing zone.

1.2 Icing nature and conditions

Depending on the conditions in which the aircraft falls during the implementation of the flight, the icing process develops differently. Icing can be dry, sublimation, drip.

Dry icing occurs most often when flying in the tropics, when the airframe structure of the aircraft encounters small ice crystals of the clouds. In this case, a loose structure of ice crystals is formed, which does not have strong adhesion to the surface of the aircraft. This type of icing does not pose a particular danger to the aircraft, except for cases when ice falls into individual aircraft units, for example, into air intakes of a complex configuration.

Sublimation icing is characteristic of the transition of water vapor contained in the air into a solid phase (ice), bypassing the liquid state. Such a process can occur even in a cloudless atmosphere, for example, during an emergency descent, when the supercooled aircraft airframe structure enters warmer layers of moist air. But this type of icing is rare and less dangerous, since the ice formed in this case has a thickness of less than 1 mm, and ice less than 5 mm thick is not classified as crystalline.

The most dangerous type of icing is drip. The development of this type of icing occurs in clouds in the presence of a supercooled aqueous liquid phase. When supercooled droplets collide with the surface of the BC, very rapid crystallization occurs. The process of crystallization of especially small droplets can occur instantaneously with the formation of ice. In this case, depending on the environment and aircraft flight parameters, the following forms of drop icing can develop:

- Clear ice, with a smooth outer surface.
- Rime ice, with a rough surface.
- Mixed ice, in the form of needle-shaped crystals.

The Clear form of ice is formed mainly from large drops d≥20 μm of the liquid aqueous phase at an ambient temperature of 0 to minus 5°C. This form of ice has

(Fig. 4) a trough-like structure with a significant capture zone along the chord and is characterized by a significant density γ= 6–9 $\frac{km}{m^3}$ and high grip force with the surface of the airframe. Under the operating conditions of aviation equipment, this form of drip icing occurs in 30% of cases.

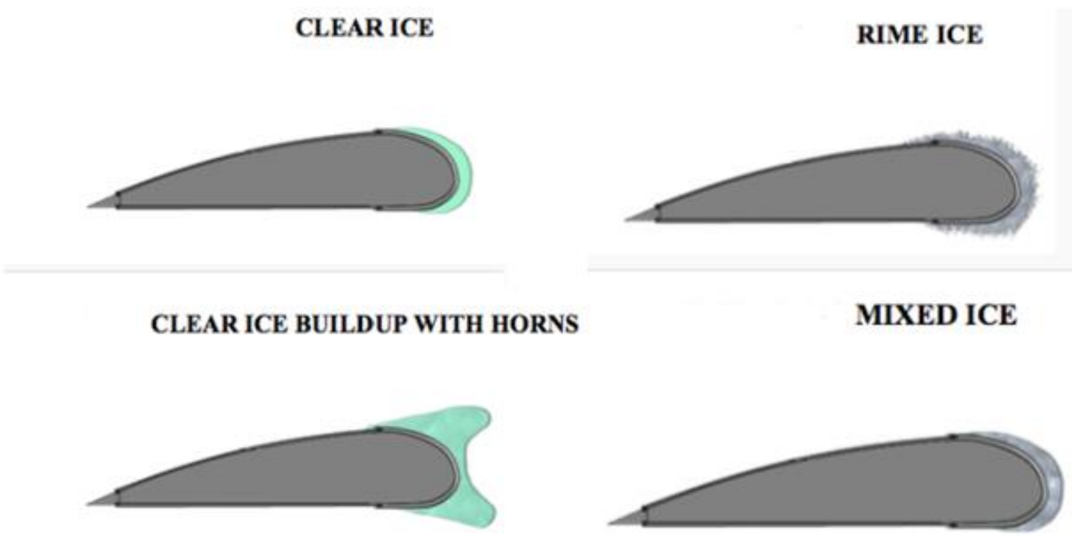

Fig. 4 Types if ice structures

Rime ice is formed from small droplets in a wide range of low ambient temperatures from 0 to minus 30°C. In this case, a wedge-shaped form of ice is formed on the bearing surfaces of the aircraft airframe. This form of icing is characterized by a lower density γ = 2–6 $\frac{km}{m^3}$, which is explained by the presence of numerous air bubbles in the ice structure during the rapid solidification of the liquid aqueous phase. This type of ice is called cloudy white. Porcelain ice formation is the main type of aircraft icing.

Clear ice forms on the leading edges of the aircraft (Fig. 5) at zero outside air temperature. The height of the needles can reach up to 35 mm. In this case, a loose structure is formed with a low strength of adhesion to the surface of the airframe structure. For example, as a result, it is likely to reduce the efficiency and stability of the compressor and the entire engine. In addition, if pieces of ice get on the rotating blades, their damage cannot be ruled out.

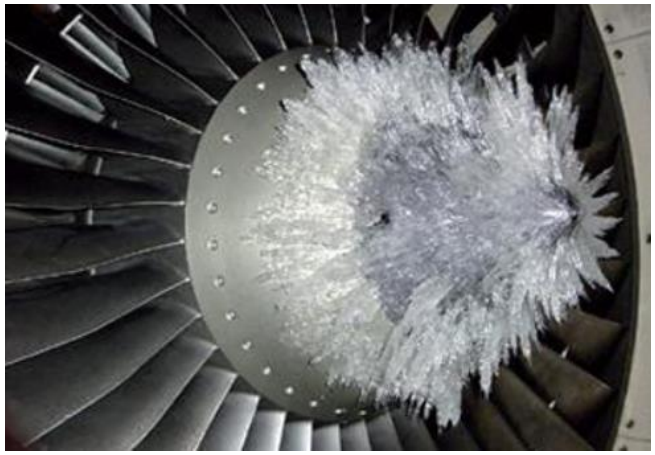

Fig. 5 Clear ice on the leading edges of the aircraft(engine)

The physical picture of the development of icing on aircraft surfaces during flight in an air environment containing a supercooled droplet liquid aqueous phase can be represented by considering the process of droplet impact with the surface of the airframe structure, their spreading and freezing. The zone of ice freezing is called the capture zone. When a polydisperse aerosol (cloud) flows around the profile of a carrier surface, for example, a wing, water drops do not follow streamlines, since they have much greater inertia than air and move along the shortest path. Therefore, some of them hit the leading edge of the profile and freeze. The larger the droplet diameter, the greater the deviation of their trajectories from the current lines around the profile.

The capture zone characterizes that part of the profile on which ice will grow. The dimensions of this zone must be known in order to assess the size of the protection area and the energy consumption to free parts of the aircraft from icing.

The capture zone, its dimensions are characterized by the capture coefficient E, which shows how many supercooled droplets per profile are captured by the latter upon impact. The numerical value of the coefficient E can be determined by the relation

$$\boldsymbol{E = \frac{a}{C}}$$

where a — size characterizing the coordinates of the extreme trajectories of the droplets tangent to the profile; C - construction height of the profile.

The icing of engine air intakes can be more intense than the icing of other aircraft surfaces, primarily due to the possibility of this process developing at positive outside air temperatures. The very arbitrary dropping of pieces of ice can cause damage to the compressor blades and destruction of the engine itself. When icing changes the aerodynamic profile of the inlet guide vanes, the working blades of the first stage of the compressor, the flow area between them decreases and the air flow through the compressor drops.

The need to maintain the required thrust requires increased fuel consumption, an increase in the temperature of the gases in front of the turbine and a decrease in engine efficiency.

Icing of the cockpit glazing, especially windshields, complicates the conditions of visual piloting, leads to errors in the actions of pilots, and the formation of ice on instrument sensors leads to their failure or disruption of normal operation, which, in turn, under certain circumstances can affect safety flights.

1.3 De-icing/anti-icing systems

Timely detection of icing is important for ensuring flight safety in order to take the necessary measures to eliminate the intensity of the development of this process. Therefore, I would like to reveal the basic systems on this topic, pointing to examples on a couple of aircraft manufactured in other countries, for further research and possible improvements to the Boeing 737. To this end, the aircraft are equipped with icing warning devices, which are divided into two main groups of indirect and direct action.

Indirect signaling devices react to the presence of supercooled water droplets in the atmosphere. The principle of operation of devices of this type is based on a change in such characteristics as electrical conductivity, electrical resistance, heat transfer. The advantage of these signaling devices is high sensitivity. Such signaling devices include an electrically conductive signaling device (contact or chemical), remote in a video location device and a thermal signaling device-intensimeter, for example, on an Il-76T salomel.

Among the signaling devices of indirect action, thermal signaling devices-intensimeters are more often used, including:

- temperature analyzer - channel for monitoring the surrounding temperature;
- water content analyzer - channel for following water content;
- the converter is a power supply device and anti-ice system shutdown delay unit.

An icing sensor designed to monitor icing conditions includes a temperature sensor, a water content sensor, and heating elements. During the implementation of flights in icing conditions, this generates an electrical signal proportional to the intensity of icing.

The pointer "Ice" gives information about the intensity of icing in the range from 0 to 5 mm/min.

The structure includes a device for built-in control of the performance of the ratemeter before flight, in flight and during maintenance. The principle of operation of such a signaling device is based on measuring the difference in heat transfer from the heated surface of the sensor along its leading and trailing edges in a dry air flow before icing.

The icing sensor is made in the form of a wing profile made of heat-resistant electrically insulating material. Heating elements are glued on its leading and trailing edges, which are switched on in flight only at a negative temperature of the incoming swelling on a temperature sensor signal.

After the aircraft takes off, the interlock supplies +27 V power to the relay and the rate indicator starts monitoring the outside air temperature. When flying in dry air, the heating elements of the icing sensor are connected in series and maintain 90–150°C on its surface. During icing, they switch to a parallel circuit and maintain the temperature of the same range on the sensor surface, but under conditions of greater heat removal. Under icing conditions, the front end surface cools due to heating and evaporation of the trapped supercooled water droplets. At the output of the thermal measuring bridge circuit of the sensor, an electrical signal appears, which is proportional to the temperature difference between the leading and trailing edges of the profile surface of the sensor. The temperature difference, in turn, is proportional to the intensity of icing.

The electrical signal, amplified, goes beyond the threshold of the water content analyzer, when triggered, the AIRCRAFT ICING light panel on the central panel of the pilots' dashboard turns on. The indicator "Ice", which is included in the water content sensor circuit, at the same time shows the numerical value of the intensity of icing.

When the aircraft reaches an altitude of H> 8000 m, if the flight occurs without clouds in “dry” air, the response threshold of the water content analyzer is rebuilt from 10. to 24 V by a signal from the high-altitude signaling device.

When the aircraft leaves the icing zone, the output signal of the sensor: water content decreases and the AIRCRAFT ICING panel turns off, the pointer needle sets the zero mark of the scale, and the rate indicator switches to the mode of monitoring only the ambient air temperature. When landing, regardless of the operating mode, the ground-to-air lock when the main landing gear is compressed, cuts off the power supply and the icing sensor.

Thus, the indicator-intensimeter has three modes of operation: duty, working and monitoring the ambient temperature.

At present, the radioisotope indicator of icing (for example, RIO-3) is most widely used, which allows not only to detect the beginning of icing, but also to continuously measure the intensity of icing, thickness and other parameters.

The sensitivity is (0.3 + 0.1) mm of ice. The indicator signals both the beginning and the end of icing, provides continuous signaling when flying in the icing zone. Strontium 90 and yttrium 90 are used as an emitter with an activity of 4-5 μCi and a half-life of 28.4 years.

The principle of operation of a radioisotope signaling device is based on the attenuation of the radiation of a radioactive isotope by a layer of ice formed on a remote detector (counter). In addition to issuing information about icing, such signaling devices make it possible to automatically turn on the anti-icing system.

To ensure the safety of flights on aircraft, anti-icing protection is provided for sections of the airframe, engines and individual units. On the Il-86 aircraft (Fig. 6), sensors of the indicator-intensimeter 4, angle of attack 5, total pressure 6, front windows 7 of the cockpit canopy, engine air intakes 9, wing leading edge (slat sections) 1, leading edges of the stabilizer and keel 8 are protected from icing. Headlights 2 and 8 are used to inspect the condition of the leading edges of the bearing surfaces. Anti-icing systems can be built using various principles for de-icing the aircraft surface. anti-icing systems are divided into mechanical, physicochemical, thermal and combined.

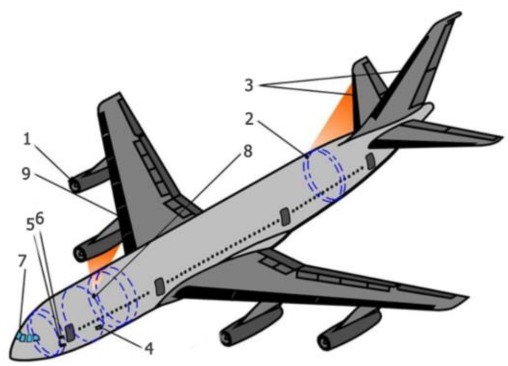

Fig. 6 Il-86 aircraft sensors

Mechanical anti-icing systems require a certain thickness of ice to work effectively. Prevention of icing by mechanical anti-icing systems is already achieved when ice 4–5 mm thick forms, when ice of this thickness is not yet dangerous for the aircraft. In the work of such anti-icing systems, two stages are distinguished: the destruction of ice and its removal by the oncoming air flow.

The first mechanical systems for protecting aircraft from icing are pneumatic anti-icing systems. Structurally, such systems are made in the form of a thin elastic protector, from which air chambers are formed. The protector is placed on the width of the icing zone of the leading edges of the bearing surfaces. The system is arranged in the form of separate sections with pressurization of a cyclic equal sequence. In this case, two options for orienting the air chambers relative to the bearing surface are possible: longitudinal placement of the chambers, transverse arrangement of the chambers.

The program of the anti-icing system is designed for turning on the sections one by one. When pressurized chamber-section is their deformation, which causes the destruction of ice and violation of its adhesion to the surface of the tread. When the anti-icing system is turned off, the air from the chambers is removed by ejection and released into the environment. The mass of such a system is relatively small and ranges from 2.8 to 3.4 kg/m² air consumption from 26 to 36 kg/h. For the normal effective operation of the anti-icing system, air supply under a pressure of no more than 1.3 MPa is required.

The variant shown in Fig. 1 has the least effect on the profile resistance. As an example of the implementation of a pneumatic anti-icing system in an aircraft design, consider the L410 aircraft system. (Fig. 7) shows a diagram of the protection of the bearing surfaces of the aircraft L410 from icing. The composition of the anti-icing system includes:

- four sections of protectors 1, 2, 3, 4 with transverse placement of cameras on the wing;
- two sections of protectors 5, 6 of the same type on the stabilizer;
- one section 7 on the keel.

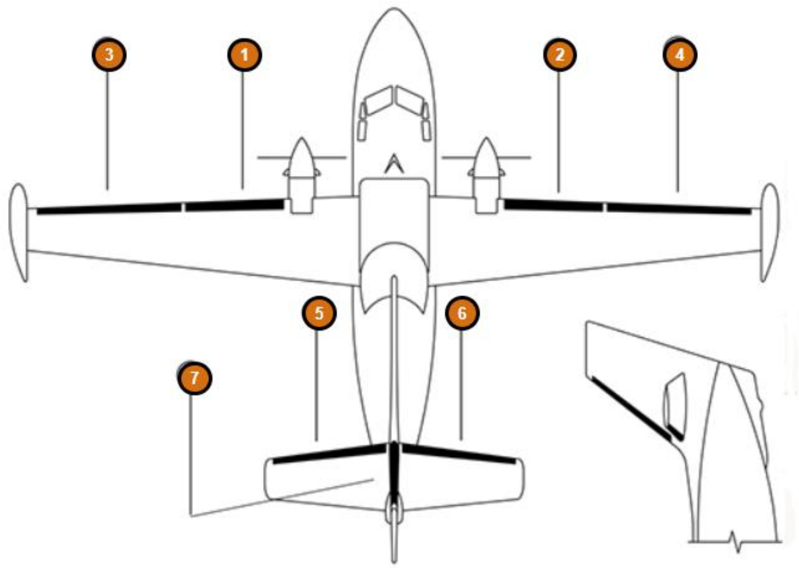

Fig. 7 L410 aircraft system

Hot air taken from compressors. engines, enters the mixer, which is part of the air conditioning system. From the mixer, the cooled air is supplied to the units of the control system, pressure and distribution valves, which are triggered by the signals of the time relay and connect the corresponding sections of the tread to pressurize them with air. The design of the system provides for the possibility of changing the frequency of pressurization cycles of the tread sections depending on the icing conditions. The duration of a normal cycle is 60 s. Separate sections of the tread are blown for 5 s. After the pressurization cycle is completed, the tread chambers fall off due to the vacuum created by the ejector. The design of the system is based on the development of the French company Kleber-Colomb.

