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КАФЕДРА ТЕХНОЛОГІЙ АЕРОПОРТІВ

ДОПУСТИТИ ДО ЗАХИСТУ
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КВАЛІФІКАЦІЙНА РОБОТА

(ПОЯСНЮВАЛЬНА ЗАПИСКА)

ВИПУСКНИКА ОСВІТНЬОГО СТУПЕНЯ МАГІСТРА

ЗА ОСВІТНЬО-ПРОФЕСІЙНОЮ ПРОГРАМОЮ
«ТЕХНОЛОГІЇ РОБІТ ТА ТЕХНОЛОГІЧНЕ ОБЛАДНАННЯ АЕРОПОРТІВ»

Тема: Технологія та засоби з протикригової обробки повітряного судна Boeing 737

Виконавець: здобувач вищої освіти групи ТА-206М
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РЕФЕРАТ

Пояснювальна записка до кваліфікаційної роботи «Технологія та засоби з протикригової обробки повітряного судна Boeing 737»: сторінок 92, ілюстрацій 35, таблиць 9, інформаційних джерел 40.

Об'єктом досліджень є технологічні процеси із протикригової обробки повітряного судна типу Boeing 737 з використанням спецмашини.

Метою роботи є оснащення спецмашини спеціальним вузлом протикригової обробки, для підвищення ефективності та зменшення витрат, забезпечення утилізації і повторного використання відпрацьованої робочої рідини з метою охорони праці й навколишнього середовища, а також підвищення якості протикригової обробки ПС.

Виходячи з мети кваліфікаційної роботи у пояснювальній записці сформульовано та вирішено наступні задачі:

1. Проведення інформаційного пошуку джерел щодо особливостей конструкції та технічних характеристик сучасних протикригових машин.
2. Аналіз процесу покращення протикригової обробки літака.
3. Розробка конструктивного вдосконалення вихрової головки.
4. Здійснення розрахунку та підібір основних елементів гідравлічної системи спецмашини.
5. Розробка розділів, присвячених питанням охорони праці та довкілля при експлуатації протикригової спецмашини.

АЕРОПОРТ, СПЕЦМАШИНА, ПРОТИКРИГОВА ОБРОБКА, ЗАСОБИ ПЕРОННОЇ МЕХАНІЗАЦІЇ, ВИХРОВА РОЗПРИСКУЮЧА УСТАНОВКА, АВІАЦІЙНА НАЗЕМНА ТЕХНІКА, ПОВІТРЯНЕ СУДНО, ГІДРАВЛІЧНА СИСТЕМА, МАТЕМАТИЧНЕ МОДЕЛЮВАННЯ, АВІАЦІЙНА БЕЗПЕКА.

LIST OF CONDITIONAL ABBREVIATIONS, TERMS

AC – Alternating current
AEA – Association of European Airlines
APU – Auxiliary power unit
EMF – Electro-magnetic field
GSE – Ground support equipment
HOT – Holdover time
IATA – International Air Transport Association
ICAO – International Civil Aviation Organization
ICE – Internal combustion engine
MNT – Maintanance
SAE – Society of Automotive Engineers
SO_2 – Sulfur dioxide
SV – Special vehicle

INTRODUCTION

Actuality of theme. Air transport is one of the leading places in the transportation of passengers and cargo. The main direction of economic and social development is to implement measures to significantly reduce fuel consumption by 3-5% through the rational operation of aircraft, reduce fuel losses, as well as increase engine efficiency, improve the aerodynamic characteristics of aircraft.

In civil aviation there are industry and international regulatory and technical programs for the development, production of mechanization, reduction of manual labor.

An urgent problem is the optimization of the process of de-icing/anti-icing of aircraft at the airports of Ukraine, because our industry does not produce special vehicles for these types of work that meet modern requirements for labor protection and the environment.

De-icing/anti-icing of aircraft is one of the key tasks of the modern period. This procedure is necessary not only for the smooth and safe flight of the aircraft.

Experience in the operation of mechanization of de-icing/anti-icing of aircraft has shown that the solution to this problem with the help of mechanized means can not be due to the creation of one universal vehicle, and several vehicles of narrow-functional purpose.

The purpose and tasks of the graduate work. The purpose of the work is to equip the anti-icing vehicle with a special unit to increase efficiency and reduce costs, ensure disposal and reuse of spent working fluid to protect labor and the environment, and improve the quality of anti-icing treatment of aircraft.

The object of research. Technological processes of de-icing/anti-icing of aircraft Boeing 737 using a special vehicle.

The subject of the research. Design and features of operation of de-icing special vehicle with advanced vortex head for ground maintenance aircraft.

Research methods. The method of expert assessments, analytical and calculation method, modern software, in particular text and presentation editors were used.

The scientific novelty of the results. The optimal design elements of the anti-icing special vehicle developed for the maintenance of the Boeing 737 aircraft were calculated and selected and the technology of its ground maintenance was optimized.

Personal contribution of the graduate. The graduate personally performed an information search on the features of layout schemes and technical characteristics of modern anti-ice vehicles, developed the vortex head of the special vehicle, calculation and selection of basic elements of the hydraulic system of anti-ice processing of special vehicles, technology and safety measures. The general layout of the thesis and its submission to the defense was performed jointly with the supervisor.

INTRODUCTION

SECTION 1

REVIEW OF MODERN TECHNOLOGIES AND EQUIPMENT FOR AIRCRAFT GROUND DE-ICING/ANTI-ICING

1.1 Aircraft ground de-icing/anti-icing procedures

Today one of the main problems of civil aviation is the problem of aircraft de-icing. Aircraft de-icing is done in order to improve flight safety and economic efficiency:

- operability of controls, units and also engines of the aircraft;
- reduction of aircraft take-off mass;
- maintaining of high aerodynamic characteristics of the aircraft;

Fig. 1.1.1 Boeing 737 anti-icing

Full or partial anti-ice treatment of the aircraft should be done depending on weather conditions and the degree of icing. In operation, when the cleanliness of the aircraft coating is of great importance, it is necessary to strictly adhere to the specified technology. However, the use of outdated equipment that takes place at airports that have a small amount of takeoffs and landings of aircraft, does not provide effective anti-icing treatment of the aircraft, and leads to increased costs for the treatment of aircraft (Table 1.1.1).

Table 1.1.1

Technical and economic indicators of anti-icing of aircraft

Name of indicators	**Type of the aircraft**	
	A 319-321	**B737**
The total area of the casing is be treated, m^2, in liters (Wing + Tail)	200	180
The average cost of anti-icing fluid (water + type I-IV) for the treatment of one aircraft per flight, kg:		
November	502	481
December	574	562
January	542	513
The average cost of anti-icing fluid (type I-IV) for the treatment of one aircraft per flight, kg		
November	270	260
December	310	300
January	240	235
The average time of deicing, min	15/18/14 (average time -15min)	
Efficiency, m^2/year	800	760
The average cost of the fluid used to deice one aircraft	273 liters * 3,5usd= 955,5 usd	265 liters * 3,5usd= 927,5 usd
Average cost of fluid used to treat one aircraft per month (average of 12 treatments)	955,5y.o.*12treat= 11466 usd	927,5 usd*12treat= 11130 usd
Average cost of fluid used to treat one aircraft per season (50 treatments)	955,5usd*50treat= 47,775 usd	927,5usd*50days= 46,375usd

However, the use of mechanization only partially meets the current technical requirements of anti-icing treatment of aircraft, and their number does not meet the needs.