Also in the anti-icing system, using physicochemical methods of combating aircraft icing, they are used. non-freezing substances that create an intermediate layer between the protected surface and the external environment or ice. Such substances must have good adhesion to the surface of the skin, chemical anticorrosion, and not be destroyed by velocity pressure. For these purposes, various coatings or washing liquids are used.

For effective operation in anti-icing systems fluids, various alcohols, mixtures of alcohols with glycerin, glycogol or ethylene glycol mixtures with water are used. For example, a mixture of 40% glycol and 60% water has a freezing point of minus 60°C. A feature of the use of liquid anti-icing systems is the need to turn them on before the onset of icing of the aircraft, therefore, such anti-icing systems are more often used on moving parts, for example, propellers, rotors of helicopters, and also where heating is dangerous (for example, anti-icing cockpit glazing made of organic glass).

Anti-icing systems fluids can provide dissolution of thin ice sheets. In case of intense icing, a delay in turning on the anti-icing system can significantly reduce their effectiveness. The disadvantage of such systems is the high consumption of washer fluids up to 1.8 l/m^2.

Thermal anti-icing systems, the most common at present, are divided into two main types: air-thermal and electro-thermal. However, other options for such an anti-icing system are also possible, for example, the use of liquids as a coolant to protect engine parts from icing using hot oil from the lubrication system.

All thermal anti-icing systems, according to the principle of operation, are divided into systems of continuous and cyclic action. More often, cyclic anti-icing systems are used, especially for electrothermal anti-icing systems, since their continuous operation requires hundreds of kilowatts of power. With large surfaces and for air-thermal systems, it is irrational to use the principle of constant action.

Therefore, on aircraft with a large flight mass, only in certain sections of the wing can the principle of constant heating be maintained. To prevent the ingress of pieces of ice, blown away by the flow, into the air intakes of the engines located behind the wing in the rear fuselage

Next, consider the system Works of electrothermal anti-icing system. It is based on the conversion of electrical energy into heat. As heating elements, wire or film devices made of materials (constantan, nichrome) are used. Uniform distribution of the input current across the width of the heating element is achieved by installing a special copper bus. On bearing surfaces with sharp leading edges, in most cases conductive films are used, for example, from an alloy of copper, manganese and magnesium. Such a film is applied to the surface to be protected, previously covered with a layer of electrical insulation by flame spraying on zigzag stencils. From above, the film is covered with a layer of electrical insulation and protected with an abrasion-resistant coating based on synthetic resins filled with steel powder. The total thickness of the element package is about 1.5 mm.

Electrothermal anti-icing systems, despite the high-power consumption for their work, more labor-intensive maintenance and complex design, are often used on aircraft, for example TU-154. Considering the high efficiency up to 0.95, the independence of the required power taken from the engine operation mode, the possibility of using it on aircraft structural elements where the layout of air channels is difficult, it can be considered expedient to install an electrothermal anti-icing system, for example, on the slats of the Tu-154 aircraft, main and tail rotors helicopters and several other cases of using such systems.

Having considered these systems, I believe that the main advantages of pneumatic anti-icing systems are: simple design, relatively low weight and low air consumption to ensure efficient operation. The main disadvantages of such systems include the distortion of the shape of the aerodynamic profile of the bearing surface during operation, which leads to an increase in the profile drag up to 110%. In the idle state of the system, an increase in resistance for the entire aircraft by 2–3% is observed. Pneumatic anti-icing systems are ineffective with needle-shaped ice, have a short resource, and the protector itself has the ability to spontaneously change shape at flight speeds of more than 500 km/h, so the use of systems of this type on high-speed aircraft is irrational.

Electro-pulse anti-icing systems also apply to mechanical systems. The principle of operation of such systems is based on the interaction of electromagnetic fields of the skin and the generator of electrical impulses. As a result of such interaction, a wave of elastic stresses with a steep leading edge is created in the skin. In this case, stresses appear in the ice layer adjacent to the skin, which exceed its dynamic strength in value, which leads to instantaneous shaking of ice from the skin. The main difficulty in the structural completion of the system lies in the choice of the loading mode in such a way that the resulting stresses do not lead to fatigue failures of the skin. The duty cycle of destruction must be very short. Based on the rate of propagation of mechanical stresses in the skin, which is close to the speed of sound, it is possible to obtain short powerful pulses in sufficiently large intervals between them to carry out energy accumulation.

And so, comparing the anti-icing system of this type implemented on aircraft as an example, the level of energy costs is $8 * 10^6$ times less than with the thermal method of protection. This means that with this approach in building an anti-icing system, you can get an anti-icing system with low power consumption.

Before considering the Boeing 737 systems, I want to draw conclusions about the choice of the type of aircraft anti-icing system is decided in relation to a specific model of aviation equipment, considering the design features, operating conditions, purpose, scope, etc.

Factors influencing the choice of an anti-icing system in an aircraft include:

- optimal and economical use of available energy.
- operating temperature range of the anti-icing system and realized degree of aircraft protection against icing.
- the possibility of design and layout of the anti-icer in relation to the protected structural element.
- ensuring the minimum takeoff weight of the system.
- remoteness of energy sources relative to protected surfaces and units.

So, the relationship of these factors requires their comprehensive assessment when choosing an anti-icing system. In this case, a compromise solution may be appropriate when the leading edge of the wing is equipped with an electrothermal protection system, and the plumage is equipped with an air-thermal one, combined settlements are used. As in the case of the Il-76 aircraft system, preference was given to the air-thermal slat protection system and the use of electric heating of the keel and stabilizer. After getting familiar with the types of anti-icing systems and looking at them in other aircraft, you can move on to the Boeing 737 in the next chapter.

CHAPTER 2
GENERAL INFORMATION ABOUT THE BOEING AIRCRAFT

2.1 Boeing Commercial Airplanes

In this chapter I want to talk about the the world's largest airline and a leading manufacturer of commercial aircraft and defense, aerospace and security systems - Boeing. As the largest exporter to the United States, the company supports airlines as well as the U.S. government and allied customers in more than 150 countries. Boeing products and services include commercial and military aircraft, satellites, weapons, electronics, defense systems, launch systems, advanced information and communications systems, and competency-focused logistics and training.

Boeing has a long history of leadership and innovation in the aerospace industry. The company continues to expand its products and service line to meet new customer needs. The broad scope of its capabilities includes creating new and more efficient members of the commercial aircraft family; design, construction and integration of military platforms and defense systems; creation of advanced technological solutions; and regulating innovative customer financing options.

Boeing's Chicago offices employ approximately 160,000 people in the United States and more than 65 countries. This represents one of the most diverse, talented and innovative workforce in the world. Its business also depends on the talents of hundreds of thousands of skilled professionals who work for Boeing suppliers around the world.

Boeing has two commercial divisions: commercial aircraft and defense and aerospace and security. These divisions are backed by Boeing Capital Corporation, a global provider of financial solutions. Shared Services Group, which provides.

Boeing with a wide range of services worldwide; and Boeing Engineering, Operations and Technology, which help to develop, acquire, apply, and protect innovative technologies and processes.

Boeing has been a leading manufacturer of commercial aircraft for decades. Today the company manufactures the 737, 747, 767, 777 and 787 aircraft families, as well as the Boeing Business Jet group. New product development efforts include the Boeing 787-10 Dreamliner, 737 MAX and 777X. More than 10,000 commercial Boeing aircraft are in service around the world, accounting for almost half of the world's fleet. The company also offers a full range of cargo aircraft, and about 90% of the world's cargo is transported by Boeing aircraft.

As a commercial aviation service provider, the company provides unrivaled 24/7 service and support to help airlines and charter companies improve their operations. Commercial aviation offers a full range of customer support, parts, engineering, modification, logistics and information services to its global customer base, which includes global passenger and cargo airlines, as well as maintenance, repair and inspection services.

Defense, Space, and Security (BDS) is a diverse global organization that provides advanced solutions for the design, manufacture, modification and support of military aircraft, helicopters, weapons and satellite systems, among others. Helps customers meet multiple requirements with a wide range that includes 702 families of satellites; AH-64 Apache helicopter; electronic security; EA-18G electronic attack aircraft; KC-46 tanker aircraft, built on the basis of the Boeing 767 commercial airliner; and the P-8 anti-submarine/anti-submarine aircraft derived from the 737 commercial jet . Driven by its ability to provide customers with the right solutions at the right time at the right price, BDS is looking for ways to make better use of information technology and continues to invest in research and development of advanced capabilities and platforms.

The Boeing Capital Corporation (BCC) is a global provider of financial solutions to Boeing customers. Working closely with Commercial Aircraft and the Department of Defense, Space and Security, BCC provides coverage needed to purchase and ship Boeing products. With an investment portfolio of approximately $3.4 billion at the end of 2015, BCC combines the financial strength and global reach of Boeing, extensive knowledge of Boeing equipment and its customers, and the expertise of a group of experienced financial professionals.

The Shared Services Organization provides Boeing business units and offices with shared internal services that support the company's global operations. These services include everything from maintenance and protection of Boeing sites around the world; Management of the purchase and sale of all leased and own property; acquisition of non-production equipment and consumables of the company; Provision of various personnel related services to current and former employees; selection and staffing of the enterprise; Corporate finance management, business/accounting, travel services and expenses; and providing creative communication services.

2.2 Boeing 737 aircraft family

Boeing Commercial Airplanes continues to lead the field of commercial aviation. Providing services and aircraft with superior design, performance and value for superior flight.

There are now more than 10,000 Boeing commercial aircraft operating worldwide, flying longer distances with each successive launch of the airframe with less fuel, constantly reducing noise and emissions. Boeing is headquartered in Seattle, Washington and employs more than 140,000 people worldwide.

So, the hero of this diploma work and the aircraft I want to talk about it is the Boeing 737! This name is the common for a family of more than ten types of aircraft and it is the most mass-produced and best-selling jet passenger aircraft in the history of aviation, it is the most popular narrow-body passenger jet in the world, it has been in production since 1967 and throughout its history, the Boeing 737 family aircraft have transported more than 12,000,000,000 (12 billion) passengers. The aircraft performs short- and medium-haul flights. At any given time, there are an average of about 1,250 737 series aircraft in the air, and every 4.6 seconds, one Boeing 737 takes off or lands somewhere in the world. All Boeing 737 family aircraft are divided into 3 groups: 737 Original, 737 Classic, 737 Next Generation (NG).

- Original: 737–100, -200 (manufactured from 1967 to 1988)
- Classic: 737–300, -400, -500 (manufactured from 1983 to 2000)
- Next Generation: 737-600, -700, -700ER, -800, -900, -900ER, BBJ, BBJ2 (produced since 1997)
- 737 MAX: 737 MAX 7, 737 MAX 8, 737 MAX 9, 737 MAX 10 (produced since 2015)

The 737 Original family of aircraft quickly fell out of favor due to fuel inefficiency, high noise levels (despite the installation of noise-absorbing mechanisms on the engines) and expensive maintenance. Most of the 737-200 aircraft have already been retired and made history, but sometimes you can find this model as a cargo version. The 737-100 variant has been out of service since 2007. The 737 Originals are originally designed for a two-man crew, a significant change from the Boeing 727, which has a flight engineer seat in the cockpit. Subsequently, this approach became the standard for all passenger aircraft.

The Boeing 737-200 is an elongated version of the 737-100 specifically for the US market. The first customer was the American United Airlines. The Boeing 737-

200C could be converted from passenger to cargo-passenger or cargo. 737-200QC - A modification of the 737-200C, only allowing you to very quickly repurpose the aircraft cabin. Serially produced from 1967 to 1988. 737-200 in 1971 was developed to 737-200 Advanced (improved), which became the standard option. This option could also be made in modifications -200C and -200QC. In addition, there were options 737-200 Executive Jet and 737-200HGW (High Gross Weight). The 200th model has long been obsolete and is currently used mainly in third world airlines (Iran, Pakistan).

The original 737-100 and -200 eventually became unprofitable and lost out to the DC-9 family, although engines and avionics were improved. In 1979, Boeing began development of a new 150-seat aircraft based on the 737-200 Advanced. In 1980, the aircraft received the designation 737-300. At the same time, work was underway to create new Boeing 757 and Boeing 767 aircraft, with which the new 737-300 received significant unification of avionics.

The Boeing 737-300 inherited elements of the airframe, flight control system, air conditioning system and many other characteristics from the -200, but in general it was already a completely different aircraft. The Classic family of aircraft is equipped with digital avionics, more efficient and economical CFM56 engines, and an improved approach to passenger cabin comfort.

Changes in aerodynamics led to the appearance of a fork, which became a noticeable difference between these model and subsequent ones from the "original".

So, my favorite airplane is the Boeing 737-300 is the first and basic representative of the 737 Classic family, extended by 3 meters, up to 33.18 meters, compared to the -200 model. The first customers of this aircraft were US Airways and

Southwest Airlines. The first flight was carried out on February 24, 1984. The first serial machines were delivered to customers in the autumn of the same year.

Also, I couldn’t mention here the interesting facts I have found about the Boeing 737:

- The first Boeing 737s were nicknamed "Baby Boeing" by pilots because they looked like a small Boeing 707.
- Aircraft of the Classic (300-500) and NG (600-900) series have non-circular engine air intakes. This technical solution was nicknamed "hamsterisation" (hamsterisation) because of the similarity with the cheeks of a hamster.
- The number of Boeing 737 parts exceeds 3 million pieces.
- It takes about 200 liters to paint the fuselage of a Boeing 737. When the paint dries, it weighs about 113 kilograms.
- Estimated cost of Boeing 737: from $51.5 million to $87 million, depending on the series and configuration
- There are an average of 1,200 aircraft in the air could be right now.

Next is the Boeing 737-400 was lengthened by 3 meters, to 35.23 meters, compared to the 737-300, primarily due to the requirements of charter carriers. Due to the increase in the volume of the cabin, it was necessary to rework the air conditioning system, which became the main difference between this aircraft in the family. Associated with these changes are two omitted windows on each side, making the -400 easily distinguishable from other 737 Classics. Also, the aircraft is equipped with additional emergency exits to the wing (two on each side, while on -300 and -500 - one each) and a tail heel, which prevents the destruction of the rear fuselage structure in the event of a tailstrike touching the runway. These design features became characteristic of the subsequent "long" 737 (-800, -900). The first customers are US Airways and Pace Airlines. The largest operator is Alaska Airlines with 40 aircraft.

Last bird in this type the 737-500, is a 2m shorter version of the 737-300, to 29.79m, with increased range. With a passenger capacity similar to that of the 737-200, the Boeing 737-500 was an adequate replacement for it.

About the Next Generation (NG) family was Boeing's answer to the dominance of the Airbus A320. Aircraft of the NG series are equipped with a completely new wing (lengthened by 5.5 meters), tail and more advanced engines. In addition, the so-called "glass cockpit" was installed on the NG, equipped with displays on cathode ray tubes, and later on liquid crystals instead of the usual "alarm clocks" - analogue dial instruments and digital systems. Most of these systems were already borrowed from the Boeing 777, as well as the design of the cockpit and passenger compartment. The total number of aircraft parts was reduced by a third, which reduced its weight, increased manufacturability and improved aircraft handling. Additional transformations also include optional vertical wingtips - winglets (winglets), which significantly reduce fuel consumption and improve takeoff and landing performance. The passenger cabin of the NG series aircraft was developed on the basis of the 757 and 767 cabins. Even the design of the Boeing 777 aircraft used the style of the 737NG cabin. In general, the aircraft of the 737 Next Generation family are a restyled version of the aircraft of the 737 Classic family. Most of the systems have remained almost unchanged schematically and functionally, however, the units have become one third smaller, and most of them have been redesigned and improved. Since the entire family was designed at the same time, the numbers in the name of the aircraft are ordered in order of increasing fuselage length.

And the last one - Boeing 737 MAX is a new high-tech family of aircraft that replaced the Boeing 737 Next Generation. The first flight of the Boeing 737 MAX 8 took place on January 29, 2016. By tradition, the liner was the answer to the Airbus challenge with the A320neo model. Boeing says the 737 MAX is 10% to 15% more efficient than the A320neo. In addition, all aircraft systems have been redesigned and improved. The aircraft is equipped with brand new Leap-1B engines and MAX AT Winglet winglets that reduce fuel consumption by at least 1.5%. Other improvements include a new tail contour, a revised auxiliary power unit design, and a front landing gear strut lengthened by 20 cm. The aircraft received a cockpit unified with the Boeing 787 and equipped with 15-inch liquid crystal displays, which significantly improve situational awareness and pilot efficiency. The cabin of the Boeing 737 MAX is made in the style of the Boeing Sky Interior and is equipped with a pleasant LED light that changes color depending on the phase of the flight, as well as a new mechanism for opening the upper shelves, comfortable tables and flight attendant call buttons. By and large, the interior design of the 737MAX is based on the Boeing 787. The 737 MAX family of aircraft consists of 4 aircraft differing in capacity and flight range.

2.3 Boeing 737 Ice & Rain Protection System

2.3.1 General Information

What is the best-selling aircraft of the Boeing family?

Of course, Boeing's best-selling and most produced aircraft was the Boeing 737. This is more than the total number of deliveries for the Airbus A320 family, but it is no longer on order. The Boeing 737 has been flying since his 1967 and has gone through several series and modifications since then.

For decades, the aviation industry has continuously improved its onboard systems for the best performance, safety and comfort. Aircraft safety is one of the main goals of engineers to create durable means of transportation. Harsh external conditions during flight, especially relative humidity and very low temperatures at high altitudes, can lead to icing of the aircraft. Ice can severely affect aircraft weight and aerodynamics, especially lift (lift can be reduced by up to 40% due to ice). Modeling and installation of a special anti-icing system is required.

Therefore, aircraft designers have developed anti-icing systems inside the wings to prevent icing. Aircraft have several anti-icing systems, mainly depending on the type of engine. Most aircraft use air intake systems that consist of using hot air intakes to heat the leading edge of the wing. Another system, called the de-icing boot system, is mostly used on turboprop aircraft and consists of a black rubber boot where it tends to land on the balloon and literally break the ice. Another system is an electric leading edge heater mounted directly on the leading edge of the wing. These examples are only an introduction to anti-icing systems being developed and used in the aviation industry. Each has advantages and disadvantages.

Here we focus on hot wind anti-icing systems. This approach is used in the Boeing 737-300/400/500 anti-icing systems, where hot exhaust heats the leading edge. This type of anti-icing system typically consists of a flow of hot air drawn from the engine's compressor stage to heat the leading edge of the aircraft wing. The wing anti-icing system consists of two independent pneumatic systems that exhaust hot air separately from each of the two turbofans. Hot exhaust is introduced from the 5th compressor stage through the engine exhaust valve. Additional bleed from stage 9 of the compressor can be used if the pressure is not sufficient. It should be noted that the exhaust temperatures are around 340°C in the 5th stage and 540°C in the 9th stage, which are too high for use in aircraft pneumatic systems such as hydraulic and potable water systems. The hot air then passes through a precooler to reduce the temperature to 200°C. This cooled air is distributed to loads such as air conditioning and wing anti-icing systems via exhaust ducts. To know when to use the anti-icing system, aircraft pilots use a visual ice indicator in the center bar of the window. When the probe freezes, the pilot turns on the anti-icing system. Therefore, slate numbers 3, 4, and 5 are fed hot exhaust air, as shown in Fig.8.

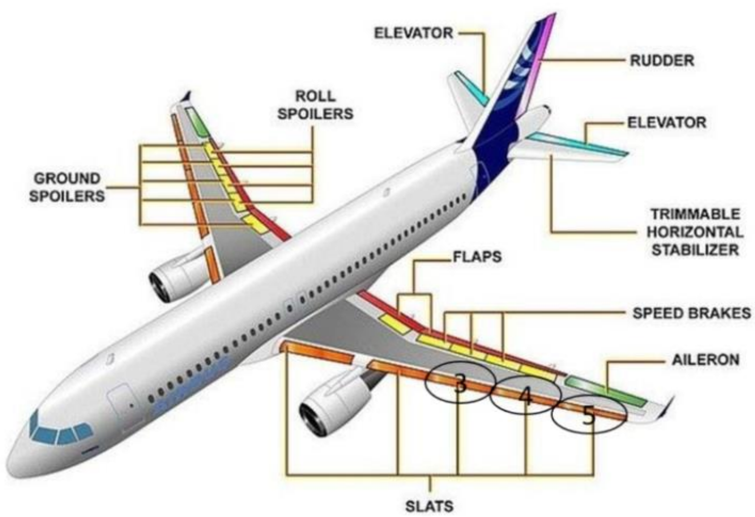

Fig.8 Slate numbers 3, 4, and 5 are fed hot exhaust air

Thermal anti-icing system, electric anti-icing system and water repellent application system will be used to protect against ice and rain.

Cabin windows

The windows on each side of the cabin are equipped with electric heaters to protect against icing and fogging. Heating windows also improves the strength of windows to protect against bird strikes. Air from the air conditioning system can be used to defrost the N1 cabin windows.

Receivers of total static pressure

All absolute and static pressure receivers, TAT receiver and airflow angle sensors are electrically heated to prevent ice formation, which can affect measurement accuracy. Additional static pressure receivers are not heated.

Removal of raindrops

Windshield wipers and water repellent maintain clean areas on the windshield during takeoff, approach, and landing.

Thermal anti-ice of the wing and engine (TAI)

Deicing using the heat of the air taken from the engine prevents the formation of ice on the slats of the leading edge of the wing and the leading edge of the nacelle of the engine

Due to their larger diameter and aerodynamics, the number 1 and 2 slates do not require anti-icing. When the anti-icing system is activated, hot exhaust air is ducted along telescopic tubes and distributed to piccolo tubes. From there it exits the piccolo tube through a small hole, heating the leading edge of the wing and flowing out. Wing through the exit hole on the underside of the wing.

Hot exhaust gases are supplied by a precooler at 50 PSI, 227°C. As previously mentioned, telescopic channels lead liquids to piccolo tubes represented by a series of tubes, chambers, and outlets. For proper modeling, the following procedure was chosen. A relative volume chamber was added to connect the drain hole to the pipe to make it look like a pipe opening.

Regarding the geometric parameters of the piccolo canal, his three tubes with cavities and multiple holes were introduced to simulate the real configuration. Simulating a cavity between the piccolo channel and the leading edge of the wing, the drainage through the holes enters the cavity. The melted exhaust flows along the leading edge of the wing and exits the aircraft along a specific path. Non-eddy convection is added between the piccolo channel and the leading edge of the wing to accurately calculate the heat transfer.

Heat transfer between the leading edge of the wing and the environment is also simulated. The leading edge of the wing alternates between steel and insulating panels. Therefore, conduction heats the first leading edge of the wing and convection with the medium cools the last leading edge of the wing.

The temperature profile of the pneumatic system by the color of the fluid ports (the squares at the ends of each element). Here the heat losses in the expansion tubes and piccolo ducts are not considered, so the maximum heat energy is transferred to the leading edge of the wing (best case scenario, but alternatives can be simulated).

I have observed that the flow within the system is very fast. The air flows rapidly in the pneumatic system, resulting in a large mass flow (0.96 kg/s) for powerful deicing.

Reasonable values were chosen for parts of the system due to the lack of geometric/thermal information. Despite the assumptions and macroscopic approaches used to model the system, the results obtained, including the leading-edge surface temperature required for proper ice melting, are acceptable.

2.3.2 Heating of cabin windows

Cockpit windows: have a sandwich construction

- "vinyl middle layer" avoid loss of P° if glass panes crack - when heat is ON, a constant T° of 40° is maintained

- heating provides ice protection and an optimum stability (in case of "bird strike")

Window Defogging: windshield air from air conditioning system is directed to N. 1 only

Window Heat Control "T° controller" and "overheat protection are provided for N. 1 & 2 - "thermal switches" are provided optionally for N. 3 (fig.9)

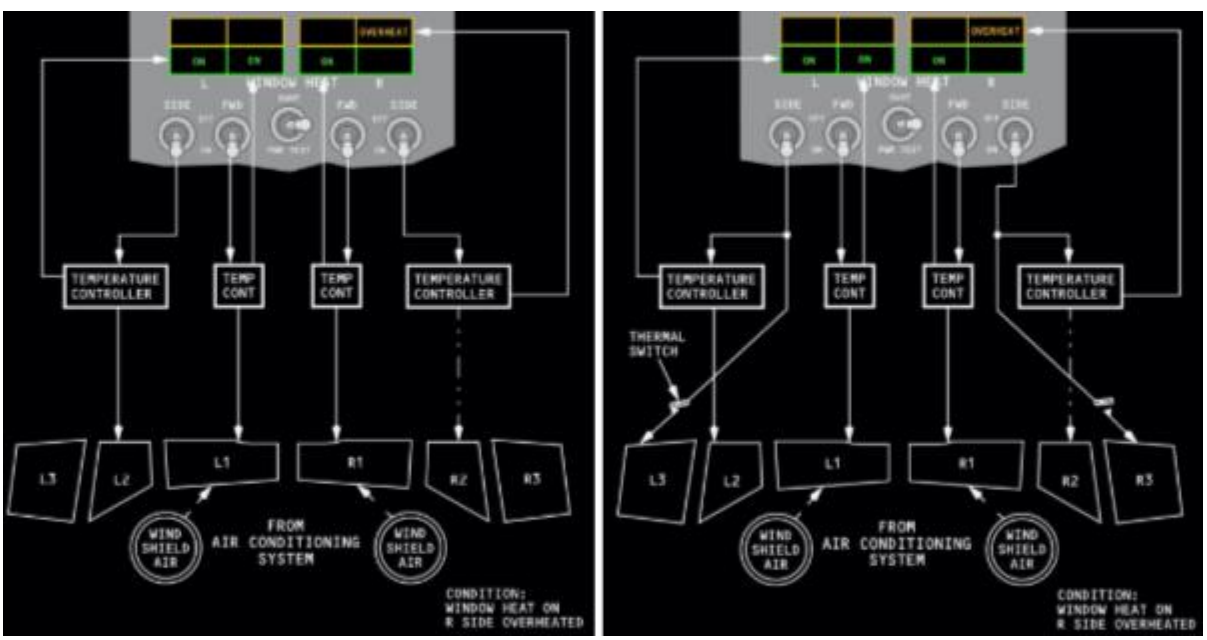

Fig.9 Window Heat Boeing 737

A conductive coating on the outer glass pane of window n. 1 & 2 permits electrical heating to prevent ice and fogging.

While on window n. 3, a conductive coating on the inner glass pane permits electrical heating to prevent fogging or is not electrically heated.

T° controllers maintain window n. 1 & 2 at the correct T° to ensure maximum strength and it automatically removes it if an overheat condition is detected. (Fig. 10) Thermal switches, located on window n. 3, open and close to maintain the correct T°.

Fig. 10 Cockpit Numbers of Windows Boeing 737

Windows L1, L2, R1, and R2 are of sandwich construction, with two tempered glass panes with a heatable vinyl middle layer. The inner pane of these windows is the thicker of the two and is the primary load carrying member. The outer pane provides no structural significance but provides rigidity and a hard, scratch-resistant surface.

Electrically conductive coatings are also installed on the outer panes of the #1 and #2 windows. When power is applied to these coatings, the windows are heated to provide Anti-ice protection. This heat also ensures that fog cannot build up between the glass panes and ensures maximum window strength to protect against bird strikes.

The electrical current is delivered by Temperature Controllers. Turn on the left FWD window heat. The Temperature Controller is now providing current to window L1. The left side FWD Window ON light illuminates whenever current flows to the L1 heater. The green ON light will extinguish when the window temperature reaches the normal operating temperature of 100°F.

Now - both Temperature Controllers are heating the respective Forward windows. It is normal for the ON lights to cycle on/off as the system provides electrical power to maintain the window temperature. You may notice that when one side of the aircraft is in direct sunlight, the associated window heat will not cycle on as often as for the window in the shade.

If a Temperature Controller determines the temperature of a window exceeds 145°F, the current will stop flowing and the OVERHEAT light will come on. The OVERHEAT light will activate the ANTI-ICE annunciator and Master Caution lights.

The ON light remains extinguished since current has stopped flowing to the overheated window. The respective window heat has tripped off and will stay off until the respective switch is reset by the pilot. Note: the OVERHEAT light will also come on if electrical power to the heater is interrupted - whether an overheat has occurred.

To reset an OVERHEAT condition, the pilot must cycle the respective switch to Off, then On. The pilot should wait approximately 2 to 5 minutes for cooling before resetting the Window Heat system. The OVERHEAT reset feature operates for the same for all 4 Window Heat switches. If the Window Heat will not operate - limit airspeed to 250 kts. below 10,000.

In a similar manner, the side window Temperature Controllers provide temperature control for the respective #2 windows.

The cycling ON lights indicates the controllers are cycling as necessary to maintain the #2 window temperature.

Windows #4 and #5 each have a glass pane laminated to the side of a vinyl core. A conductive coating on the inner pane permits heating to prevent window fogging.

The #4 windows have an additional vinyl layer and acrylic sheet laminated to the inside surface.

Temperature control to the #4 and #5 windows is maintained by thermal switches. One thermal switch -on each side - opens and closes to control current flow to both windows #5 and #4 - of the associated side. The #5 thermal switch will close when heat is required. Notice that both windows #5 and #4 are not powered when this thermal switch is open. There are no lights to indicate the operation of the heat applied to windows #4 or #5.

When the SIDE switches are ON, if the Temperature Controller determines that the associated #2 window is too hot, it will trip the system and illuminate the OVERHEAT light. Notice that during an OVERHEAT, the Temperature Controller interrupts power to only the #2 window.

Operationally, the Window heat must be on 10 minutes before takeoff.

The POWER TEST applies full electrical power to all windows, bypassing the automatic temperature control. The Window Heat switches must be ON for this test.

Ensure that not all Window Heat ON lights are illuminated before initiating this test. During the PWR TEST, the ON lights illuminate and OVERHEAT protection remains available. When the PWR TEST position is released, normal operation returns to the Window Heat system.

If the Window Heat TEST switch is moved to the OVHT position, a simulated OVERHEAT will occur. All OVERHEAT lights will illuminate. The ON lights may extinguish immediately or may remain illuminated for as long as 70 seconds. The OVERHEAT condition must be reset by resetting the Window Heat switches.

If window arcing, delamination, shattering, or cracking occurs, the respective Window Heat must be turned off. When a window is damaged, it may be necessary to reduce the cabin differential pressure by changing the aircraft or cabin altitude.

An abnormal procedure identifies the maximum cabin differential with damaged windows.

2.3.3 Engine anti-icing system

Engine Anti-Ice (EAI) heats the hood to prevent the formation of ice that could break off and enter the engine. The 3/4/500 gyro was originally tapered to prevent ice from accumulating but was changed to an ellipse to push the ice away from the engine core. NG has the best of both worlds with a cone camera (pictured left) that does both jobs. The EAI is designed for continuous use on the ground and in the air in freezing conditions. It uses the air coming out from the 5th stage, which is replenished, if necessary, by the 9th stage of the linked engine. The COWL ANTI-ICE light will illuminate if there is a temperature above 440°C (not NG) or a pressure above 65 psig on any channel. In this situation, the relevant engine thrust must be reduced until the light goes out. Engine and wing valve opening lights use light blue/dark blue - valve position for logic mismatch/match.