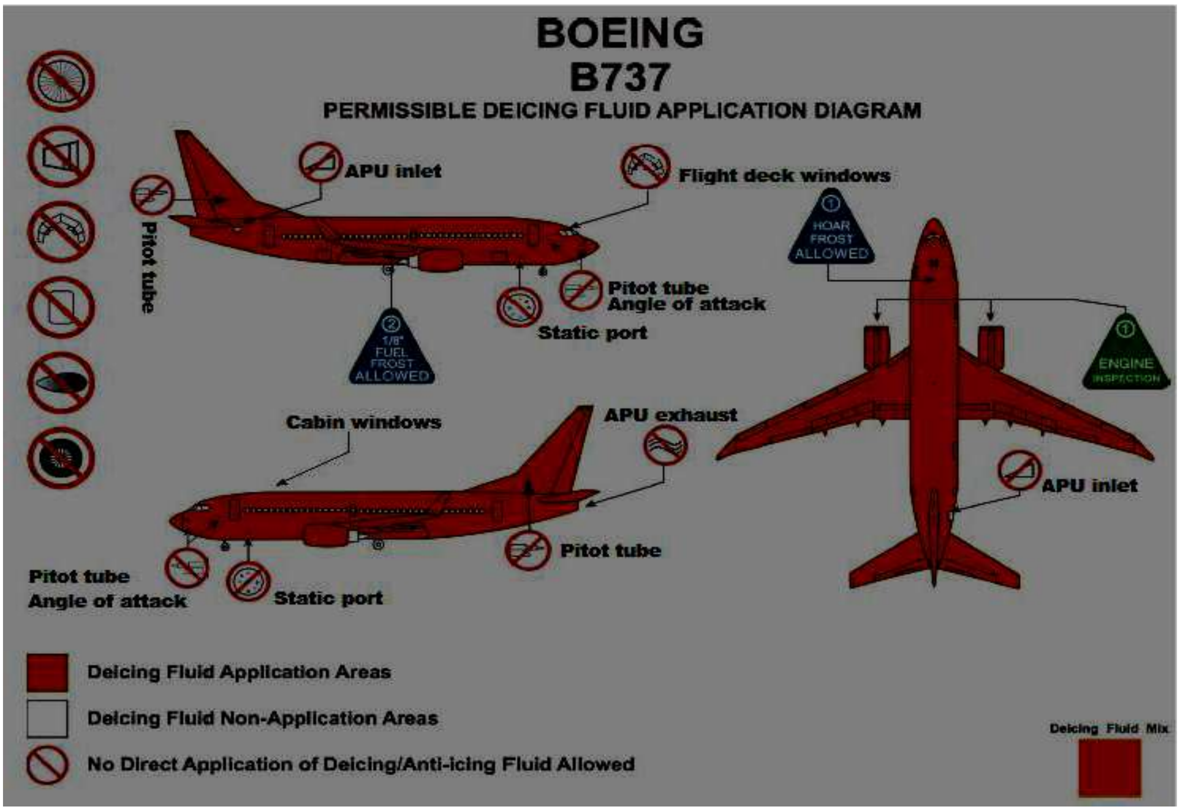
When the aircraft is on the ground in the autumn-winter period, at negative temperatures and dew point temperature equal to ambient temperature, the outer surface of the casing is covered with frost, snow or ice, which interferes with normal take-off due to deteriorating aerodynamic properties and weight gain. For example, when ice appears on the casing of the B737 aircraft with a thickness of 1 mm, the weight of the aircraft increases by 500 kg. The quality of anti-icing treatment affects fuel consumption. Thus, in the absence of anti-icing treatment, in addition to increasing the risk of accidents, fuel consumption in cruising flight mode increases by 0.1%.

Aircraft handling areas and, in particular, open aircraft parking stands are not equipped with equipment for the collection and reuse of anti-icing fluids. Therefore, the process of anti-icing treatment is carried out with deviations from modern requirements for occupational health, safety and environmental protection [1].

The essence of the anti-ice treatment process is the use of physico-chemical and thermal methods:

- Physico-chemical method is based on the removal of icing from the casing of the aircraft with hot water and liquid type "I". In this case, the bulk of ice and snow is removed by exposure to hot water and mechanical impact of the jet. To protect against re-icing, the surface is additionally treated with liquid type "II" or type "IV".

- The thermal method of de-icing removal from the aircraft casing is based on the use of hot gas jet flow from a gas turbine engine. The bulk of ice and snow are removed by a stream of hot air. Then the surface of the aircraft casings also treated with a liquid of type "II" or type "IV". In some installations, liquid type "II" or type "IV" is applied to the surface of the aircraft together with the flow of hot gas. But this method is used more to remove ice and snow from engines, where the use of anti-icing fluid is impractical or unacceptable (Fig. 1.1.2).



Symbol	Explanation
🚫	Do not spray into engine inlet.
🚫	Do not spray flight deck windows or wind screens.
🚫	Do not spray main cabin windows.
🚫	Do not spray at or into pitot tubes, TAT probes or angle of attack sensors.
🚫	Do not spray into APU inlet.
🚫	Do not spray into APU exhaust.
🚫	Do not apply fluid to aircraft brakes.
🚫	Do not spray into engine exhaust.
🚫	Do not spray into aircraft exhaust or intake vents.
🚫	Do not spray into Avionics vents.
🚫	Do not spray directly at static ports.

Fig.1.1.2 Permissible de-icing fluid application diagram [2]

From the above indicators it follows that the technological process of anti-icing treatment of aircraft is characterized by considerable complexity, huge costs of anti-icing fluids and therefore far from perfect. The cost of one ton of concentrate of anti-ice fluids of type "I, II, III, IV" used for anti-ice treatment is 4000-6000 usd / t. they are used in the form of aqueous solutions of high concentration (from 15 to 100%).

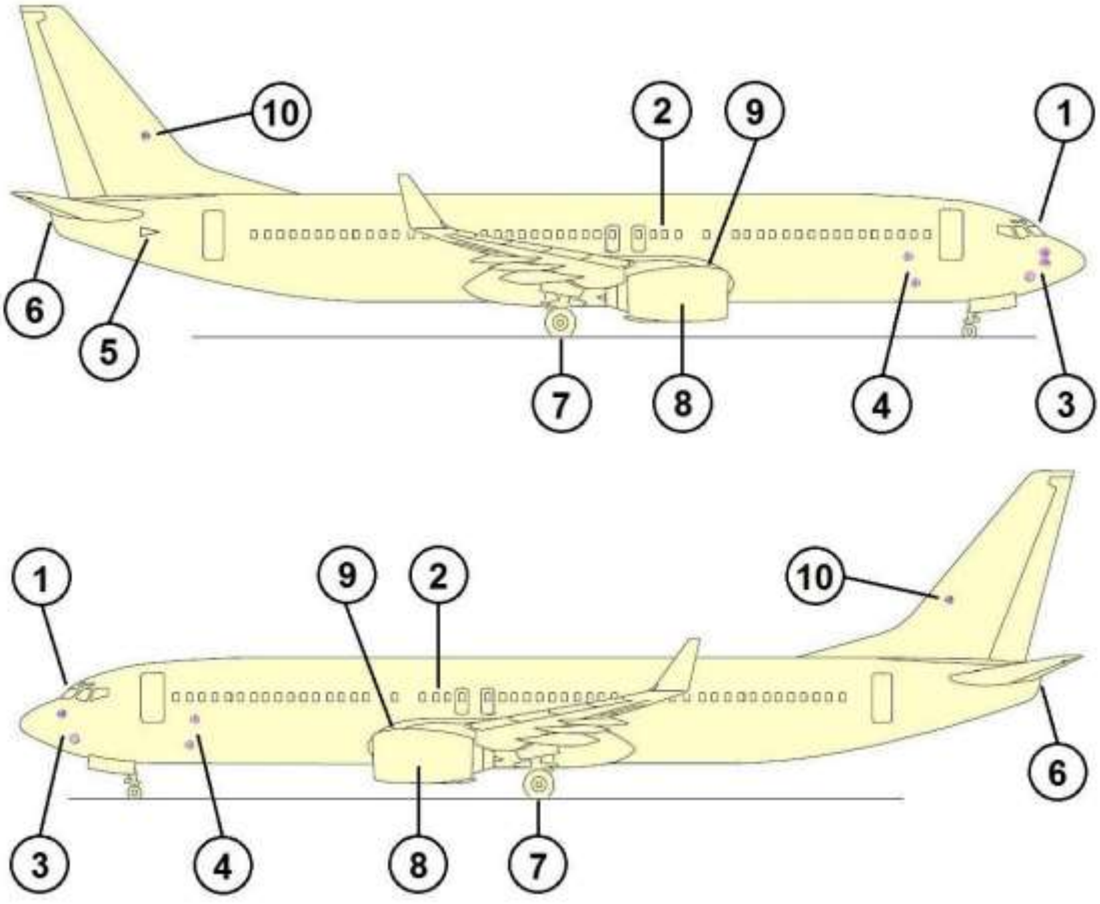


Fig.1.1.3 No spray areas of B737 [3]

1. Cockpit windows;
2. Cabin windows;
3. Pilot tubes, total air temperature (TAT) probes;
4. Static ports;
5. Auxiliary power unit (APU) inlet;
6. APU exhaust;
7. Aircraft brakes;

8. Engine inlets and exhaust;
9. PT2 probes;
10. Elevator feel pilot probes.

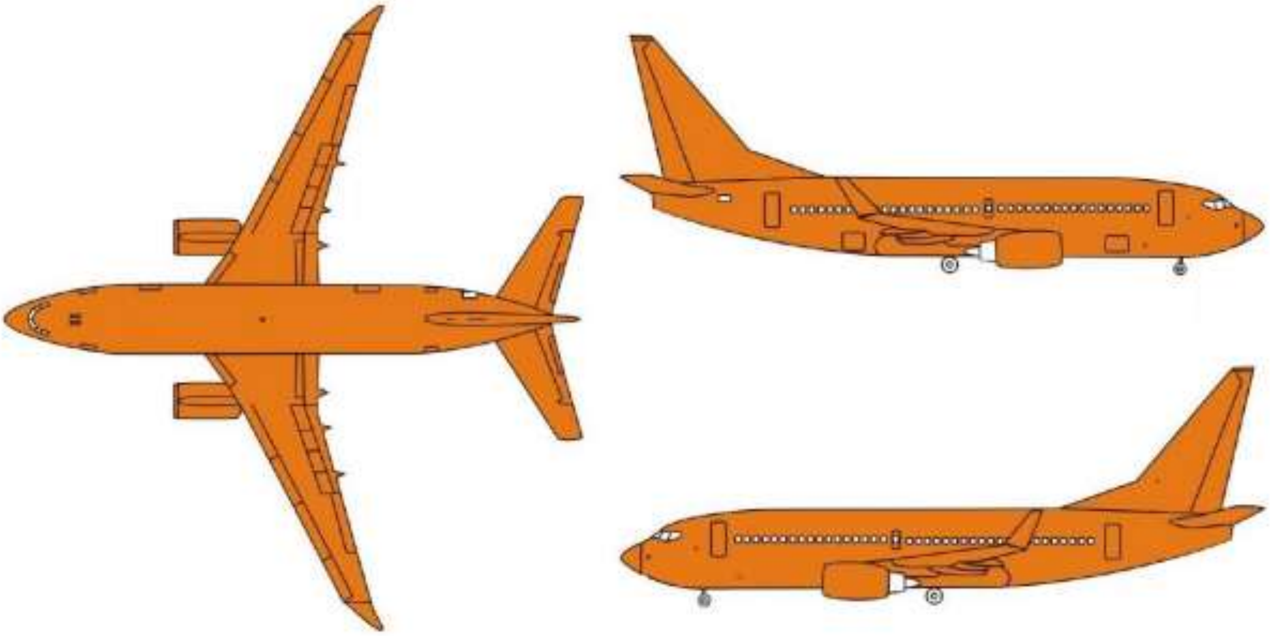


Fig. 1.1.4 De-icing fluid application areas

There must be no ice, snow, slush or frost on the leading edge devices, control surfaces, tab surfaces, upper wing surfaces and balance bay cavities. However, a layer of frost of a maximum thickness of 3.17 mm is permitted on the bottom wing surfaces between the front and rear spars (this layer of frost is caused by cold fuel in the wing wank areas).

There must be no contaminants on engine intake and the engine fan blades must be free to turn.

🟧 De-icing fluid application areas.

⬜ De-icing fluid non application areas.

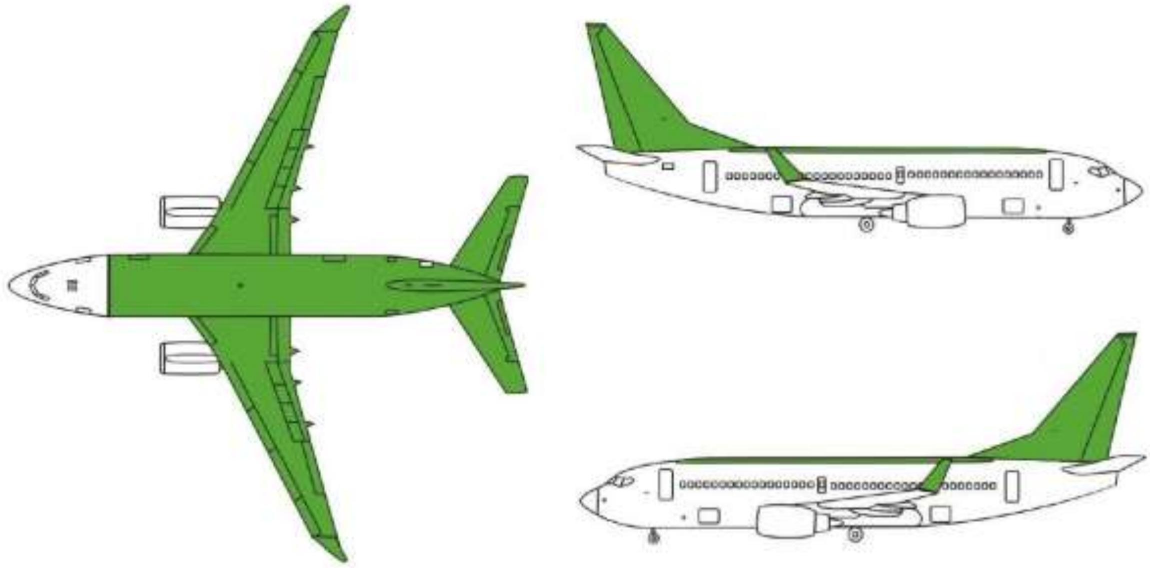


Fig.1.1.5 Anti-icing fluid application areas

Do not apply type II and IV fluid directly on the fuselage area forward of the main deck passenger/crew door. Do not apply fluid on the cockpit windows.

🟩 Anti-icing fluid application areas

⬜ Anti-icing fluid non application areas.

Existing technological de-icing is a complex and time-consuming operation that increases the processing and maintenance time of the aircraft. Its improvement is an important and urgent task. To eliminate the shortcomings of the existing technological process of cleaning in the first place it is necessary:

- mechanize the process by eliminating manual labor;
- improve working conditions and ensure safety;
- ensure environmental protection;
- to ensure objective and high-quality control of this aircraft cleaning operation.

Based on the analysis of the technological process of cleaning, and the requirements for maintaining the integrity of the aircraft skin, modern mechanized installations for anti-icing treatment of aircraft must have:

- universality of a method of clearing of all types of pollution on a covering;
- preservation of a paint and varnish covering at anti-ice processing, removal of icing;
- specific loads on the casing of 200 ... 500 hPa (depending on the type of aircraft and the height of its flight);
- uniform distribution and intensive movement of working liquids on the processed surface;
- the maximum possible rotation of the mechanical activator (brush) to intensify the process;
- collection of the processed liquid from the processed surface without spraying;
- capture of volatile components of working liquids for reuse or utilization;
- cleanliness of the cleaned surface according to the accepted accepted standards;
- industrial sanitation and safety for workers, environmental protection.

Means of mechanization of processing include a mechanical brush with rotational - translational motion. These brushes, produced by domestic factories, are difficult to work with and spray anti-icing fluid, so they are practically not used at airports for anti-icing treatment of aircraft, in addition, there is a high probability of damage to the aircraft during operating.

Anti-ice treatment plants that most often meet the requirements proposed for the cleaning process are experimental centrifugal brushes with vacuum suction and waste collection. The working body they have special movable blades that are pressed against the surface to be cleaned by springs. The disadvantages of the described designs are the large weight, the presence of hydroscopic moment and vibration.

There is also another area for mechanization of the anti-ice treatment process - the construction of special parking lots for the collection, purification and reuse of water for anti-ice treatment and the construction of anti-ice installations. The cost of building a special open parking lot for the collection, cleaning and reuse of anti-icing fluids only at positive temperatures has increased significantly. It is currently almost impossible to neutralize some harmful liquids.

In addition to all the above methods and means of mechanization, there is a fundamentally new vortex method of cleaning, which provides automated supply of working fluid to the surface to be washed, while removing contaminated fluid (continuous process), which is not provided by any of the existing methods.

The vortex anti-ice installation consists of two - three replaceable vortex spray heads, an air vacuum pump, drain tanks, a cyclone and a filter for separation and purification of liquid at its repeated use or utilization. When cleaning the casing, the vortex spray head orients itself and is held on the casing by discharge. In addition, the brush rotates to intensify the process and destroy the boundary layer in the air vortex flow. This allows for closed-loop cleaning and thus eliminates the application of working fluid in an open way, combining the application of working fluid with the operation of its removal together with waste. The combination of these operations allows you to make the cleaning process continuous, and the dynamic impact of working fluids and brushes - fast-acting.

Installations operating on the basis of the vortex method provide an increase in the cleaning of the aircraft casing due to:

- automation of the processes of transportation of working fluids, their application to the aircraft skin and collection of cleaning products for reuse (waste-free process);
- reduction of consumption of working liquids;
- improving working conditions;
- elimination of environmental pollution.

Also the technological process in comparison with a mechanical brush is simplified, comparisons of technological process of the mechanized anti-ice processing at use of a mechanical brush and the vortex spray installation are given in Table 1.1.2.