In particular, the VALVE OPENING L and R lights on the wings may remain green after take-off and during maneuvering. Because it is pneumatically driven, it can be opened with moderate engine thrust. The MAX engine anti-freeze control panel has the new yellow ENGINE ANTI-ICE lettering. When illuminated, indicates that the fume hood defrost system is locked due to a system failure or the engine core defrost valve is not closed. (Fig.11)

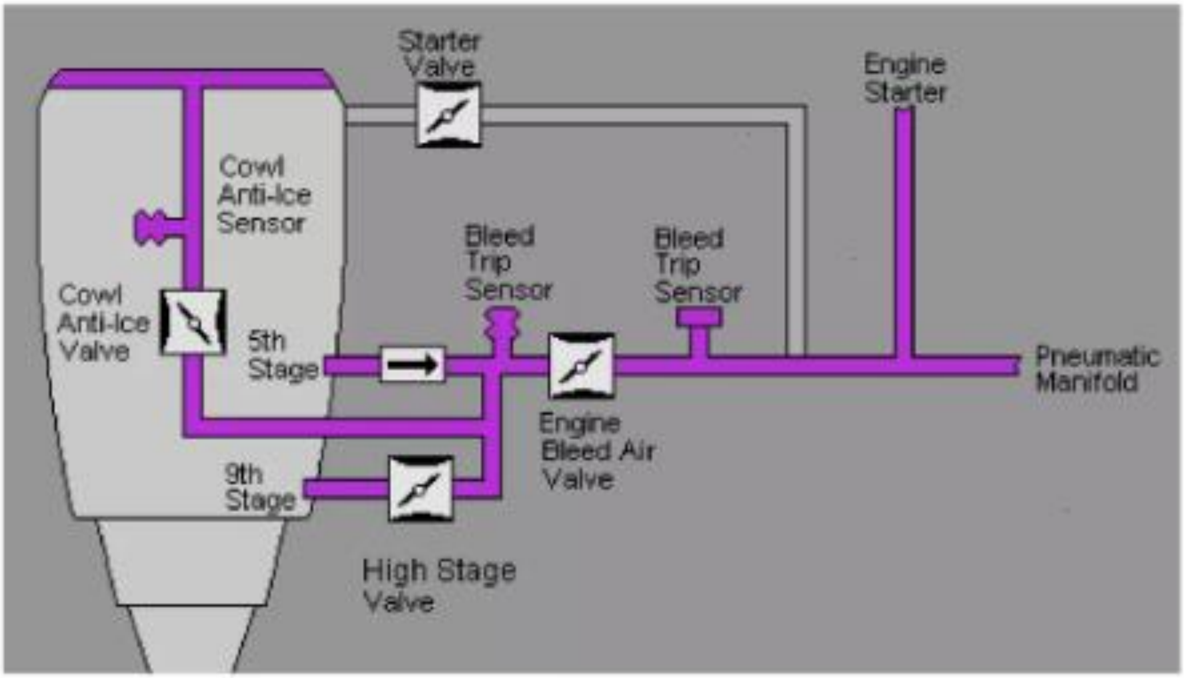

Fig.11 Engine anti-ice system B737

- prevents icing on engine cowl lip

- it is available on ground and in flight

- the required bleed air is extracted upstream of "engine bleed air valve"

- "cowl anti-ice valve" is electrically controlled and pneumatically operated

- "cowl anti-ice sensor" protects engine cowl from over P°

Engine Anti-Ice Panel

1. COWL ANTI-ICE lights

Illuminated when: over P° condition in duct downstream of engine cowl anti-ice valve exists

2. COWL VALVE OPEN lights

Illuminated:

Bright - valve is in transit or disagrees with switch position or bleed P° is insufficient

Dim - valve is open and agrees with switch position

3. ENGINE ANTI-ICE Switches

ON > related cowl anti-ice valve is open + stall warning logic is set for icing conditions

OFF > related cowl anti-ice valve is closed + stall warning logic returns normal if wing anti-icing has not been used in flight

Thermal Anti-Ice Indication

Green - cowl anti-ice valve is open

Amber - cowl anti-ice valve is not in position indicated by related engine anti-ice switch.

2.3.4 Wing anti-icing system

Anti-icing of the wing provides protection of the slats of the leading edge of the wing, using the air taken from the engine, supplied through pipes from the main pipeline of the air intake system. Anti-icing wings do not cover the deflecting socks.

Anti-icing control valves are actuated by AC motors. When the valve is open, the extracted air is fed through the distribution pipe of the wing to the leading edge, through the telescopic pipe to each slat and then outboard. Wing anti-icing is effective at any position of the slats.

On the ground, moving the wing anti-icing switch to the ON position will open both control valves if the thrust on both engines is below the takeoff warning setting and the temperature inside both wing manifolds is less than the thermal relay cut-in temperature.

Both valves are closed if the thrust of one of the engines is above the takeoff warning setting or if one of the thermal switches detects a pipeline overtemperature. The valves automatically open again if the thrust on both engines decreases and both thermal switches cool down. (Fig.12)

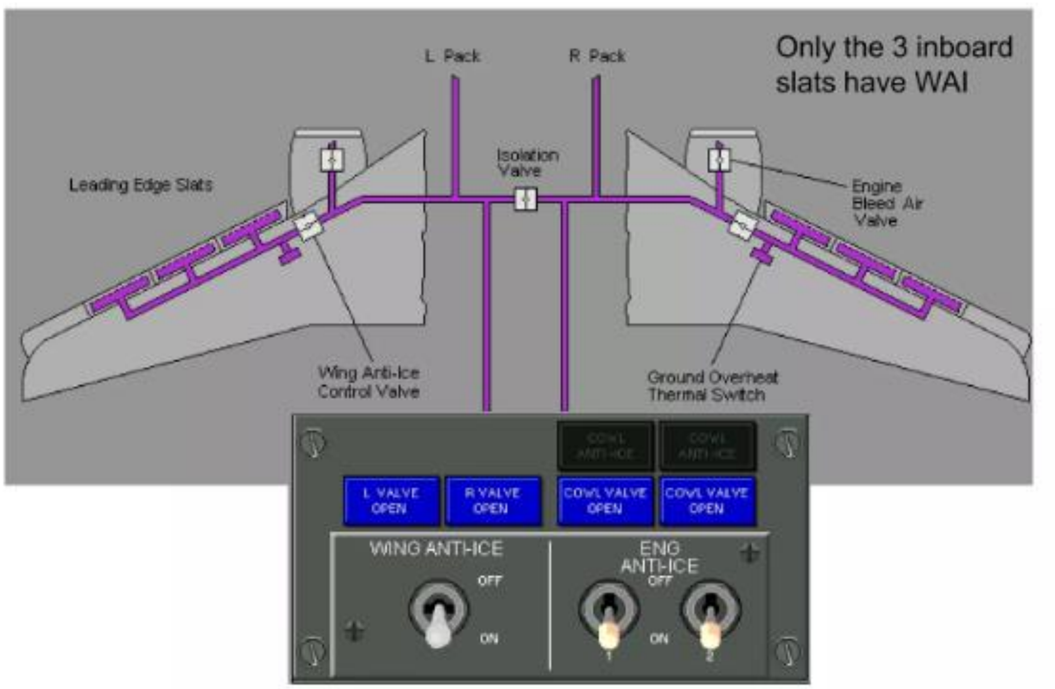

Fig. 12 Wing anti-icing system B737

When the air/ground sensor is in the ground mode and the Anti-icing switch is in the ON position, the switch remains in the ON position regardless of the position of the control valve. The wing anti-icing switch is automatically disabled on takeoff when the air/ground sensor switches to air mode.

In flight, both control valves are open when the wing anti-icing switch is in the ON position. The logic circuit for setting the pipeline temperature and setting the draft is bypassed and does not affect the operation of the control valve in flight. The position of the valve is monitored by the blue VALVE OPEN indicator.

To review: When on the ground, the thrust setting and sensing of thermal switches protects the wing ductwork from over temperature conditions.

Crew indication of this shutdown will be the bright illumination of the VALVE OPEN lights when the Wing Anti-ice switch is ON.

When in flight, the shut off due to thrust setting and thermal switches is bypassed, because the wings will not overheat due to the natural airflow.

What about a takeoff with WING ANTI-ICE selected ON?

Well, as I have learned, the Wing Anti-ice control valves will close when thrust is advanced for takeoff. In addition, the WING ANTI-ICE switch will move to OFF when the aircraft becomes airborne.

If the pilot wants Wing Anti-ice to operate in flight, the WING ANTI-ICE switch must be moved to ON after takeoff; normally after climbing above the obstacle clearance height. Note: Check airline Flight Manual for specific requirements to turn on Wing Anti-ice. Don't operate Wing Anti-ice when the OAT (ground) / TAT (airborne) is above 10°C/50°F. Note: These are the same temperatures that prohibit operation of Engine Anti-ice.

Let's describe non-normal conditions when a wing valve is not in the correct position. A failure of the Wing Valve is identified by a bright blue L or R VALVE OPEN light, which indicates the associated valve position disagrees with the selected switch position.

If the Wing Anti-ice switch is ON and a valve remains closed, the QRH directs the crew to avoid icing conditions, as the associated wing cannot be anti-iced.

If the Wing Anti-ice switch is turned OFF and a valve remains open, the QRH directs the crew that if the TAT is above 10°C and no visible moisture is present, close the Isolation Valve and turn off the associated engine bleed. This action shuts off the supply of bleed air to the associated wing

CHAPTER 3

RESEARCH AND IMPROVEMENT OF BOEING 737 ANTI-ICE

3.1 Theoretical substantiation of the possibility of using anti-icing protection system for the tail section of the Boeing 737.

The formation of a layer of ice on the surface of the aircraft, swept by the air flow, is caused by the presence of water in the atmosphere, which is in a different state.

In one case, ice occurs as a result of settling and freezing on the plane of small drops of water, "floating" in the air and stored in a liquid state at negative temperatures. These droplets of supercooled water form (often together with ice crystals) those forms of clouds that we observe in the cold season. Therefore, icing of this type occurs only when flying in an environment containing supercooled drops in clouds or, for example, in conditions of supercooled rain).

Otherwise, icing is a consequence of sublimation of water vapor contained in the atmosphere, that is, a consequence of its transition directly into ice, bypassing the liquid phase.

Icing at high subsonic flight speeds

The speed of the air flow is directly included in the formula for the intensity of icing. But in addition, as the speed increases, the settling coefficient of the drop E increases, which leads to an even faster growth of ice.

From the theory of a wing moving at subsonic speed, it is known that the flow around a profile in a compressible fluid corresponds to the flow at a greater angle of attack of a thickened profile in an incompressible fluid.

The relative thickness of this fictitious profile $\overline{c_{ф}}$ and its angle of attack are related to the relative thickness of this profile $\overline{c}$ and its angle of attack α by the ratios:

$$\overline{c_{ф}} = \frac{\bar{c}}{\sqrt{1-M^2}}\ , \qquad \alpha_{ф} = \frac{\alpha}{\sqrt{1-M^2}}\ ,$$

where the number M is the ratio of the speed of the air flow to the speed of sound.

Because other things being equal, a thick profile freezes less intensively than a thin one, it follows that the compressibility of air reduces the coefficient of droplet settling.

From this correct position, as a matter of fact, some researchers made the incorrect practical conclusion that the reduction of the subsidence coefficient because of air compressibility can largely compensate for the increase in the intensity of icing with an increase in speed. A comparison of droplet trajectories in a compressible air flow with droplet trajectories in incompressible air showed that the effect of compressibility is relatively small and can be neglected for the solution of many practical problems.

This can be understood as follows: the effect of compressibility on the streamline is perceptible only near the body. For example, for a cylinder at a distance greater than its radius, compressibility no longer affects the streamlines.

On the other hand, the effect of compressibility is practically not manifested for the central part of the streamlines, that is, near the critical point. As a result, drops with great inertia do not have time to change their motion, and thus the influence of air compressibility on their trajectory is very insignificant. Small drops that settle on the body are always located in the central part of the air flow, that is, where the influence of compressibility is also insignificant. Compressibility affects only drops of medium sizes (with medium values of the P parameter). In Fig. 13. the effect of compressibility on the total subsidence coefficient is shown depending on the P parameter for a round cylinder. As can be seen from the figure, E_1 less than E_2 max 3%. For the profile, the reduction of the total droplet settling coefficient due to the compressibility of the air may be slightly larger. However, the local subsidence coefficient near the critical point is practically unaffected by compressibility.

Thus, the compressibility-induced decrease in droplet settling coefficient will not significantly counteract the increase in icing intensity with increasing flight speed.

$$\frac{E_1 - E_2}{E_2}$$

The effect of air compressibility on the total drop settling coefficient depending on the P parameter for a round cylinder.

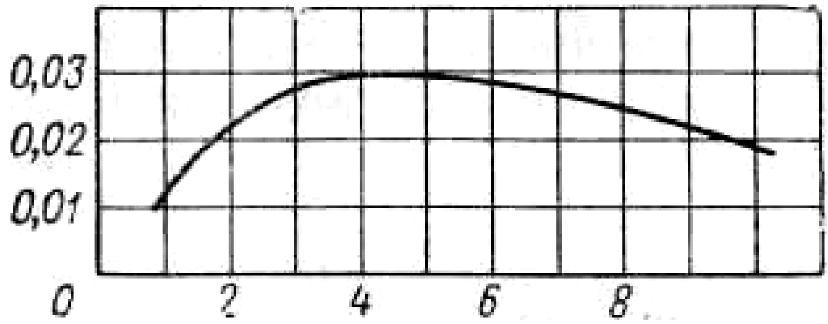

Fig. 13 the effect of compressibility on the total subsidence coefficient

However, when sufficiently high speeds are reached, another phenomenon is observed that prevents further icing.

Let's write the well-known Bernoulli equation for air (considering its compressibility):

$$\frac{V_1^2}{2} + \frac{k}{k-1} \cdot \frac{p_1}{q_1} = \frac{V_2^2}{2} + \frac{k}{k-1} \cdot \frac{p_2}{q_2}$$

Here V_1 V_2 - according to the air speed in some two intersections selected in the air stream.

p_1 p_2 - pressure.

q_1 q_2 - air density in intersections.

$K = c_p/c_v$ - the ratio of the heat capacity of air at constant pressure to its heat capacity at constant volume.

Using the equation of state of the gas in the form p=gqRT (where g is the acceleration of gravity, R is the gas constant, T is the absolute temperature), equation can be transformed into the following form:

$$\frac{V_1^2}{2g}+\frac{k}{k-1}RT_1=\frac{V_2^2}{2g}+\frac{k}{k-1}RT_2$$

or by converting the terms of the equation into heat units

$$A\frac{V_1^2}{2g}+\frac{k}{k-1}ART_1=\frac{V_2^2}{2g}+\frac{k}{k-1}ART_2$$

A - heat equivalent of mechanical work.

It is known from thermodynamics that AR=c_p – c_v , where $\frac{k}{k-1}$AR= $c_{p.}$

Using this relation, equation in its final form

$$T_1+\frac{AV_1^2}{2gc_p}=T_2+\frac{AV_2^2}{2gc_p}$$

Let the first intersection be chosen at a sufficiently large distance from the profile, and the second at its critical point, where the flow is completely decelerated, that is, V2 = 0.

Then: $$T_2-T_1=\frac{AV_1^2}{2gc_p}$$

i.e., with complete braking of the air moving at a speed V, it heats up by the amount $\frac{AV^2}{2gc_p}$ and, therefore, the temperature of the air at the critical point of the profile will be greater than the temperature of the surrounding air (T_1) to the specified value.

The formula that determines the so-called kinetic heating can be simplified by putting appropriate values in it

$$A = \frac{1}{427}\frac{ккал}{кГ \cdot м} \quad ; \quad C_p = 0{,}24\frac{к \cdot кал}{кг \cdot град} \quad i \quad g = 9{,}81 м/сек^2$$

Taking this substitution into account, we get

$$\Delta T = T_2 - T_1 \approx \frac{V_2}{2000}{}^0C$$

As you know, air compression in the absence of heat exchange with the environment (adiabatic compression) is accompanied by an increase in its temperature. In practice, fast air compression processes can be considered quite close to adiabatic ones. Slowing down the flow of air leads to its compression and the associated increase in temperature. It is obvious that at the critical point, where the flow is completely inhibited, the heating of the air will be the greatest. But on the side surface of the profile, where the air speed can exceed the speed of the oncoming undisturbed flow, the air is heated. This is explained by the fact that when flowing around the surface of the body, a thin boundary layer of retarded air is formed, the appearance of which is caused by the forces of viscosity. Since the air speed in the layer immediately adjacent to the body surface is lower than in the more distant layer, internal friction occurs, which leads to the release of heat and an increase in the temperature of the air in the boundary layer.

Thus, with an increase in flight speed, on the one hand, the intensity of icing increases, and on the other hand, kinetic heating of the aircraft surface occurs due to the compression and friction of the oncoming air flow.

It is obvious that if the surface temperature of the aircraft turns out to be positive as a result of heating, the formation of ice does not occur. At one time, it was based on assumptions that icing would not pose a danger to aircraft traveling at speeds of about 700 km/h. However, this turned out to be wrong.

For convenience, it can be easily converted as follows:

$$\Delta T \approx 0{,}38\left(\frac{V}{100}\right)^2,$$

V - aircraft speed in km/h.

It can be seen from this formula that at flight speeds of less than 300 km/h, the heating of the leading edge of the wing will not exceed ~3.5°C.

The formula gives a close to reality value of kinetic heating at the critical point of the profile when flying in so-called "dry" air (behind clouds). In icing conditions, the amount of kinetic heating will be much smaller.

3.2 Calculation of sufficient specific power of the tail anti-icing system of the Boeing 737.

Let's calculate the specific power of the anti-icing system on the horizontal stabilizer and keel of the Boeing 737-300 aircraft.