Table 1.1.2

Comparison of technological process of anti-ice treatment with the use of a mechanical brush and vortex spray unit and without its use

Technological process	**Usual spray head**	**Vortex spray unit**
Cleaning	Fluid supply in an open way	Treatment with liquid supply in a closed volume of vortex spray heads

Continuation of Table 1.1.2

Contamination washing	Liquid from the hose of a SV with a flow rate of more than 30 kg / m^2	Vortex spray with a consumption of 10 kg / m^2
Surface cleanliness	Needs verification	Remote inspection by the operator is possible
Occupational hygiene	Not provided	Provided
Enviromental protection	Not provided	Provided

As a result of the analysis of methods and means of anti-ice treatment, the most advanced is the vortex method of cleaning the aircraft casing. Of the existing means of mechanization, no special vehicles for anti-ice treatment of aircraft using the vortex method have been created yet. To solve this problem, a special vehicle ELEPHANT BETA (Fig. 1.8), which is currently used at Boryspil Airport, can be used. This special vehicle involves the simultaneous work of two employees of the ground services (driver and operator of the special vehicle).

Fig. 1.1.6 General view of the “Elephant Beta” Aircraft Deicer [4]

Table 1.1.3

The specification of the “Elephant Beta” Aircraft Deicer [5]

Width	2,5 m
Length	15 m
Height	3,6 m
Gross weight of the equipped vehicle	27 t
Working height of the processed surface	15 m
Speed	50 km/h
Height of the heated solution	15 m
The heating temperature of the solution	65º
Quantity of fluid	
-water	4000 kg
-special liquid	2000 kg
Time of heating of working liquid to temperature of 65 degrees	20 min
Time of rise of the nozzle block to the greatest height	220 sec
Loading capacity of a working cabin	210 kg
Rotation speed	0,5 rpm

The special vehicle can also be used for other purposes of anti-icing treatment, inspection and service, provided that the personnel operating the anti-icing system has a qualification similar to the training of personnel performing the main activity.

With the purchase of new generation of innovative equipment, a special vehicle for anti-ice company "Safeaero" (Fig.1.1.7) can be used as the most suitable for equipping it with a vortex spray unit designed to remove ice, snow and frost from aircraft surfaces. This special vehicle involves all anti-icing operations performed by one employee of the ground service (driver-operator), which reduces the cost and processing time of the aircraft, which improves the economic component of the anti-ice treatment process B 737 and other aircraft.

Fig.1.1.7 General view of the “Safeaero 220” Aircraft Deicer

Table 1.1.4

The specification of the “Safeaero 220” Aircraft Deicer [6]

Width	2,85 m
Length	8,25 m
Height	3,5 m
Gross weight of the equipped vehicle	28 t
Working height of the processed surface	20 m
Speed	50 km/h
Height of the heated solution	15 m
The heating temperature of the solution	65º
Quantity of fluid -water -special liquid	 6200 kg 2000 kg
Time of heating of working liquid to temperature of 65 degrees	22 min
Time of rise of the nozzle block to the greatest height	240 sec
Loading capacity of a working cabin	200 kg
Rotation speed	0,6 rpm

1.2 An overview of the de-icer design

The designed special machine is designed to perform work in preparation for winter flights for all types of aircraft. It can be used for non-contact anti-icing treatment of aircraft at any time of the year in macroclimatic areas at ambient temperatures from - 40ºC to + 40ºC.

Fig.1.2.1 General view of deicer in a folded position [7]

The special machine is a set of units and mechanisms mounted on the chassis, providing lifting and moving the work site with the operator and the spreading unit, the supply of anti-icing fluid under pressure to the injectors for anti-icing cleaning of aircraft surfaces.

Moving the work site with the operator and the anti-icing unit is done by raising and lowering the boom and turning the column around the vertical axis. Lifting of a boom and turn of a column is carried out by means of power hydraulic cylinders. The supply of fluid to the hydraulic system of the lifting device and the drive of the spray unit is carried out by a double-acting plate-rotor pump “БГ 12-24 АМ” mounted on the transfer case.

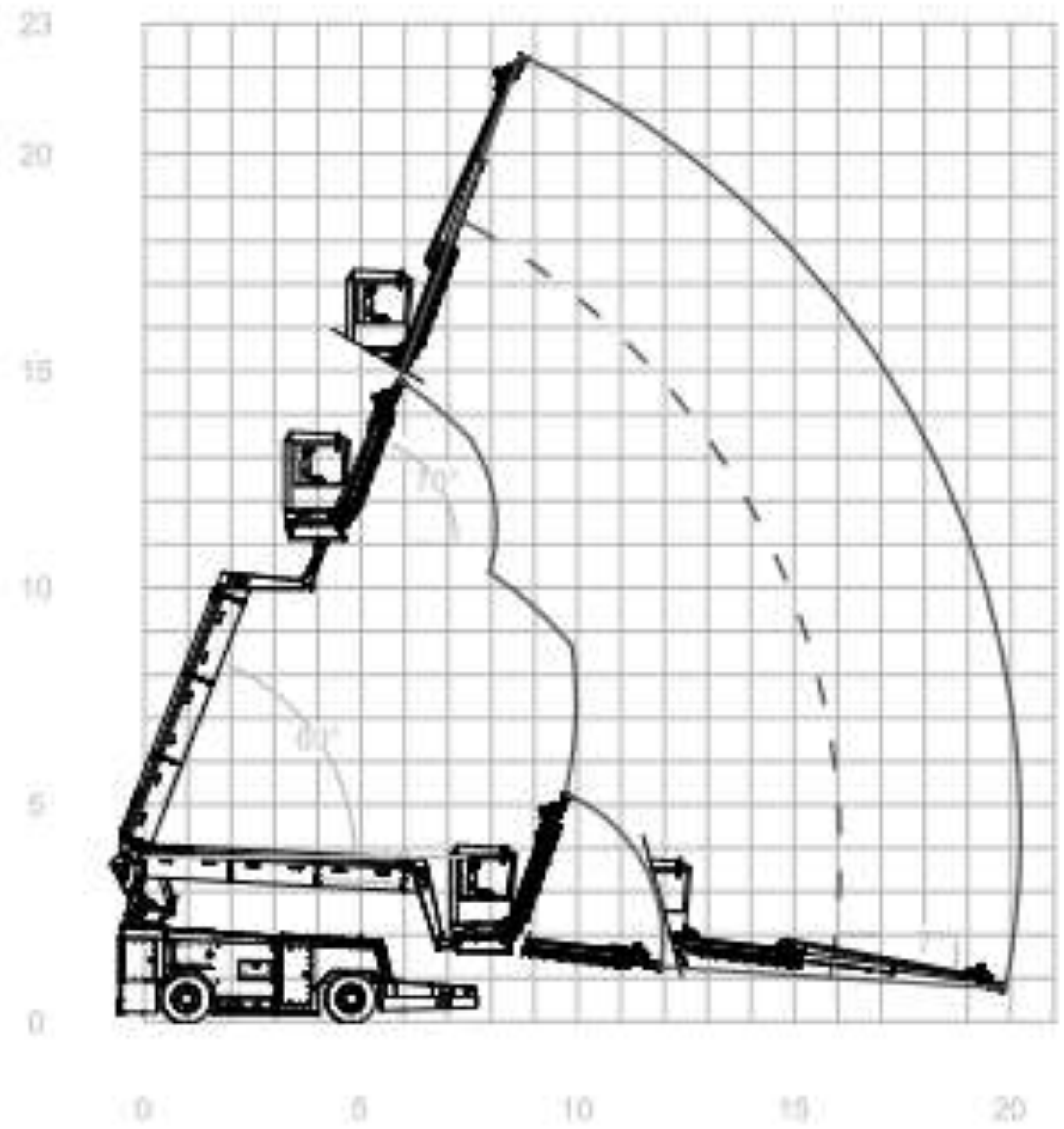


Fig.1.2.2 The scheme of vertical movement of the boom of the Safeaero special vehicle [8]

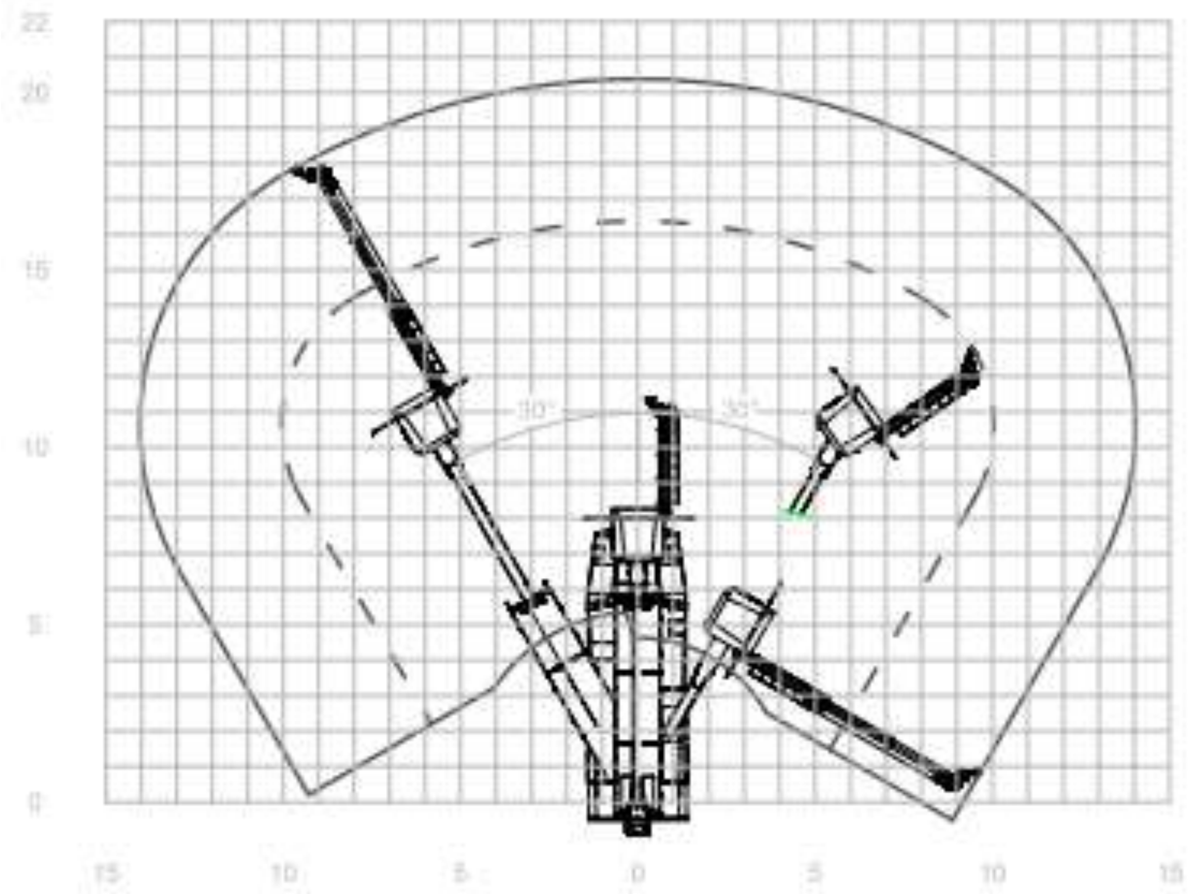


Fig.1.2.3 The scheme of horizontal movement of the boom of the Safeaero special vehicle [8]

The telescope, boom and swivel column are hinged and mounted on a support frame with swivel brackets to which the outriggers are mounted. Hydraulic cylinders of spring switches are installed on brackets.

Outriggers and springs are designed to ensure the stability of the installation during operation of the device.

The movement of the boom and the telescope is controlled by a remote control installed in the cabin, which is located on the upper platform (Fig.1.2.2).

In the middle of the boom is mounted a mechanism for stabilizing the work platform, which provides a horizontal position of the site at any position of the boom and telescope.

The speed of the boom is proportional to the deviation of the "joystick". Changes in speed during boom operations are made in order to ensure smooth and safe operation. However, it is always recommended to gradually reduce the speed of the joystick before stopping the boom.

The boom rises to a maximum height of 13 m, at the moment of separation of the boom and the telescope from the lodgment, the handrails of the ladder are automatically lowered, then it is permissible to rotate the telescope. When the boom and telescope are lowered onto the lodgment (at the moment of contact), the ladder handrails will automatically rise.

Fig.1.2.4 General view of deicer in unfolded position

To turn the telescope, you must first raise the boom to lower the ladder handrails, then you can turn the telescope with the joystick about 350 degrees to the left of the starting position. Within the working sector 30 - 300 degrees from the starting position, you can lower the boom on the lodgment. Moving the telescope up, down, forward and backward provides a joystick on the remote control in the upper platform cab.

Fig.1.2.5 Boom and telescope control panel for special vehicles [9]:
telescope control toggle switch; boom control toggle switch; joystick control telescope; switch of working liquid supply; lever control unit for spray heads.

The movement of the boom and the telescope must be very careful and optimal. Before performing any emergency maneuver, it is necessary to ensure optimal visibility of the boom and the operator's cockpit, because when the boom is turned in the direction of the aircraft or other objects, damage can occur.

Antenna sensors are installed at the end of the telescope, if one of the sensors touches an obstacle, such as the fuselage of the aircraft, all movements of the machine are stopped immediately.

Caution must be exercised when moving the telescope and boom from an obstacle, as the touch sensors are in the off position in this case. If the movement of the telescope or boom is selected incorrectly, it will damage them or damage the aircraft.

The supply of working fluid for cleaning the surfaces of the aircraft is carried out using the pump “ЦВК-6,3/160” which receives the drive from the transfer case.

Tanks serve as capacity for working liquid. From the tanks, the working fluid (working solution) enters the pump and then under pressure through the pipelines attached to the boom through the telescope to the nozzles.

When processing the aircraft, one or two people are involved, depending on the selected model of the special vehicle Safeaero. Processing of the aircraft can be carried out both in the process of movement of the special vehicle around the aircraft and in the stationary state of the special vehicle.

To prevent freezing of the working fluid in the system, at the end of the work the purge of the working fluid supply system is carried out. For these purposes, the installation has a pneumatic system. Charging of cylinders of pneumatic system with compressed air is carried out from an external source through the charging union.

To maintain the required temperature of the working fluid in the tanks of the installation is a heating system. The unit is equipped with a heater with a diesel burner. The diesel burner heats the tank 1 directly, and the other tanks are heated indirectly by convection. When the temperature of the liquid in the tank is below + 57^0C, the heater turns on automatically and heats the liquid to a temperature of ≈ + 60^0C.

Units of the installation that ensure its operation – pumps “ЦВК-6,3/160”, “БГ12-24АМ” and generator “ГСР-3000 М-4” receive drive from the car engine through the gearbox, propeller shaft and transfer case, and vacuum - pump and spray unit drive from hydraulic motors “G16-14M” and “G16-11M”, respectively. The transfer case is switched on and off thanks to the control handle from the driver's cab.

Control of units of hydraulic systems of the lifting device and the drive is basically electro-remote. There is an AC generator “ГСР-3000 М-4” and two rechargeable batteries in the unit to power the control systems, lighting devices and loudspeaker communication.

The drive of the spray unit is mounted on the shaft, on the upper working platform. To move the drive of the spray unit relative to the axis of the shaft of the work site used worm gear, driven by a plate hydraulic motor “Г16-11М”. The gear wheel of the worm gear is mounted on the shaft of the stabilizing mechanism of the work site, and the worm on the body of the spray unit.

The spray unit consists of three vortex heads with a diameter of 200 mm with a rotating brush mounted inside each rotating brush.

Fig.1.2.6 Spray unit of the Safeaero special vehicle

To ensure the quality of the vortex installation on the machine installed plate-rotor vacuum pump “BP-7/60%-2,2”, the characteristics of which are given in Table 1.2.1.

Table 1.2.1

Technical characteristics of the plate-rotor vacuum pump

Indexes	**BP-7/60%-2,2**
Nominal speed of action under suction conditions, m3 / s (m3 / min)	0,13(7,8)
Nominal pressure , kPa: - suction - injection	40 100
Nominal rotor speed, s^{-1} (min^{-1})	25(1500)
Power consumption, kW not more at nominal suction pressure in vacuum mode	10,5
Cooling	By air
Diameter, mm: - cylinder - rotor	167 136,6
Rotor length, mm	450
Number of plates, pcs	6
The angle of the plates	$14^{0}25'$
Overall dimensions, mm: - length - width - height	805 770 730
Weight, kg, no more	210

To collect the spent liquid, a tank-2 unit is used, equipped with vacuum necks, drain line, safety valve for maximum discharge and maximum tank filling, moisture separator and line for suction of used working mixture of air and anti-icing fluid.

The spray unit copies the surface of the aircraft casing in the mode of a floating hydraulic cylinder, due to the suction of vortex spray heads to the skin. The telescope is moved by a hydraulic cylinder with a small stroke and a parallelogram system that provides a fivefold increase in stroke.