Let's divide the wheel into four separate heating sections. The average length of the Boeing 737-300 keel heating zone for thermal knives and the cyclic heating zone is approximately 5 meters. Knowing the length of the average chord of the keel is 3.25 m we calculate the surface area of the thermal knives of the keel:

$$S_1 = (0{,}03 \times 5) + (8 \times 2)(3{,}25 \div 100 \times 14) \times 0{,}03 = 0{,}37 \ (\text{м}^2)$$

Let's divide the horizontal stabilizer into six heating sections

The average length of the heating zone of the horizontal stabilizer of the Boeing 737-300 aircraft for thermal knives and the cyclic heating zone is approximately 4.8 meters, knowing the length of the average chord of the horizontal stabilizer of 2.05 m, we will calculate the surface area of the thermal knives of the horizontal stabilizer

$$S_2 = (0{,}03 \times 4{,}8) + (12 \times 2)(2{,}05 \div 100 \times 14) \times 0{,}03 = 0{,}35 \ (\text{м}^2)$$

Since we have two stabilizers, the surface area of the thermal knives of the horizontal stabilizer will be equal to 0.7 (m2).

Then, accordingly, the total surface area of the thermal knives of the tail part of the Boeing 737-300 aircraft will be equal to:

$$S = 0{,}7 + 0{,}37 = 1{,}07 \ (\text{м}^2)$$

The heat transfer coefficient is determined according to the graph, and in this case it should be taken into account that the zone of increased α value is quite narrow, so the average value of the coefficient along the toe should be taken into account, which is of the order of 450 W/(m2 * degree). So, at t0= -50C, the specific power of the considered knife should be approximately 23,000W/m2.

Diagram of the arrangement of heating elements on the tail part of the Boeing 737-300 aircraft. (Fig 14)

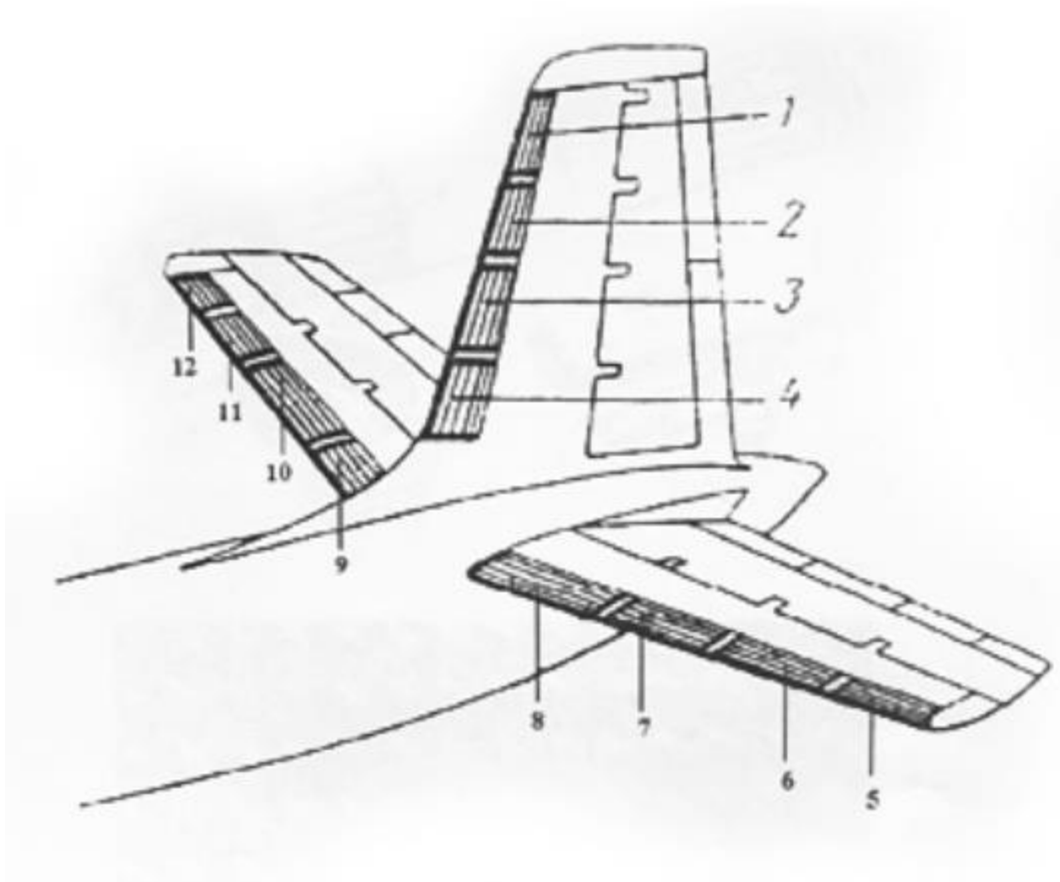

Fig.14 Boeing 737 theoretical Tailplane Heat System

Let's calculate the required amount of energy to power thermal knives. In our case, for the plane Boeing 737-300.

$$P_1 = 23000 \times 1{,}07 = 24610 \text{ (W)}$$

Strips of continuous heating are located along the leading edge of the stabilizer and keel and along the chord at the joints of the cyclic heating sections.

Cyclicity of anti-icing work 1:12. Depending on the icing conditions, you can choose one of two possible cycle options: 10:120 (10 s heating, 120 s cooling) or

20:240 (20 s heating and 240 s cooling). Cycle modes are changed manually using a switch located in the cabin. Thus, one complete cycle occurs every 130 or 260 seconds. The heating elements on the keel are located symmetrically relative to the leading edge: on the stabilizer, due to the negative angle of the stabilizer installation, the zone on the upper surface heats up more than on the lower one.

For our case, the energy consumption of thermal knives and the cyclic system has a ratio of 1:1.18. From this ratio, we can obtain the energy consumption of the cyclic system:

$$P_2 = 24610 \times 1{,}18 = 29040 \text{ (W)}$$

Conclusion: In this section, we performed an approximate calculation of the power required to power the system anti-ice of the Boeing 737-300 tailplane at the two extreme icing points at temperatures of -20 C and -50 C and concluded that the output power of it in minimum mode is sufficient for full power supply of the Boeing 737-300 tailplane anti-ice.

3.3 Boeing Aircraft Innovations with Ground De-icing/Anti-icing Operations

Operators of large commercial aircraft have been using de-icing fluids for many years to ensure that their aircraft can take off and fly safely during winter operations. The basic principles of anti-icing treatment, such as the importance of cleaning the aircraft before the takeoff, remain the same. Recently, new types of anti-freeze fluids have been developed to help operators better deal with contaminants such as sleet, ice and snow. Boeing has reviewed Aircraft

Maintenance Manuals (AMM) and service letters to provide operators with the most up-to-date information about these fluids. Knowledge is essential to understand the properties of new fluids and use them properly.

1. Concept of cleaning an aircraft

Federal Aviation Regulations (FAR) of the US Federal Aviation Administration (FAA) prohibit taking off if frost, ice, or snow has adhered to the aircraft's wings, propellers, or control surfaces. FAR also prohibits take-offs when there is reason to believe that frost, ice or snow will accumulate on the aircraft, unless the operator has an approved ground de-icing program that includes a holding schedule . increase. In addition, the wait time must be supported by data acceptable to the FAA.

The dwell time is generally considered to be the time from application of the de-icing or de-icing fluid to the onset of failure (i.e., when frost, ice, or snow accumulates after both de-icing, de-icing, etc .). The concept of a clean aircraft is important because the performance of an aircraft is based on a clean design. Aircraft are designed to take advantage of the predictable effect of airflow on clean wings. Contaminants such as frost on wings, ice and snow can disrupt this airflow (Figure 1), causing reduced lift, increased drag, increased stall speed and abnormal pitch characteristics. FAA retention time de-icing / anti-icing fluids are an effective means of maintaining the concept of keeping aircraft clean during winter ground icing operations. De-icing, de-icing, or both are required when contamination is detected on the aircraft. De-icing removes contaminants from aircraft surfaces, Society of Automotive Engineers (SAE) type Heated fluids are commonly used for de-icing.

Anti-icing prevents the accumulation of frost, ice or snow on clean aircraft surfaces for a period of time called soak time. SAE Type II, III, or IV fluids are typically thickened for longer retention times than Type I fluids and are used for anti-icing applications. It works best when applied unheated and undiluted to a clean aircraft surface. In Fig. 2 shows how the anti-icing / anti-icing fluid works. The liquid forms a protective layer when applied to a clean surface. This layer has a lower freezing point than frozen sediment and melts on contact with liquids. As the layer this out with molten sediment, it becomes less effective and frozen sediment can build up. The holding time is indicative. Other variables can make the fluid less effective.

These include high winds, jet blast, sleet, heavy rain, airframe surface temperatures below ambient temperature, and direct sunlight. The SAE, Association of European Airlines (AEA), and the International Standards Organization (ISO) publish retention time guidelines for each type of anti-icing fluid. The FAA also publishes SAE exposure time recommendations and approved fluid recommendations for manufacturers. In addition to deicing or de-icing the aircraft, the liquid must be expelled from the aircraft during takeoff and must not unacceptably affect performance.

A fluid manufacturer can ensure acceptable aerodynamic properties by subjecting fluids to the aerodynamic acceptance tests included in his SAE standards. SAE Type III and IV Fluids are a new development. The flow characteristics of Type III fluids are suitable for commuter aircraft whose takeoff speeds are generally greater than 60 knots. Type IV fluid evacuation characteristics must meet the same set of criteria as Type II fluids. These fluids are suitable for large jet transport aircraft with take-off speeds generally above about 100-110 knots.

In order to comply with the clean aircraft concept, the operator should use a deicing / anti-icing system with a holding time long enough to allow safe winter operation with ground icing and acceptable aerodynamics.

2. Industrial deicing/anti-icing fluids standards.

The deicing/anti-icing fluid is designed and manufactured according to industry standards promulgated in the U.S by SAE. The AEA and ISO publishes similar standard. SAE AMS 1424 and 1428 are procurement specifications containing performance requirements for deicing/anti-icing fluids. AMS 1424 applies to SAE Type I fluids and AMS 1428 applies to SAE Types II, III and IV fluids.

These standards include specifications for aerodynamic fluid acceptance testing jointly developed by the American Aerospace Industry Association (AIA) and the European Aerospace Industry Association (AECMA). This test demonstrates that an aircraft ground anti-icing/anti-icing fluid exhibits acceptable aerodynamic drainage characteristics when the fluid is tested according to this standard and meets its acceptance way.

It also said that certain evidence must be provided if the test results are to be used to prove that the liquid complies with acceptable standards. This includes ensuring that the testing facility, associated personnel, and resources meet the requirements of testing procedures. This information must be documented and submitted to an independent accreditation body. An accreditation body certifies the technical adequacy and competence of a test site or facility.

The amount of liquid retention time is important, but the SAE standard does not include a retention time performance specification. Instead, it contains two requirements for anti-icing performance. Water Spray Endurance Test (WSET) and

High Humidity Endurance Test (HHET). These tests are just two of the many weather conditions encountered during winter operations that may have been addressed in the hold time guidelines.

SAE publishes hold time guidelines in SAE ARP 4737. This document provides guidelines for the methods and procedures used to perform maintenance tasks and services required for deicing/anti-icing aircraft on the ground. SAE ARP 4737 does not provide performance specifications or methods for determining hold time guidelines. The data used to determine hold time guidelines is generated by testing programs sponsored by the FAA and Transport Canada.

The data for the hold time guideline is obtained during testing in real winter storms due to the difficulty of simulating snow in the laboratory. Data generated with laboratory tests or helicopter sprayers similar to the WSET and HHET tests. It is reviewed and approved by the SAE G-12 Holdover Time Subcommittee.

3. Improvements for deicing/anti-icing process

SAE has introduced several changes to its deicing/anti-icing fluid standards. Most notable is AMS 1428, the standard for non-Newtonian (pseudoplastic) deicing/anti-icing fluids. SAE Type II and IV fluids meeting this standard are typically used for deicing large jet transport aircraft. This is because, in addition to glycols, these fluids contain thickeners that make them pseudoplastic. The local viscosity of a fluid decreases with increasing load. Fluids that act in this way can be applied to the aircraft in thicker layers than SAE Type I fluids and do not drain from the aircraft immediately in static conditions, resulting in significantly longer retention times. During takeoff, the shear stress on the liquid increases, the viscosity of the liquid decreases, and the liquid flows overboard. AMS 1428 was issued in January 1993. At the time, it only applied to SAE Type II fluids. This included aerodynamic acceptance tests as well as WSET and HHET tests. However, WSET and HHET tests do not include duration. Manufacturers were asked to conduct tests and report times.

Since then, several changes and improvements have affected existing and new fluids:

- Longer retention time.
- Added new fluid types to SAE standard.
- The new standard for fluid removal.
- Solution for drying properties.
- Other new performance standards.

Longer retention time.

In 1994, fluid manufacturers introduced Type II fluids with significantly longer retention times than other available Type II fluids. Including the new fluid's longer retention time in other type II fluids significantly increases the time range for all type II fluids. The extended range may not be representative of the specific Type II fluid being used and may mislead pilots into thinking it is safe to take off when it is unsafe. Laboratory test data showed that his WSET time for the new fluid was up to three times longer than existing Type II fluids, depending on test conditions. Based on this data, the SAE G-12 Retention Time Subcommittee proposed issuing additional retention time guidelines that apply to all Type II liquids at his WSET time of 80 minutes. At the request of the United States, the Air Line Pilots Association changed the new fluid designation to Type IV fluid. This gave the crew confidence that Type IV hold times were being met when using the new anti-icing fluid on the aircraft.

New fluid types in SAE standard.

In October 1996, AMS 1428 was revised to include Type IV liquids. This revision, known as AMS 1428A, contains Type III fluids, relevant appropriate aerodynamic acceptance tests, and WSET and HHET times for Types II, III, and IV fluids (both neat and diluted). It also included minimum requirements. AMS 1428B is a minor revision of AMS 1428A. Certification bodies for wind tunnels that conduct aerodynamic acceptance tests have stipulated that the Performance Assessment Agency will replace AIA. This change was necessary because the wind tunnel needed to be recertified and the AIA Technical Committee that did the original certification no longer existed. After the introduction of the Type IV and AMS 1428A fluid retention time guidelines, fluid manufacturers developed thickened fluids with longer retention times. When these new fluids were submitted for aerodynamic approval and retention time testing, it became clear that the differences between Type IV fluids were greater than those for Type II fluids. It has also been shown that some liquids have unacceptable drying characteristics.

Retention times for Type IV liquids differ significantly from those for Type II liquids due to differences between manufacturers. There is also a large variation in retention times between different liquid concentrations. In some cases, the normally long retention times of diluted Type IV liquids may be shorter than neat Type II liquids (eg, 75:25 or 50:50 mixtures). The SAE G-12 Retention Time Subcommittee addressed this issue by appropriately addressing the SAE Type IV guidelines based on worst case liquids. These guidelines limited the benefits that operators could derive from using Type IV liquids with longer retention times. The SAE G-12 Hold Time Subcommittee approved these hold time data and proposed that the FAA issue manufacturer-specific hold time guidelines if this procedure is currently in use.

The new standard for fluid removal.

Aerodynamic acceptance test criteria for acceptable fluids are based on measured boundary layer displacement thickness (BLDT). This is directly related to lift loss during takeoff. During this test, the amount of liquid remaining at the bottom of the test track is also measured and reported. This process is called liquid removal and reflects the drainage properties of liquids. During the development of Type IV liquids with very long retention times, the liquids met his BLDT criteria but were not excluded from the test section. As a result, liquid removal standards were developed based on Type II liquids with good drainage properties.

Solution for drying properties.

After additional operating experience with Type IV fluids, some operators reported concern that some of these fluids would dry out in cold, dry air. Some manufacturers have withdrawn Type IV fluids with drying properties after observing strippable films and aggregated gels under certain conditions prone to drying. The SAE G-12 Fluids Subcommittee addressed the issue of drying by developing a laboratory test for drying by exposure to cold, dry air.

Other new performance standards.

The Fluids Subcommittee has also revised the thin-film thermal stability test to include pass/fail criteria. This test simulates liquid drying on the leading edge of a heated wing operated on the ground. AMS 1428C, published in October 1998, incorporated liquid removal criteria, testing for drying by exposure to cold, dry air, thermal stability of thin-films, and other changes.

3.3.1 Deicing and Anti-icing Fluid Residues Issue

After I had been doing a little research, I found that even the best innovations come with some problems. Aircraft deicing and anti-icing fluids can leave residue on critical areas of wings and stabilizers. This residue rehydrates the and swells into a gel-like material that can freeze during flight of the and cause limitations in flight control systems. Attention to these residues should therefore be part of regularly scheduled inspection and cleaning processes. Additionally, experience has shown the industry that using a two-stage deicing/anti-icing process can reduce the amount of liquid residue that forms on the wing and stabilizer.

How we already now from the previous chapters, operating an aircraft in winter conditions can be very difficult. Clearly, the removal of ice, frost or snow is a prerequisite for safe aircraft operation. However, the use of thickened deicing/anti-icing fluids to enable takeoff in active snowfall adds another dimension to winter operations. While these fluids have arguably made winter operations safer, they are also known to cause problems and can affect the airworthiness of aircraft. This article provides insight into these issues and how to resolve them. One of the most important consequences of winter operations is the need to apply de-icing and anti-icing fluids to the ground to protect critical areas of the aircraft from being degraded by snow, ice, or frost. When used and applied properly, these fluids keep the aircraft in the approved configuration for takeoff and safe flight.

However, recent events indicate that thickened deicing/anti-icing fluid (Chapter 3.1 - Type II, III, or IV) residue can remain in aerodynamically quiet areas and accumulate over time. Under suitable weather conditions, this residue rehydrates into a gel-like substance that swells many times its original size(Fig. 15). Residual gel can freeze during flight and, if it is in the area of flight control components and connections, can restrict the movement of control surfaces and cause the aircraft to move in one or more flight axes. Controllability problems can occur:

Fig. 15 Residue in gel form on the elevator balance panel of a 737-800 airplane

Therefore, aircraft exposed to deicing/anti-icing fluids should be regularly inspected for liquid residue and any residue found should be removed. Failure to do so may affect the airworthiness of the aircraft. There have been reports of impaired flight control for aircraft operating throughout the European region during the winter months of the last two years. These reports concerned not only small commercial aircraft, but also regional and commuter aircraft. The event has occurred on both types of aircraft, those with hydraulically-powered flight control systems and those with non-hydraulically-powered flight control systems. This phenomenon is more prevalent in smaller aircraft, as severe winter weather conditions can subject small and medium aircraft to more fluid handling each day, increasing the likelihood of anti-icing fluid residue build-up.

Therefore, all handlers/opetarors should understand that providing the aircraft handling to clean the snow and ice on the wings and stabilizers and treating it with deicing/anti-icing fluids is not enough to keep aircraft safe for today's winter operations. Is important to understand.

However, I would argue that inspections to remove deicing/anti-icing residue in hidden locations on the wings and stabilizers need to be better organized.

It is also important that operators and/or their service providers take steps to ensure that all deicing/anti-icing fluids are properly stored and handled according to the fluid manufacturer's recommendations. Improper storage and use can result in poor fluid performance or use of large amounts of fluid, causing more residue to form. For example, if the liquid is sprayed from the back of the wing instead of the front, which is the correct method, more liquid may enter the flight control area through the air vent gaps on the control surfaces.

Nevertheless, statistics shows that Europe has more problems with deicing/anti-icing fluid residue than North America and Asia. Industry experts agree that one reason for this is different deicing and anti-icing practices across continents. A one-stage deicing/anti-icing process is commonly used in Europe. This process uses a heated mixture of Type II fluid and water, typically in a 75/25 ratio, to apply the deicing/anti-icing fluid in one application. A two-step process is commonly used in North America. This process involves de-icing with a Type I heated liquid or a mixture of heated Type I liquid and water, followed by the application of a Type IV anti-icing liquid. Type I helps remove residue from previous anti-icing liquid treatments.

3.3.2 Recommendations for cleaning and inspection of the Boeing 737 for the fluid residues.

Boeing issued a service letter in January 2000 notifying operators of possible deicing/anti-icing fluid residue problems. At the time, the service letter cited new warnings added to the Society of Automotive Engineers (SAE) Aerospace Recommended Practice (ARP) 4737 method document. This notice was also included in the cold weather section of the Airplane Maintenance Manual (AMM) of the time. New service letters have been issued for some models, providing information on where to check for residues and updated cleaning residue procedures. The service letter also includes revisions to the AMM and provides detailed information on where to look for residual fluid. Service letters and revisions to the AMM recommend that all aircraft exposed to deicing/anti-icing fluids during winter operations follow the inspection and cleaning procedures outlined below. The frequency of inspections should be based on each operator's experience in winter operations. Boeing recommends that all aircraft exposed to deicing/anti-icing fluid undergo inspection and cleaning procedures before and at the end of the winter season. Boeing also recommends inspecting and cleaning all aircraft at least once a month during the winter months. This frequency is based on input from operators who have experienced multiple flight control issues with deicing/anti-icing fluid residue. Some operators conduct inspections much more frequently than once a month, and Boeing plans to conduct inspections as frequently as possible until enough data is collected to more precisely define the inspection period. Operators are advised to carry out inspections.

So here is the Boeing recommends the following inspections and cleanings: 1. Access the following areas where flight controllers and other system components are located:

- The wing spar, including the actuating components of the spoilers, ailerons, flaps, flaperons, as well as the control surface hinges and trim compartments.

- Wing leading edge devices, including executive components.
- Rear horizontal stabilizer spar including actuating elements for elevators, elevator tabs and controls surface loops and balancing bays.
- Vertical stabilizer including drive rudder and steering components surface loops.
- APU compartment and hold tail cone

2. Visually inspect these areas for dried or rehydrated debris. The residue can be very difficult to see, especially if it's dry. The dried residue is usually a thin film partially covered with dirt and grease. Rehydration residue is often a more visible thick gel-like substance.
3. Spray a fine mist of warm water on the area to rehydrate the residue and make it easier to identify. In some cases, rehydration can occur quickly, but the process is often slowed down, especially if residue builds up from multiple uses over an extended period of time. Wait at least 15 minutes.
4. If no rehydration residue is seen, repeat this procedure at least 3 more times, including waiting 15 minutes to allow rehydration to occur if possible. This recommendation of repeated spraying and waiting for rehydration is based on the experience of several operators during the last two winter months. Do not spray the controls with water when the ambient temperature is below freezing unless the aircraft is in a heated hangar. This can cause ice buildup and affect flight control.

5. If any residue is found, remove it with warm water using a rag or soft brush and remove the gel-like substance by hand. A low pressure water jet or compressed air can also be used to flush out residue. Do not allow water or compressed air to push residue into inaccessible crevices. Research and experience have shown that using a Type I de-icing fluid or a mixture of water and a Type I is also an excellent

cleaning agent for removing residue. Test data show that using detergent additives with water can actually reduce cleaning effectiveness.

6. This cleaning process removes grease from control system bearings and fittings and may remove corrosion inhibitors from control cables. Care should be taken not to spray cleaning solutions on bearings, fittings, control cables and electrical connections. During the cleaning process, residues can also flow into other areas where they can settle and cause future problems. Attention must be paid to the flow of the cleaning process to other areas of the aircraft, and these areas are also flushed until the operator is satisfied that all de-icing/anti-icing fluid residue has been completely removed from the aircraft. is needed. As with the inspection phase, do not splash water on the controls when the ambient temperature is below freezing unless the aircraft is in a heated hangar. This can cause ice buildup and affect flight control.

7. Boeing recommends re-lubricating all bearings, fittings, and control cables in the cleaned area per the appropriate AMM instructions.

8. All areas whose corrosion inhibiting compounds have been removed or depleted by the residue cleaning process should be reworked following proper manual procedures for standard overhaul operations.

I consider that during winter, Boeing 737 and moreover each aircraft should be inspected and cleaned every two weeks. This frequency is based on input from operators who have experienced multiple flight control issues with deicing/anti-icing fluid residue. Some operators conduct inspections much more frequently than the two weeks, and Boeing plans to conduct inspections as frequently as possible until enough data is collected to more precisely define the inspection period. Operators are advised to carry out inspections. Furthermore, any operators' experiences with several different aircraft models have shown which rehydrates and swells into a gel-like substance that can compromise aircraft flight control.

It has been shown to have the potential to adversely affect aircraft flight control systems. Failure to remove these residues on a regular basis can adversely affect aircraft performance. Therefore, these considerations should be part of the airline's winter operations: Understand the frequency of deicing/defrosting the aircraft; Make sure personnel following the correct procedures when accompanied by airline staff or a third party; Is the fluid properly stored, handled, and applied; establish a schedule for inspection and cleaning of residual anti-icing/anti-icing fluid to ensure there are no flight control restrictions; include the use of necessary lubricants and anticorrosive where residues have been removed.

CHAPTER 4

OCCUPATIONAL SAFETY AND HEALTH

Labor protection of workers is gaining more and more importance nowadays. This is expressed by increasing production efficiency, implementing measures aimed at preserving human health and working capacity, improving the use of basic production assets, and reducing the number of accidents.

The main legislative acts defining the main provisions on labor protection are the Constitution of Ukraine, the Code of Labor Laws, the Law of Ukraine "On Labor Protection", the Law of Ukraine "On Ensuring Sanitary and Epidemic Welfare of the Population", the Law of Ukraine "On Fire Safety", the Law of Ukraine "On mandatory state social insurance against industrial accidents and occupational diseases that caused the loss of working capacity" and state inter-industry and industry regulations on labor protection.

A modern airline is an enterprise with wide and versatile functions. Among its tasks are both the transportation of passengers and cargo, as well as the repair and maintenance of aircraft, for which not only aircraft are used, but also auxiliary means - ground structures, runways, aviation and technical bases (ATB), ground vehicles, repair and technological equipment, etc. The operation of aircraft and ground-based means of flight support is associated with the influence of dangerous and harmful production factors that negatively affect the health of engineering and technical workers of aviation enterprises.

DSTU 2293:2014 (National Standard of Ukraine) "Labor protection. Terms and definitions of basic concepts" Terms and definitions" terms and definitions of the main concepts of labor protection are established. Here are the main ones:

Labor protection is a system of legal, socio-economic, organizational-technical, hygienic or medical-prophylactic measures and means aimed at preserving the health and working capacity of a person in the process of work.

A dangerous (production) factor is a production factor, the influence of which in certain conditions can lead to injuries or other sudden deterioration of the health of the employee.

Harmful (production) factor – a production factor, the influence of which can lead to a deterioration of the state of health, a decrease in the working capacity of an employee.

Working conditions are a set of factors of the production environment that affect the health and working capacity of a person during his professional activity.

Safe working conditions: occupational safety - a state of working conditions under which the influence of dangerous and harmful production factors on the worker is eliminated, or the influence of harmful production factors does not exceed the maximum permissible values.

4.1. List of dangerous and harmful production factors.

According to DSTU 7238:2011 "System of occupational safety standards. Means of collective protection of workers. General requirements and classification". This standard applies to means of collective protection of workers (hereinafter referred to as means of collective protection), which are used to prevent or reduce exposure to working hazards (dangerous and harmful production factors), and establishes general requirements, safety requirements and classification of these means. They include:

- movable and folding covers and panels of distribution devices, switching and other equipment, as well as movable panels of network protection machines and dashboards.
- protruding elements of automatic machine structures, etc. switching devices.
- sharp edges of the equipment and the ends of the counter wire.
- the presence of sources of electrical voltage greater than 42 V alternating and direct currents, which can form a closed electrical circuit through the body of a person servicing the equipment.
- chemical reagents used in equipment maintenance.
- increased temperature in the working area of some parts of the equipment (up to 75°C).
- absence or insufficient industrial lighting during equipment maintenance.
- psychological stress (human factor), etc.

Technical maintenance of the electricity supply system of L.A. associated with the possibility of receiving physical injuries (stuck places, cuts, etc.), as well as electric shock.

When passing through the human body (depending on the flow path), electric current can cause damage to vital human organs or an electric shock - the result of the process of inhibition of the nervous system due to numerous irritations of nerve endings. This can cause cardiac arrest or cessation of breathing, even if the heart or respiratory organs are not in the path of the electrical current.

The use of organic solvents for cleaning the surfaces of the unit (from organic and inorganic contaminants) or careless handling of them can cause poisoning of the service personnel (in case of ingestion of e.g., TTN-95, Sky droll).

Heated parts of the equipment can cause burns when in contact with them, as well as long-term stay of personnel in the immediate vicinity may cause metabolic disorders and deterioration of the general state of health.

Inadequate industrial lighting (less than 300 lux) leads to increased injuries and excessive strain on the visual organs. At the same time, the quality of the performed work deteriorates, the psychological load increases, and fatigue occurs.

Prolonged work in a room with high air temperature (more than 25oC) causes a violation of salt metabolism in the body and can lead to diseases of the kidneys, stomach and nervous system. In the working zone, DSTU B A.3.2-12:2009 "System of labor safety standards. Ventilation systems. General requirements" This standard establishes general requirements for ventilation, air conditioning and air heating systems of industrial, administrative and public buildings and structures (hereinafter referred to as ventilation systems). The standard does not establish requirements for ventilation systems of underground and open mining, subways, vehicles, unique buildings and structures of special purpose, buildings and premises in which explosive substances and means of landing are produced, stored or used, as well as for systems used in technological processes and to pneumatic transport.

Furthermore, Potential Health Effects of Aircraft Deicing Fluid Concentrate Eye Contact: May cause slight temporary eye irritation. Corneal injury is unlikely. Skin Contact: Prolonged contact is essentially nonirritating to skin. Repeated contact may cause flaking and softening of skin. Material may be handled at elevated temperatures; contact with heated material may cause thermal burns. Skin

Absorption: Prolonged skin contact is unlikely to result in absorption of harmful amounts. Inhalation: At room temperature, exposure to vapor is minimal due to low volatility; vapor from heated material or mist may cause respiratory irritation and other effects. Ingestion: Very low toxicity if swallowed. Harmful effects not anticipated from swallowing small amounts. Effects of Repeated Exposure: In rare cases, repeated excessive exposure to propylene glycol may cause central nervous system effects.

Stability/Instability Thermally stable at recommended temperatures and pressures. Conditions to Avoid: Some ingredients in this product may decompose at elevated temperatures. Gas evolution during decomposition can lead to overpressure in closed systems. Incompatible materials: Avoid contact with: Strong acids. strong base. A strong oxidizing agent. Hazardous polymerization will not occur. Thermal decomposition products depend on temperature, air supply, and the presence of other substances. Decomposition products may include but are not limited to ether. alcohol. organic acid.

4.2. Organizational and technical measures and tests for the exclusion or reduction of dangerous and harmful production factors.

Anti-Icing Fluid is used for deicing light commercial aircraft on a variety of platforms. This flammable liquid, composed of 85% ethylene glycol, 10% water, and 5% isopropyl alcohol, raises questions about its potential hazards. These hazards include, but are not limited to, heating small puddles of spilled or leaking liquid, dripping liquid onto hot surfaces, and contact of liquid mist with sources of ignition. It will not be. A simple test was performed to demonstrate the more basic properties of the flammability of anti-icing fluids. These tests were (1) Flash Point Test, (2) Hot Flammability Test, (3) Hot Surface Ignition Test, and (4) Spray Flammability Test. Anti-icing fluid is expected to be highly flammable under certain conditions. The ignition temperature is known to be around 150°F, but the liquid releases little energy during the reaction. The liquid will burn when heated in a pan to approximately 250°F and exposed to an ignition source, but at a relatively low temperature. Dropping a liquid on a hot surface won't react, but in an enclosed space he may perform relatively well if heated above 750°F (approximate self-ignition temperature). When exposed to a flame, the liquid will burn as a mist at ambient temperature and pressure but will not react when the ignition source is removed.

1. *Flash Point Test*

When flash point testing of anti-icing fluids is performed according to ASTM D 56-87 standards using a Tag Closed Cup Flash Point Tester, a response is observed between 140°F and 150°F, which is standard. This reaction consisted of a small but distinct blue flame that immediately appeared in the tester's observation window. Alcohols generally have low flash points, but this low reaction temperature was unexpected given that the mixture was only 5% isopropyl alcohol. No blue flame was observed when the test was continued at higher temperatures, but when testing the flash, the smoke consistently extinguished the test flame. The fluid was further heated to about 250°F. At approximately 240° F., the cup tester held the flame on the tester when the test flame was applied and continued to hold the flame when applied for the remainder of the test. No violent reactions (puffs or pops from the tester) were observed. This test was performed three times at 140°-150°F with flames observed in one test. His two other tests showed the same potentially fast response behavior at about 140°-150°F, and no blue flame was observed.

2. Hot-pan flammability test.

A 2-foot by 2-foot pan of anti-icing fluid was sufficiently heated from below with a propane torch and exposed to an ignition source, resulting in a pool fire. On two separate occasions when the liquid was between 250°F and 260°F, self-sustaining faint blue flames were initiated on the liquid. On one occasion, this fire was started by a spark source an inch or two above the liquid level in the pan. The second time, the pot started to fire without producing a spark. A review of the video showed that the fire was caused by stray flames from a propane torch. This flame had large plumes of flame that sometimes engulfed the pot. In both cases where the heat source and spark were removed, the fire was self-sustaining and showed no signs of self-extinguishing or diminishing. Fig.16 reproduces the temperatures measured in the second test and clearly shows the 250°F liquid temperature at which the pan ignited, indicated by a rapid rise in vapor temperature. Fig.16 also shows the relatively low temperature at which the liquid burned. The highest temperature observed (12 inches above the liquid) was about 600°F. Also, in both cases, sparks were applied at slightly lower temperatures (approximately 240°F), but no fire or flame was observed. The fire was extinguished with copious amounts of carbon dioxide. Note that if the pot temperature is still above 260°F and the heat source is removed, the spark will not re-ignite the pot for 1 minute after the fire has been extinguished.