1.3 Technology of application of the deicer

The installation is usually serviced by two operators. One is on the work site, the other - in the cab or near the installation. In some Safeaero, de-icing can be done by one person.

The surface of the aircraft is treated from several positions. When choosing a position, place the installation on a flat surface at a distance of 1.5 - 4 meters from the aircraft so that the sector of movement of the booms horizontally (186^0 to the right and 162^0 to the left of the starting position) covers the maximum possible surface of the aircraft. After selecting the position, the car is placed on the handbrake.

After selecting the position, the installation is deployed. The installation is uncovered, the cover of a protection of power plant and instrument panels on the block of electric equipment opens. The installation is connected to the general grounding of the aerodrome by means of a grounding cable. Depending on accessibility, a spray unit is used, and ground pistols are used in inaccessible places. The handle of the distributor mounted on the flange of the pressure pipe of the pump ”ЦВК-6,3/160” is switched to the required position "Nozzles" or "Tanks", and the handle of the distributor mounted on the mounting plate of the pump “ЦВК-6,3/160” - to the position “Open”, “Right” or “Left”. The junction box is switched on and then the power supply of the unit and the intercom are switched on. The pump “БГ 12-24 АМ” is switched on, outriggers are released [10].

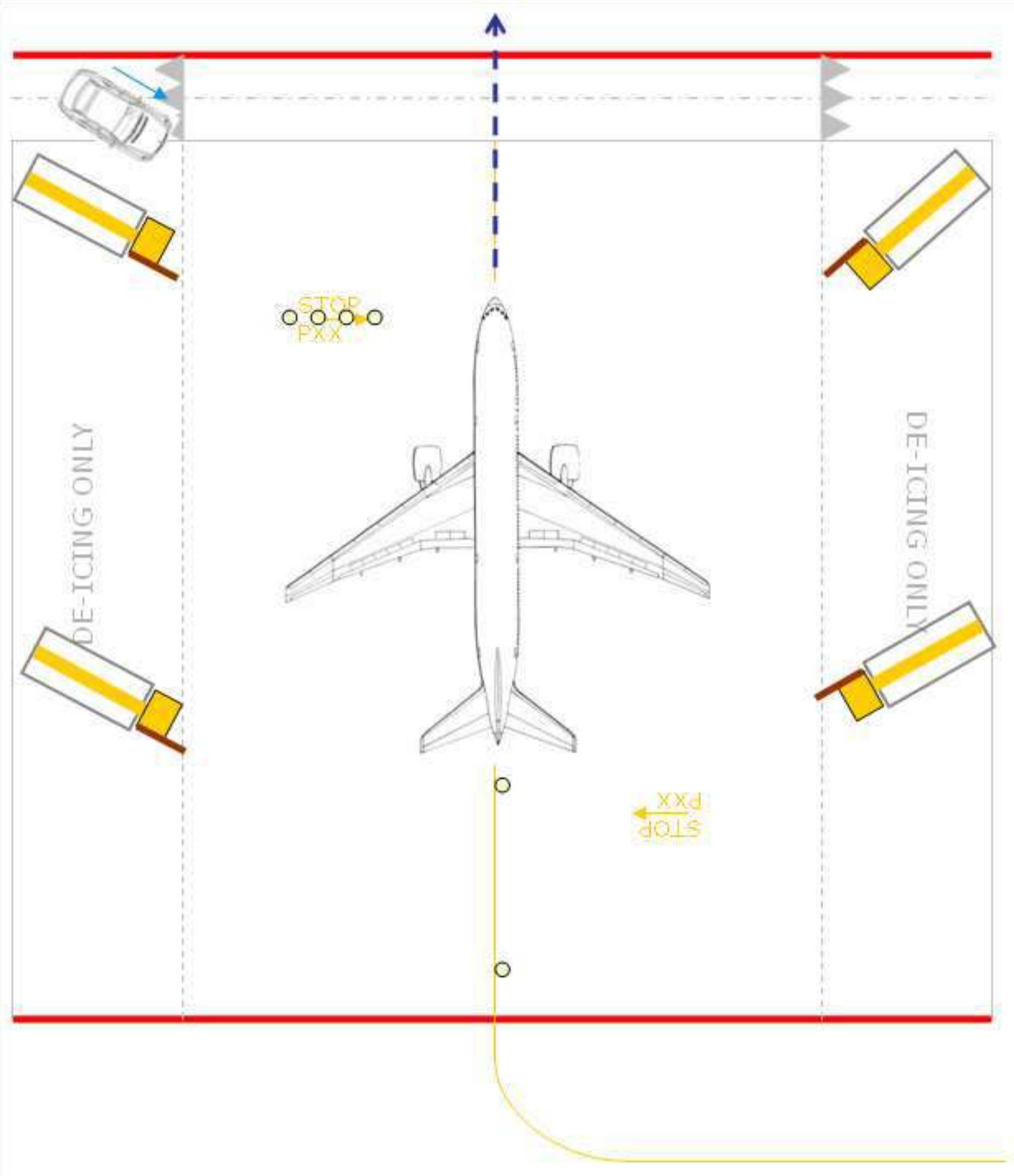


Fig.1.3.1 Parking area of the de-icing/anti-icing vehicles [11]

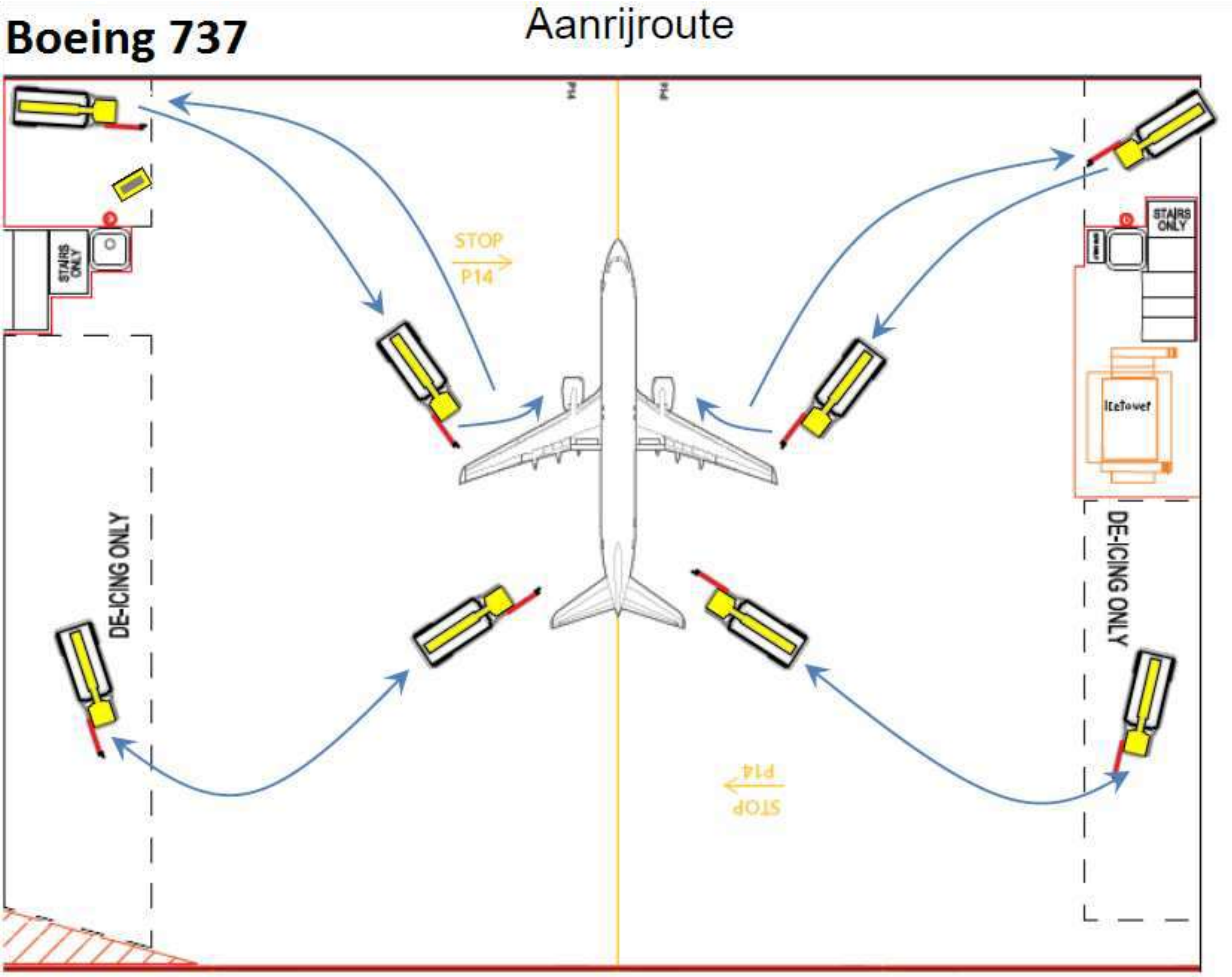


Fig.1.3.2 Maneuvering area of the de-icing/anti-icing vehicles [12]

The accessible surfaces of the aircraft are cleaned with the help of a spray unit. The spray unit is controlled, the working fluid supply and the vacuum pump “ЦВК-6,3/160” are switched on by switches mounted on the control panel. When changing the position of the unit for further work, the pump is switched off, the booms are folded, the outriggers are removed, the springs are switched on and the transfer case is switched off. The installation is transferred to another position. The transfer case is included, outriggers are pushed, work begins.