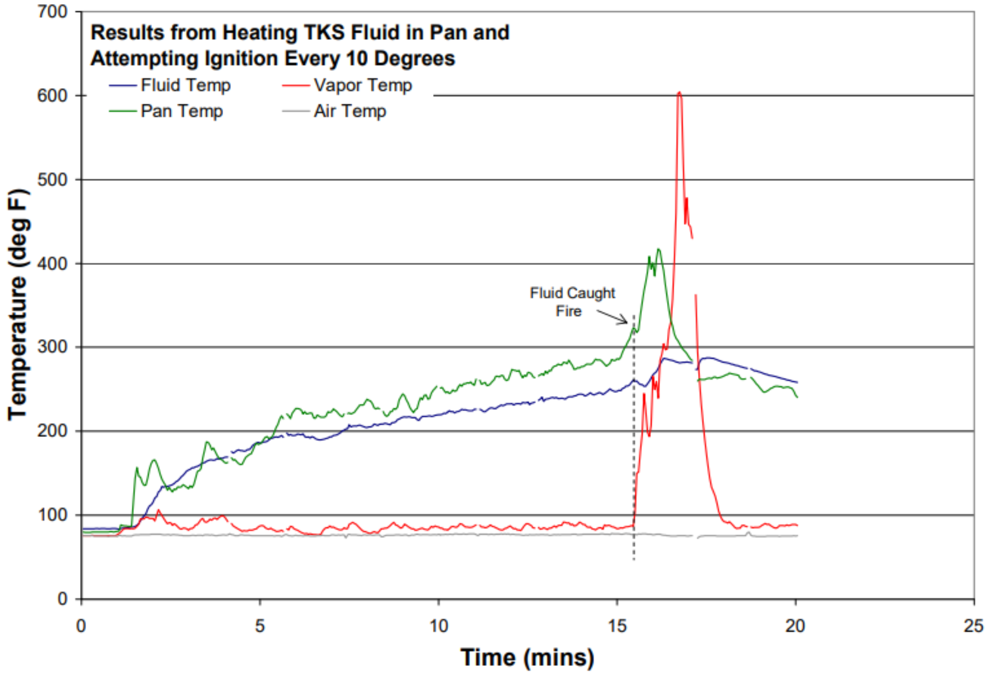

***Fig.16** Measured Temperatures Obtained from Heating a Pan of TKS Anti-Icing Fluid*

3. Hot-surface ignition.

Ignition on hot surfaces. No flame or reaction was observed when a small amount of anti-icing fluid was dripped onto the surface of the hot plate. The platen temperature varied from 250°F to 700°F. The plate temperature was 700°F and the flow rate was varied from a slow drip to a small steady stream. The liquid generally vaporized on contact, but no fire or flame was observed. When high flow rates are used with platen temperatures above 600°F, a small amount of liquid under the heater plate pools under the radiant heaters in the burner assembly, eventually producing an underplate reaction accompanied by pressure waves and blue flames. will be front (pop). This indicates a relatively low self-ignition temperature (reported at 750°F) typical of all alcohols and glycols and no evidence of ignition on hot surfaces. This is expected as the temperature under the slab he likely is over 750°F.

4. Spray Flammability Test

Sprayed as a fine mist under pressures of 20 PSIG and 40 PSIG, the anti-icing fluid reacted when exposed to direct flame and began burning with an orange flame. Responses from flares consistently occurred when the flares were applied at various distances from the spray nozzle but did not always occur when the flares encountered the mist. The mist did not continue to burn when the burner was removed, and no flame front returned to the nozzle regardless of the pressure or distance the burner was applied. Using a spark as the ignition source, the liquid ignited sporadically, but only when the spark was placed in a small area near the center of the spray at the high-pressure spray setting.

4.3. Organizational and technical measures for fire and explosion safety.

According to DSTU 8828:2019 "Fire safety. Terms" is the condition of an object in which the possibility of the occurrence and development of a fire is excluded with the established probability, and in the event of its occurrence, the influence of dangerous fire factors on people is prevented and the protection of material values is ensured, explosion safety - the state of the production process, in which the possibility of an explosion is excluded or, in the event of its occurrence, the influence of dangerous and harmful factors.

To prevent the possibility of a fire on the device being designed, the following measures have been taken:

- the cross-section of the wires of the generator windings, power wires of the generator and other used wires is selected considering the permissible current density through them and laid with appropriate thermal insulation from the heated parts of the engines.

- all materials of windings, magnetic system, electrodes, insulators are non-flammable or non-flammable.

- in order to eliminate overheating and maintain the normal thermal mode of operation of the windings of the generator and the magnetic circuit, their liquid cooling is used.

– protection of the generator and electrical circuits powered by it from short circuits and overloads, which prevents fire, is carried out with the help of the equipment for regulating the protection and control of the direct current SEP.

- the aircraft must be securely grounded while in the parking lot or in the hangar.

The aircraft parking area must be equipped with fire-fighting equipment:

- at least one mobile carbon dioxide installation per aircraft.

- manual carbon dioxide fire extinguishers at the rate of at least one per aircraft.

– boxes with sand and a shovel, as well as metal boxes with a lid for collecting garbage and used rags.

- it is forbidden to use fire-fighting equipment for other purposes.

In the event of a fire, clear cooperation of the engineering and technical staff is necessary.

To eliminate the fire, the following measures must be taken:

- immediately notify the fire department about the place and source of the fire.

- organize the evacuation of people and valuable equipment from the site of the fire.

- organize fire extinguishing with all available means.

When the power is on, you can use fire extinguishing agents that have fire-extinguishing substances that do not conduct electric current (carbon dioxide, powder, inert gases). These are fire extinguishers of types ОЧ-2, ОЧ-5, ОЧ-8, ОЧВ-3, ОЧВ-7, UP-1M, UP-2M. To eliminate a fire on the generator on the ground, it is possible to activate the engine fire extinguishing system from the crew cabin or chassis compartment.

Extinguishing Media: To extinguish combustible residues of this product use water fog, carbon dioxide, dry chemical or foam.

Fire Fighting Procedures: Keep people away. Isolate fire and deny unnecessary entry. Use water spray to cool fire exposed containers and fire affected zone until fire is out and danger of reignition has passed. To extinguish combustible residues of this product use water fog, carbon dioxide, dry chemical or foam.

Special Protective Equipment for Firefighters: Wear positive-pressure self-contained breathing apparatus (SCBA) and protective firefighting clothing (includes firefighting helmet, coat, trousers, boots, and gloves). If protective equipment is not available or not used, fight fire from a protected location or safe distance.

Unusual Fire and Explosion Hazards: This material will not burn until the water has evaporated. Residue can burn.

Hazardous Combustion Products: Under fire conditions some components of this product may decompose. The smoke may contain unidentified toxic and/or irritating compounds.

4.4 Instruction on safety, fire and explosion hazards.

4.4.1 *Terms.*

Specially trained and instructed personnel no younger than 18 years of age who have studied the design and principle of operation of individual nodes and the entire system, and who have passed an exam on knowledge of safety and fire safety requirements when servicing the facility, are allowed to work on system maintenance.

This instruction is used when performing maintenance work on the power supply system. A high voltage of 200-115 V alternating current is present in the SEP, which is transmitted through it to the devices.

Trained personnel who have the necessary skills and are in good health, who have passed all the briefings and passed the necessary exams, are allowed to work.

The work is carried out by a team of at least 2 workers, one of whom is appointed to be responsible for the execution of the work and is responsible for the correctness and completeness of the work performed.

Dangerous factors during work are high voltage, moving and rotating unfenced parts of mechanisms.

Personnel must be provided with the necessary overalls - cotton suit and shoes - glue-based boots annually, cotton gloves as needed. Personal hygiene requirements are met by employees themselves. Personnel wearing heavily soiled overalls or shoes are not allowed to work.

4.4.2 *Safety requirements before starting work*

Check the availability and serviceability of tools and devices. Receive tasks for the implementation of works (if necessary, from the operator or the responsible employee), agree on actions to maintain the device.

Make sure that all preparatory operations are done (the necessary mechanisms are locked in the appropriate positions, the necessary parts of the equipment are de-energized). Having received permission to start work.

Personal Protection. Equipment Eye/Face Protection: Use safety goggles (with side shields). When working with hot substances: Use chemical goggles. If droplets are likely, wear a face shield that can use chemical goggles or wear a full-face respirator to protect your face and eyes. An eyewash should be placed in the immediate work area. Skin Protection: Wear clean clothing that covers your body. Protect skin from burns when handling hot materials. Selecting a specific item depends on the operation. An emergency shower should be in the work area when working with hot materials. Hand Protection: For prolonged or frequent contact with this material, use chemical resistant gloves. Use insulating gloves if necessary. Examples of preferred barrier materials for gloves include butyl rubber. natural rubber (“latex”); neoprene. Nitrile/Butadiene Rubber ("Nitrile" or "NBR"). polyethylene Ethyl Vinyl Alcohol Laminate (“EVAL”). Polyvinyl chloride (“PVC” or “vinyl”). Avoid gloves made of: Polyvinyl alcohol (“PVA”). NOTE: When choosing a particular glove for a particular application and duration of use in the workplace, consider manual dexterity, thermal protection), potential for bodily reactions to the glove material, and the glove supplier's instructions/specifications. and all relevant workplace factors must also be considered. Respiratory Protection: Air levels should be kept below exposure guidelines. Use an approved air-purifying respirator when exposure guidelines and/or airborne comfort levels may be exceeded. The following types of air purifying respirators should be of an effective type: organic vapor cartridges with particulate prefilters. Ingestion: Observe good personal hygiene. Do not eat or store food in the work area. Wash your hands before smoking or eating.

4.4.3 *Safety requirements during work performance.*

Use tools only for their intended purpose. Be especially careful when working in places with limited visibility, as well as when working with heating devices and combustible or flammable liquids.

Do not clutter the technological passages with rags, insulation or other materials, do not install unnecessary temporary equipment for a test run in them. Timely pick up leftover wires, faulty equipment parts from the workplace.

Work with the use of personal protective equipment (special clothing, special shoes). When working in parts of the power supply unit under voltage, use dielectric gloves, a tool with insulating handles.

If the nature of the necessary operations is found to be inconsistent with the received task for the implementation of the works, the work must be stopped and the person responsible for the implementation of the works, as well as the operational employee, should be informed about it. Engineering Controls

Ventilation: Use local exhaust ventilation or other engineering controls to maintain airborne concentrations below exposure limit requirements or guidelines. In the absence of applicable exposure limits or guidelines, general ventilation is sufficient for most operations. Local exhaust ventilation may be required for some operations.

4.4.4 ***Safety requirements at the end of the work.***

At the end of the work, clean up the workplace, vacate the storage areas occupied for temporary storage of materials. Assemble the installation to its original position. If a trial run is necessary, it is allowed not to close the doors of the cabinets or the lids of the units, using the provided blocking shutdowns to produce the necessary works under the supervision of the person responsible for the execution of the works. At the end of the debugging work, turn off the equipment and report the results to the person responsible for the work.

After the test run, bring the parts of the equipment to their initial position before switching on.

Pick up the team from the work site, make sure that all team members are present.

Notify the responsible and operative personnel about the end of the work, as well as all comments on the work and information about the condition of the equipment received during the work.

4.4.5 ***Requirements in emergency situations.***

In the event of an accident, fire or discovery of new malfunctions of the repaired equipment, notify the person responsible for the work and the operational worker.

Care should be taken when moving loads or heavy pieces of equipment, as well as when working with heating devices. To prevent the occurrence of fire, do not allow significant heating of equipment parts without the possibility of heat dissipation (due to ventilation or not allowing overheating of more than 100 °C), work with flammable or flammable liquids only in the presence of ventilation or carry out relevant operations in the open air.

In the event of a fire, turn off the power to the equipment, notify the person in charge of the work and follow the instructions of the person in charge of the work, if necessary, call the fire brigade, and begin to contain the fire before its arrival.

If there are victims, provide them with appropriate first aid. If it is impossible to extinguish the fire on the spot, proceed to localization of the fire with improvised means.

At the end the issue of labor protection is one of the most important at the current stage of the life of our society, in a period when employers set themselves the main task - to extract the largest amount of profit as quickly as possible and with a minimum investment of funds and taking advantage of the recent shortage of jobs in the country, little attention is paid allocate, and sometimes even ignore the requirements of labor safety.

Also, tests have also confirmed that anti-Icing Fluid is expected to be flammable under appropriate conditions. Although the flash point of the liquid is much higher than stated on the safety data sheet, it is still relatively low (~150°F), and the reaction appears to release little energy. The liquid will burn when heated in a pan to approximately 250°F and exposed to an ignition source, but at a relatively low temperature. It does not react when liquid is dropped on a hot surface but can exhibit relatively violent properties when heated above 750°F (approximate autoignition temperature) in a confined space. Liquid mist will burn at ambient temperature and pressure but will not react when the ignition source is removed. Only sporadic ignitions (no fireballs) were observed when the nebula was spark-ignited, and these were confined to small nebulae near the center of the spray.

The increase in the number of occupational diseases, accidents at work, which lead to injuries, and sometimes to the death of people, all this makes us think about the perfection of our legislation in the field of labor protection. One of the directions of the state's activity to improve the situation in the field of labor protection is the expansion of the use of local norms, which allows the labor protection features of a particular enterprise to be reflected in collective and labor agreements.

CHAPTER 5
ENVIRONMENTAL PROTECTION

Since aircraft de-icing and anti-icing fluids and pavement agents are commonly used in very open and exposed outdoor environments, its dispersion begins immediately after application. Aircraft Deicing and Anti-icing Fluid (ADF) is usually applied to aircraft at specific airport locations. These locations vary by airport and may include a boarding area, apron or de-icing area. The ADF is designed to drip and cut off the plane's surface after application to avoid affecting the aircraft's lift during take-off. Type I exits the aircraft relatively quickly. Most of these fluids fall into the roadway at fluid application sites. The rest drips or cuts from planes as they move through the airport, mostly falling onto sidewalks and other airport surfaces. Type IV fluids are designed to stay on aircraft surfaces for a longer period than Type I fluids to protect aircraft surfaces from snow and ice build-up until take off. wing. Relatively small amounts of Type IV fluids fall on the roadway at application sites. Type IV fluids drip or squirt from aircraft during taxiing or takeoff, mostly falling onto sidewalks or other airport surfaces. Smaller amounts of ADFs are airborne during application or aircraft taxiing and take-off and may be carried by the wind to other parts of the airport or beyond the boundaries of the aerodrome. There are few quantitative studies on the dispersion of ADF after application. The Environmental Protection Agency (EPA) analysis of baseline pollutant loads assumes that 75% of Type I fluids fall to the ground at application sites (Swettenham et al. 1999). Because Type IV fluids are designed to remain on board aircraft until take-off, the EPA assumes that only 10% of these fluids fall to the ground at the time of application (US EPA 2011) The rest of the liquid disperses to areas outside the site of application. Airports apply pavement de-icing equipment directly to the ground.

Treated surfaces may include runways, taxiways, aprons, ramps and gates. The degree of road surface settlement varies according to the nature of rainfall. Once on the ground, the ADF and the pavement de-icing device can disperse in several ways. ADFs and pavement de-icing agents on paved surfaces often spill into stormwater management systems. Many airports also have vegetation or other permeable surfaces adjacent to paved areas. In these areas, ADFs and sidewalks can seep into the ground and eventually enter groundwater if present below the airport. ADF and pavement de-icing devices in stormwater management systems can discharge to surface waters or, in some places, into stormwater collection and treatment systems. Airports typically collect and treat stormwater from ADF application sites. Rainwater from these areas tends to contain a higher percentage of de-icing pollutants than other airport areas. These areas are also relatively limited in size and thus provide an easier opportunity for collection and disposal. Airports are less likely to collect and process ADF and pavement de-icing agents dispersed in other areas of the airport due to their larger surface area and greater precipitation, which increases complexity. complexity and cost of collection and treatment. In addition, concentrations of pollutants in stormwater tend to be lower in these areas, although the total load can still be significant. ADF and road surface de-icing agents dispersed throughout the airport are more likely to flow into surface waters or seep into permeable airport surfaces.