The following types of technological maintenance are installed for the special machine in operation in accordance with the requirements of the technical documentation of the basic special machine “ELEPHANT BETA” / “Safeaero”:

- On-line (daily) maintenance;
- Maintenance №1;
- Maintenance №2;
- Maintenance №3;
- Seasonal maintenance.

On-line (daily) maintenance is performed by an engineer - the driver of the installation every 8 hours every day.

Maintenance (MNT) №1, №2, №3 must be carried out in a single time, due to the operating time of the installation:

- MNT - 1 in 50 (+-5) hours, monthly;
- MNT - 2 in 250 (+-10) hours, quarterly;
- MNT – 3 in 500 (+-25) hours, annually.

Types of maintenance of special vehicles are given in Table 1.3.1:

Table 1.3.1

Types of maintenance of special vehicles

Maintenance designation	**Maintenance code**
Check	Ch
Exchange	Ex
Lubrication	LR
Adjustment	Ad
Tilt	Ti
Cleaning	Cl

The types of lubricants used in maintenance of special vehicles are given in Table 1.3.2:

Table 1.3.2

The types of lubricants used in the maintenance of special vehicles

Lubrication №	**Type of lubrication**
1	Statoil ESL 454 or Nulon L82
2	ESSO UNIVIS J26
3	SAE 15W - 40
4	Acetic acid
5	Esso Surret Fluid 4K Statoil Greaseway LCK90
6	SAE 20
7	Gearway 65 SAE 80W-90

Maintenance of special vehicle are given in Table 1.3.3

Table 1.3.3

№	**Special vehicle maintenance**	**On-line mnt.**	**MNT-1**	**MNT-2**	**MNT-3**	**Type of lubr.**
1. Main vehicle	1.1 Oil level in the tank Replacement every 2 years	Ch-LR			Ex	2
	1.2 Hydraulic tank				Cl	
	1.3 Hydraulic filter - input - reverse			Ch-Ex	Ch-Cl	
	1.4 Hydraulic connections		Ch-Ti			
	1.5 Level switch in the hydraulic tank				Ch	

Continuation of Table 1.3.3

	1.6 Liquid tanks				Ch-Cl	
	1.7 Hatch hole/cover			Ch-LR		1
	1.8 The choice of fluid		Ch			
	1.9 Inlet filter in the liquid tank				Ch-Cl	
	1.10 Minimum level, liquid system				Ch	
	1.11 Spray nozzle			Ch		
	1.12 Liquid pumps		LR		Ch	
	1.13 Three-way valve		LR		Ch	
	1.14 Valves			Ch		
	1.15 Connections,valves and hoses of the liquid system		Ch-Ti			
	1.16 Ground pistols			Ch		
	1.17 Liquid flow meter				Ch-CL	4
	1.18 All movements of the boom and telescope			Ch-Ad		
	1.19 Intercom negotiation system		Ch			
	1.20 Operation of emergency systems		Ch		Cl-LR	1
	1.21 Operation of manometers and devices				Ch	
	1.22 All lamps / lights on the special installation			Ch-Ex		
	1.23 Auxiliary engine: - oil level - revolutions (1800 rpm)	Ch-LR			Ex Ch-Ad	3
	1.24 Telescope circuit			Cl-LR		6
	1.25 Mounting the telescope cylinders			LR		1
	1.26 Cabin doors, locking system				LR	6
	1.27 Pedal in the cab				LR	6
	1.28 Worm gear (rotary) Tightening torque: 91Nm				Ch-Ti	
	1.29 Telescope support bolts Tightening torque:24 Nm				Ch-Ti	
	1.30 Clearance control in the telescopic device				Ch	
	1.31 Control of antenna sensors				Ch	
	1.32 Visual inspection of all systems, including welds, joints, loaded support parts, all axles and cab axles				Ch	

End of table 1.3.3

2. Landing gear	2.1 Landing gear:					
	- Landing gear engine oil level	Ch-LR				3
	- antifreeze of the chassis engine					
	- tire pressure (9 bar)	Ch-LR	Ch - LR	Ch-LR		
	- acid level in the battery					
	2.2 Speed limiter			Ch	Ex	
3. Liquid	3.1 Liquid system		Ch			
	3.2 PLC - controller for proportional mixing					
	- drive		Ch			
	- cost meter					
	- percentage of mixing		Ch	Ch	Ch	
	3.3 Refueling system				Ch	
	3.4 Top level sensor in the filling system				Ch	
	3.5 Heater on diesel fuel					
	- the passage of liquid through the heater			Ch-Ad	Ch-Cl	
	- efficiency (low / full load)					
	- burner nozzle				Ex	
	- dismantling of the burner and control of the amount of soot and dirt					
	- heating of the technical compartment			Ch	Ch-Cl	
	- fire protection system			Ch		
4.Spray unit	4.1 Pile of vortex heads		Ch		Ex	
	4.2 Screw of fastening of a brush of a head		Ch-Ti			
	4.2 Mounting the vortex head unit			Ch-Ti		
	4.3 Telescopic boom			Ch		
	4.4 Parallelogram transmission			Ch		

The listed types of service are carried out in the specified term under normal operating conditions. When operating the installation in adverse conditions (dusty and humid air at very low temperatures, etc.), the time between regular maintenance can be reduced.

The work carried out during current and scheduled maintenance is given in the "Technical description and operating instructions". In addition to these works, current and scheduled maintenance of the anti-icing unit, vacuum pump, vacuum pump drives and spray unit, as well as additional units are provided.

1.4 De-icing/anti-icing fluids

The main purpose of anti-icing fluids is to remove ice deposits from aircraft surfaces and to lower the freezing point of precipitation that hits the aircraft, thereby preventing frost, ice, snow and slush from accumulating in critical areas.

1.4.1 De-icing and anti-icing processes

Depending on the weather conditions, a certain type of equipment is used:

- De-icing equipment;
- Anti-icing equipment.

De-icing is the process designed to remove snow, ice, frost from a surface of the aircraft. De-icing involves carrying out the procedure immediately before departure, provided that the weather conditions remain stable. There is no snow or rain, which becomes a source of ice on the surface at negative temperatures. It is enough to treat the surface and you can fly without fear that the processes of ice formation will appear again.

Anti-icing is the process designed to prevent from ice forming for a certain period of time (called holdover time), in bad weather conditions for example snowing or raining. Anti-icing involves the following:

- The composition of anti-icing fluid is more concentrated;
- The fluid does not allow icing to form until take-off, despite the external negative weather conditions;
- Additives are added to the fluid to retard the effect of icing.

1.4.2 Snow removal methods

During the operation of passenger aircraft, several processing methods have been developed, which can be equally applied:

- Mechanic method. The surface of the aircraft is cleaned by hand using brushes, rubber scrapers and brooms. This is a cheap method, but very time consuming and laborious, and therefore it is not used in airports with high traffic.
- Air-thermal method. Special blowing machines are used that create a powerful flow of warm air. The use of this method is also limited due to the high risk of casing damage on imported aircraft. Also, thermal methods include placing the aircraft in a warm hangar and refueling with warm fuel.
- Physicochemical method. The surface of the aircraft is dousing with chemical reagents (anti-icing fluid). The most modern and effective way that not only fights ice, but also prevents its re-formation. In the event of continued precipitation, the surface of the aircraft after the first stage of treatment is coated with a thin layer of a different type of anti-icing fluid (differing in viscosity), which provides longer-term protection. The protective action time depends on the type of anti-icing fluid and weather conditions and can range from a few minutes (freezing rain) to 45 minutes (frost).

1.4.3 Types of de-icing and anti-icing fluids

Deicing fluids are composed of ethylene glycol or propylene glycol, along with other ingredients such as thickening agents, surfactants, corrosion inhibitors, colors. Propylene glycol-based fluid is more common because it is less toxic than ethylene glycol [13].