Due to the variability between individual airports in ADF usage and pavement de-icing, the extent and configuration of paved and permeable areas, as well as rainwater collection and treatment, there are large variation in the amount of pollutant from de-business access to surface waters at each airport.

5.1 Formulation of airport de-icing and anti-icing products

There are four categories of Aircraft Deicing and Anti-icing Fluid (ADF) fluids: Type I, Type II, Type III, and Type IV. Type I fluids are aircraft deicers and Type IV fluids are aircraft deicers. Both liquids are primarily composed of a freezing point depressant (usually propylene glycol or ethylene glycol) and water. Liquids contain chemicals commonly known as "additives" that function as surfactants, corrosion inhibitors, pH modifiers, flame retardants, defoamers, colorants, oils, antioxidants, and antimicrobials.

It contains relatively small amounts (about 1-3%). Type IV liquids also contain a thickening agent to increase viscosity and adhere to aircraft surfaces until takeoff. ADF works by reducing the temperature at which snow, and ice adhere to aircraft surfaces. Based on data from responses to the EPA Airline Deicing Questionnaire (2006), the most used ADF at U.S. commercial airports is Type I propylene glycol deicing fluid, accounting for approximately 77% of ADF use or purchases. occupies A recent trend in the use of ADFs is the increasing use of propylene glycol-based ADFs instead of ethylene glycol-based ADFs. Table 0 provides EPA estimates of ADF usage for each country based on information from survey responses for the 2002-2003, 2003-2004, and 2004-2005 deicing seasons. increase. Because glycol concentrations vary by manufacturer's ADF formula, the ADF amounts in Table 1 are normalized to represent 100% glycol concentration. Also, EPA used the ADF purchase information to provide the recommended usage for the airline industry.

Chemical	**Average Total Airport Use/Purchase (million gallons/year)**	**% Of ADF Use/Purchase**
Type I Propylene Glycol Aircraft Deicing Fluid	19.305	77.1
Type IV Propylene Glycol Aircraft Anti-Icing Fluid	2.856	11.4
Type I Ethylene Glycol Aircraft Deicing Fluid	2.575	10.3
Type IV Ethylene Glycol Aircraft Anti-Icing Fluid	0.306	1.2

Table 1: Commercial Airports - National Estimate of Aircraft De-icing and Anti-Icing Fluid Use/Purchase

According to responses to the EPA Airport Deicing Questionnaire, potassium acetate is the most used deicing agent at US airports. Potassium acetate makes up about 80% of all deicing fluids used at airports. A recent trend in road deicer use is for US airports to phase out or reduce the use of urea due to concerns about its impact on water quality. Table 2 shows the estimated national average airfield chemical consumption (based on data from the 2002-2005 deicing seasons) for major commercial airports.

Pavement Deicer Chemical	**Estimated Total Airport Use (tons/year)**
Potassium acetate	22,538
Airside urea	4,127
Propylene glycol-based fluids	3,883
Sodium acetate	3,100
Sodium formate	1,117
Ethylene glycol-based fluids	774

Table 2: Commercial Airports - National Estimate of Pavement De-icing Chemical Use

According to EPA national estimates for chemical or material use, about 70% of airports use deicing chemicals for pavements, the remaining 30% rely on sand application for de-icing/anti-icing.

5.2 Environmental impacts from the discharges from the airport de-icing operations

The following are some of the identified cases in which airport de-icing emissions have impacted water quality, aquatic ecosystems, and human use of aquatic resources. The identified impacts include:

- Reduce the level of dissolved oxygen in water bodies receiving de-icing rainwater.
- Increasing the concentration of nutrients in water bodies where rainwater melts.
- Death of fish after de-icing fluids in storm sewers.
- Impact of anti-icing storm runoff on downstream aquatic ecosystems. This includes a reduction in the abundance and diversity of organisms or the destruction of aquatic communities.
- Pollution of underground and surface drinking water resources.
- Aesthetic disturbances in surface water including foaming, odor and discoloration.
- Complaints of headache and nausea in a subject exposed to the smell of melted rainwater.

A particularly well-known concern is the oxygen demand created by ADF and deicer-contaminated stormwater. All major components of ADF and road de-icing equipment require oxygen during decomposition. Airport deicers break down in surface water, thus consuming dissolved oxygen in the water column. If dissolved oxygen levels become too low, aquatic life can be affected or killed. Finally, chronic hypoxia can alter the biochemistry and overall community structure of aquatic ecosystems. Raw or partially treated wastewater discharges from cities and towns were a common cause of hypoxia in surface waters prior to the introduction of more stringent wastewater treatment requirements under the Clean Water Act. The potential for oxygen depletion in wastewater from airport deicing operations is many times greater in raw wastewater. For example, Type I propylene glycol-based deicing fluids are generally diluted into a mixture containing about 50% propylene glycol prior to application. Pure propylene glycol has a Five-Day Biochemical Oxygen Demand (BOD_5) concentration of approximately 1,000,000 mg/L. Therefore, a typical dilute propylene-based deicing fluid has a BOD_5 concentration of about 500,000 mg/l. In contrast, BOD_5 concentrations in untreated sewage are typically around 200 mg/L. The amount of liquid used for deicing a single non-propeller aircraft range from hundreds to thousands of gallons, depending on the type of precipitation event and the size of the aircraft. Therefore, deicing a single non-propeller aircraft can produce a BOD_5 load greater than 1 million gallons of raw sewage. Large hub airports often have hundreds of flights per day. Road deicers applied to airport pavements can also exert significant BOD_5. Therefore, the BOD_5 produced by daily deicing activities at major airports could be comparable to the BOD_5 associated with raw sewage for more than 1 million people.

In addition to oxygen-demanding substances, airport de-icing products contain several additives. Some of these additives have toxicity or other properties that can harm aquatic ecosystems. Other additives have not yet been publicly identified due to the proprietary nature of deicing product formulations and the limitations of existing research on deicing product formulations. Without information on the identities of these additives, it is not possible to determine the potential environmental effects of these chemicals. Many of the surface waters into which airports discharge de-icing materials are small streams with limited absorption and dilution capacity to handle large amounts of oxygen-demanding substances and other pollutants. EPA assessed the degradation of several surface waters that directly receive waste from airport de-icing operations and found that many of these waters were listed as degraded under Section 303(d) of the Clean Water Act. Many of these waters exhibit forms of degradation that may be related to emissions from airport de-icing operations (e.g., lower dissolved oxygen levels). Other bodies of water are stressed and altered by other types of pollutants. Regulatory options would eventually reduce the magnitude of the airport's de-icing pollutant emissions to some of these surface waters and could improve the health of these degraded aquaresources.

5.3 Documented environmental impact of airport deicing activities

Environmental Protection Agency searched the public literature for information on pollutant emissions from airport deicing and how they relate to environmental impacts. Literature sources included peer-reviewed literature, government reports, newspapers, reports of government agencies, and publications of various organizations. This section presents the results of the EPA literature search completed in December 2007. The EPA has compiled over 90 separate documents describing the environmental impact of airport de-icing ducts. In some cases, pollutant emissions from deicing are clearly linked to environmental impact. Other cases have suggested that the impact on deicing contaminants is less conclusive. Compiled articles describe a variety of airport and unloading conditions. Surface waters are often exposed to multiple stressors, including pollutants from airport activities other than deicing, other industrial effluents, and invasive species. Determining the cause of water disturbances can be difficult and requires complex analyzes that have not yet been performed or published. EPA has summarized the proposed and final case studies in this section.

These case studies are intended to provide additional information about the potential environmental impact of deicing pollution. About half of the articles describe impacts with a clear link to contaminant influx from airport deicing. Most of the environmental impact documentation focuses on observed effects in surface waters that are directly affected by the input of airport deicing pollutants. Impacts on wildlife, such as killing fish and killing other organisms, are the most reported environmental impacts. Table 3 summarizes the total number of studies that EPA has found on different types of environmental impacts that are classified as having certain or suggested relationship with airport de-icing operations.

Impact	**Connection to Airport Deicing Definitive**	**Connection to Airport Deicing Suggested**	**Total Number of Studies**
COD, BOD, DO, Nutrients	11	5	16
COD or BOD	10	10	20
DO	8	9	17
Nutrients			
Wildlife Impacts			
Fish Kill	8	10	18
Other Organisms	25	20	45

Human Health Impacts			
Health	4	4	8
Drinking Water	1	7	8
Aesthetic Impacts			
Foam	4	6	10
Odor	14	17	31
Color	11	9	20
Violations			
Permit Violations	17	10	27

Table 3: Recorded environmental impacts associated with airport de-icing emissions

Although the EPA's literature search is thorough, it is unlikely that EPA has found all the available literature on the environmental impact of airport de-icing agents. The possible environmental impacts of airport de-icing agents have not yet been documented and disclosed as it is often time and labor intensive to detect, analyze and document the hazards. environmental impact of industrial wastes. An additional limitation to the compilation of EPA documentation is its ability to reflect current conditions at individual airports. Since the publication of articles describing the environmental impacts of several airports, some of these airports have installed collection and treatment systems or have modified deicing methods to reduce emissions of hazardous substances. de-icing contamination.

5.4. Measures to reduce the harmful impact on the environment

The invention relates to an environmentally friendly fluid for preventing icing of aircraft, and the indicated liquid is especially suitable for various equipment intended for spraying.

The task of the present invention is to create a fluid that lowers the freezing/icing point, suitable for airplanes and runways, the use of which is safe for the environment and economical and does not pose any risk to health.

According to this invention, the preferred compound used as a component of the specified anti-icing fluid for aircraft and runways is trimethylglycine or trimethylglycine hydrate salts. Trimethylglycine or betaine is especially preferred. Betaine, for example, can be obtained by extraction from natural products, such as sugar beets, or by a biochemical process in such a way as to make it possible to obtain a biological anti-icing liquid with a favorable service life.

The liquid used to prevent icing of airplanes and runways, according to this invention, contains 10-60% trimethylglycine or its derivative and 40-90% water; preferably 40-55% trimethylglycine or its derivative and 45-60% water, and all percentages are by weight.

Among the advantages of this anti-icing liquid is its non-toxicity and safety, as well as the absence of an odor. Some of its physical properties are the same as those of glycol solutions, and it can be used at temperatures between -50 and +100°C. It is preferably used at temperatures ranging from -40 to +80°C. A characteristic property of deicing agents is that they lower the freezing point. This freezing temperature should not be higher than -20°C, and in the case of betaine, the freezing temperature can even be reached up to -50°C. If necessary or desirable, the anti-icing liquid of this invention may be mixed with conventional corrosion inhibitors, stabilizers and marking additives, thickeners, surfactants, other deicing agents such as glycols or salts, and with acidity regulating compounds; all these substances are well known in the art.

The anti-icing fluid according to the present invention is less toxic and pollutes the environment less than the anti-icing liquids already known in the art. The specified liquid is not classified as hazardous waste, and it can be easily removed, which reduces costs. The waste of this liquid can be treated without taking any special safety measures, and it can be absorbed by the soil or go down the drain, while ethylene and propylene glycol, as well as ethanol, which are commonly used in technology at the present time, must be removed by special methods, as hazardous waste.

The anti-icing fluid of the present invention is suitable for use in various fields for deicing or de-icing airplanes, runways, etc., especially at low temperatures and in situations where the fluid must be environmentally friendly and non-toxic. Compound toxicity estimates are based on Lethal Dose 50% (LD_{50}) values taken from the literature. The LD_{50} values used were obtained from oral administration of test compounds in rats. The results are shown in Table 4.

Compound	**LD_{50} mg/kg**
Ethylene Glycol	4 700
Propylene Glycol	20 000
Ethanol	7 060
Trimethylglycine	11 179

Table 4

The vapor pressure of the liquid of this invention is below 5 Pa. The LD_{50} value is more than 10,000 mg/kg (for rats by oral administration), and the flash point of this liquid is above 100°C. Further, the freezing point of a 50% solution is less than -38°C, and its surface tension is less than 55 dynes/cm. The shelf life of this liquid when stored under standard conditions at room temperature is over 2 years. Viscosity, an important characteristic of a freezing point depressant, can be stably kept within the desired range.

Trimethylglycine is a non-toxic and odorless raw material of natural origin, which biodegrades in natural conditions by 80% in 20 days. Slow biodegradation is a problem associated, for example, with propylene glycols that have been used in the past.

Trimethylglycine solutions are safe to handle due to the low vapor pressure and correspondingly low volatility of these solutions. In contrast, for example, ethylene glycol has a vapor pressure limit of 50 ppm - total vapor to liquid ratio (TVL) for safety reasons. Environmental safety has already been mentioned as one of the main advantages of using a trimethylglycine solution as an anti-icing fluid for aircraft and runways.

So, de-icing/anti-icing chemicals have very complex effects on ecological processes and research related to them is urgently needed. Over the past decades, scientists around the world have made numerous advances in the study of soil, water, plants, air, and so on. Among these areas, soil and water research is more intensive, and changes in the biological and ecological aspects of plants and aquatic animals are much less. But still, the disadvantages of the above anti-icing fluids for ground handling of aircraft are high toxicity due to the use of ethylene glycol and diethylene glycol with a high glycol content of 40-95 wt.%. Currently, much of the research on de-icing chemicals is devoted to the development of real environmentally friendly chemicals. However, the impact of anti-icing reagents on the regional environment is a long-term ecological process, and there are few studies of regional spatial and temporal differences in the environment, especially the soil-water systems of the metropolis. Thus, this chapter summarizes work on de-icing chemicals and attempts to propose a conceptual model of their impact on local assessment of soil and water conditions: how harmful ingredients migrate into the environment and whether enrichment exists; which fields and water bodies are most susceptible to the effect of enrichment; usage of patents and inventions of scientists; annual pollution statistics should be provided.

Conclusion

The topic of this master's thesis is devoted to the issue of the inspection process and anti-icing system of the Boeing aircraft.

In particular, the work considers the issue of improving the anti-icing system of the tail of the aircraft.

The essence of the problem is that on aircraft of this type, the tail fin is heated with the help of accompanying flows from the exhaust gases of gas tube engines. Because the Boeing 737 is a low-flying aircraft, in its regular mode of operation, it is assumed that the exhaust gases, coming out of the engines, are partially reduced with the incoming air and fall on the surfaces of the tail fin and heat them, thereby providing an anti-icing effect. But as the operational experience shows, such a constructive approach in individual cases is not entirely effective. This is evidenced by the presence of small ice remnants on the tail feathers.

In my opinion, they are undesirable, and especially during the landing stage of the aircraft, because they can, although not significantly, affect the aerodynamic characteristics of the aircraft and its controllability and stability.

In this regard, the work proposes to modernize the anti-icing system by installing an electric heating system in the tail fin.

Therefore, the analysis of the process of de-icing on structural modern aircraft was carried out in the work, thermal and electrical calculation of the electric heating system was carried out. The main structural elements are section heaters of the type that are powered by alternating current of the three-phase on-board system with a voltage of 208 V, 400 Hz. Each section of the heater is connected to the control system, which ensures cyclic switching on and off, ensures uniform heating of the surface. The electric heater system has two main and additional operating modes.

In the main solution, the heating section is connected according to the "star" scheme, and in the additional one, the elements themselves are also according to the triangle scheme, thus ensuring, if necessary, an increased value of heat release.

It has also been shown that de-icing fluid residues can adversely affect aircraft flight control systems. If these residues are not removed on a regular basis, aircraft performance can be adversely affected as different types thicken(gel-like) when mixed. Thus, these considerations should be part of the winter flights of airlines in different countries, such as transatlantic flights.

The work also deals with issues of labor protection and environmental protection.

Because the tests also confirmed that the anti-icing fluid could ignite under the right conditions. Only sporadic fires were observed (no fireballs) when ignited by a spark, and these were confined to a small mist near the center of the spray. The increase makes us think about improving legislation in the field of occupational safety. One of the state's actions to improve the situation in the field of labor protection is the expanded use of regional norms, which allow the labor protection features of a particular enterprise to be reflected in associations and collective agreements.

Damage caused by anti-icing agents has a very complex effect on ecological processes and needs urgent research. Among these fields, soil and water research is more intensive, and changes in the biological and ecological aspects of plants and aquatic animals are much smaller. This is a long-term ecological process, and there are few studies on regional spatiotemporal differences in the environment, especially in large urban groundwater systems.

In this way, the modernization of the anti-icing system of the Boeing 737 aircraft will improve its aerodynamic stability and controllability of the aircraft, especially at the nozzle position, which will generally increase the level of flight safety. Same about the chemicals used in the ground anti-icing in the airports.

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