According to SAE International (Society of Automotive Engineers) standards there are four different types of aviation de-icing/anti-icing fluids:

- Type I;
- Type II;
- Type III;
- Type IV;

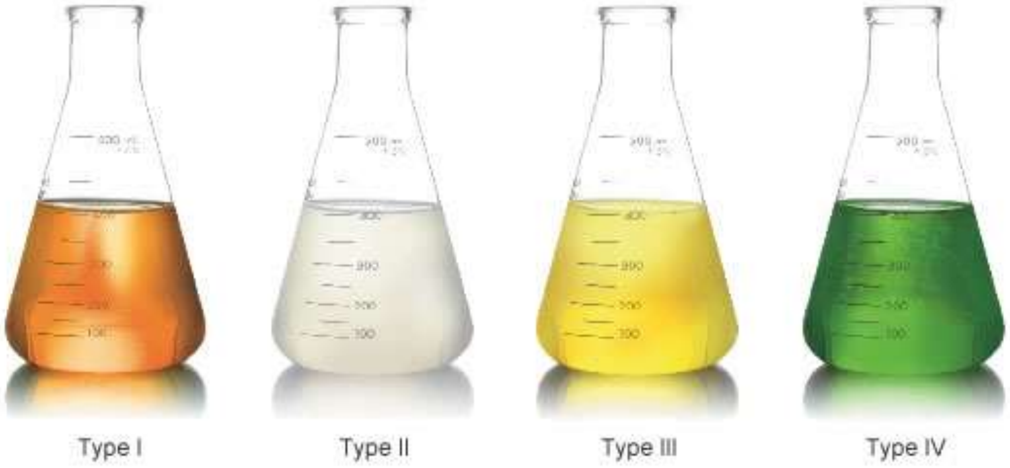


Fig. 1.4.3.1. De-icing/anti-icing fluids review [14]

Type I fluids allow to remove ice, because sprayed on hot (55–80 °C) at high pressure, but they have a low viscosity and they are considered as “unchickened”. This type of fluid can be used on any aircraft, as they blow off at low speeds. They also have the shortest holdover time (HOT-this is the time during which the protective properties of the liquid are maintained.) in active frost. Usually have orange color to aid in identification and application.

Fig. 1.4.3.2. De-icing fluid type I [15]

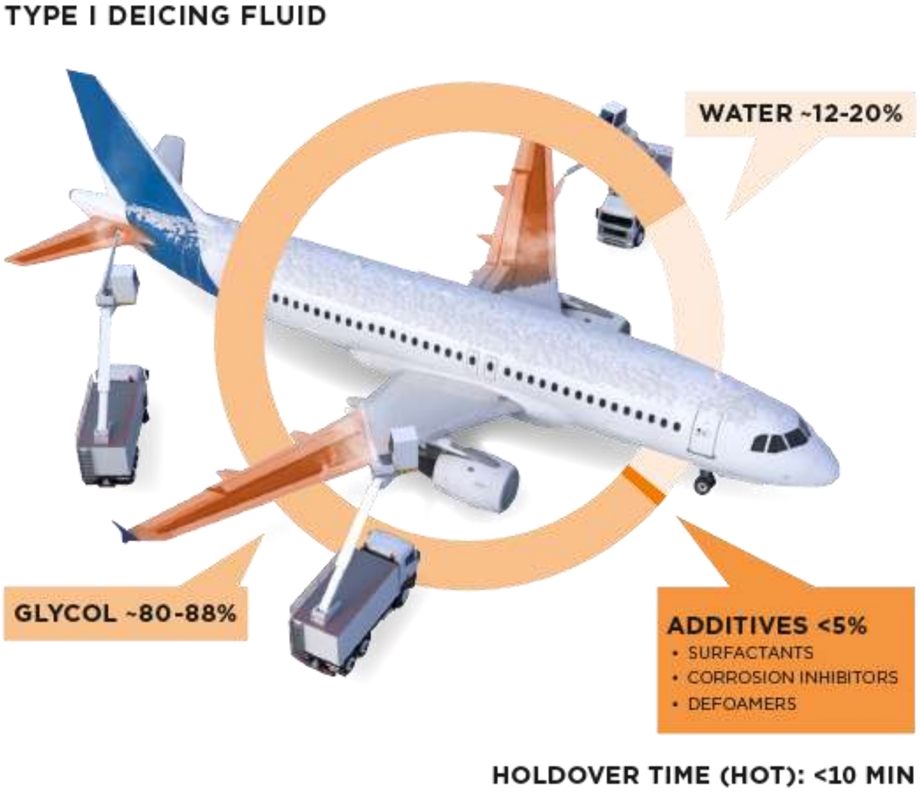
Type II fluids protect against icing. This type of fluid are pseudoplastic, which means that they comprise a polymetric thickening agent, which increases viscosity to prevent their flowing from surfaces of the aircraft. Unlike the type I fluid, type II fluid prevents snow and ice contamination from apron to take-off. Usually the fluid membrane will remain in place until the aircraft does not accelerate to speed 190 km/h. Commonly this fluid has white color and completely unnoticed on the aircraft.

Type III fluids also protect against icing. But this fluids have properties between Type I and Type II fluids, because they are designed specially for use on slower aircrafts with a speed 120 km/h. Type III fluids also contain thickening agents and offer longer HOT than previous Types. Type III fluids are yellow.

Fig. 1.4.3.3. De-icing fluid type III [16]

Type IV fluids have the same purpose and meet the same requirements as Type II fluids. But this type of fluids provide a longer HOT, because the liquid contains a high concentration of thickening agents that provide protective properties. Also have green color as another fluids.

Fig.1.4.3.4. Deicing fluid Type IV [17]



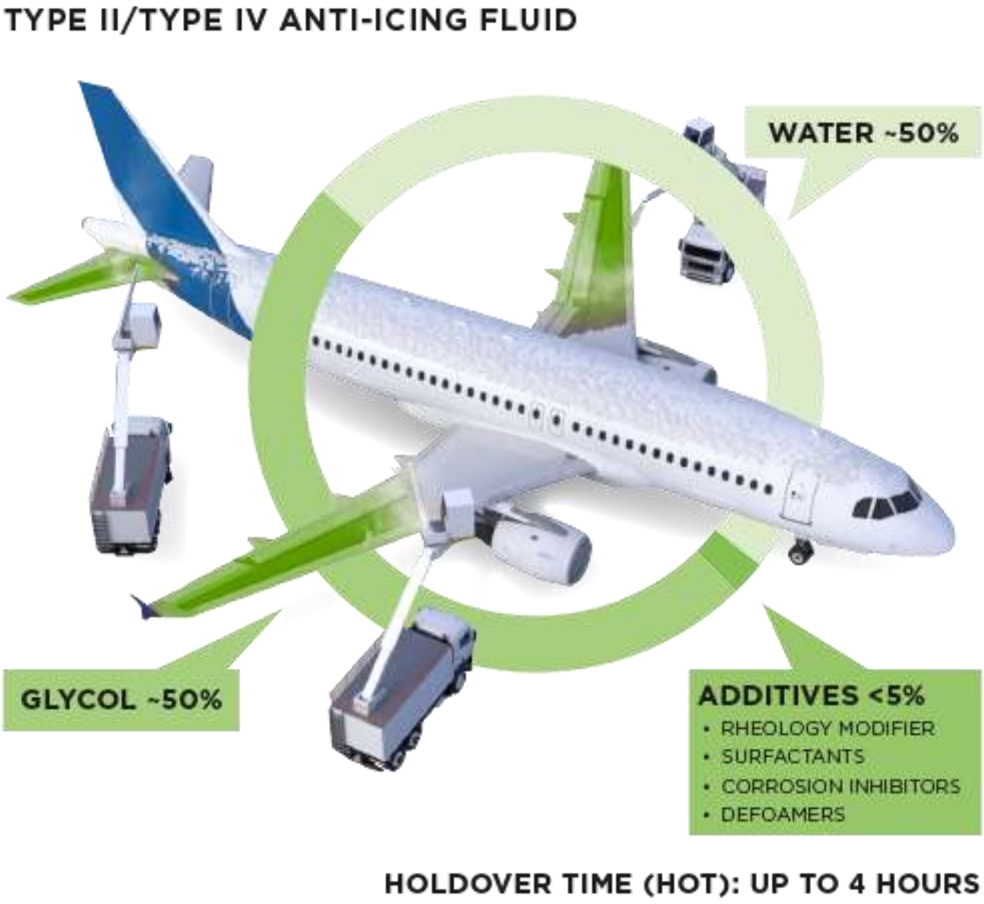
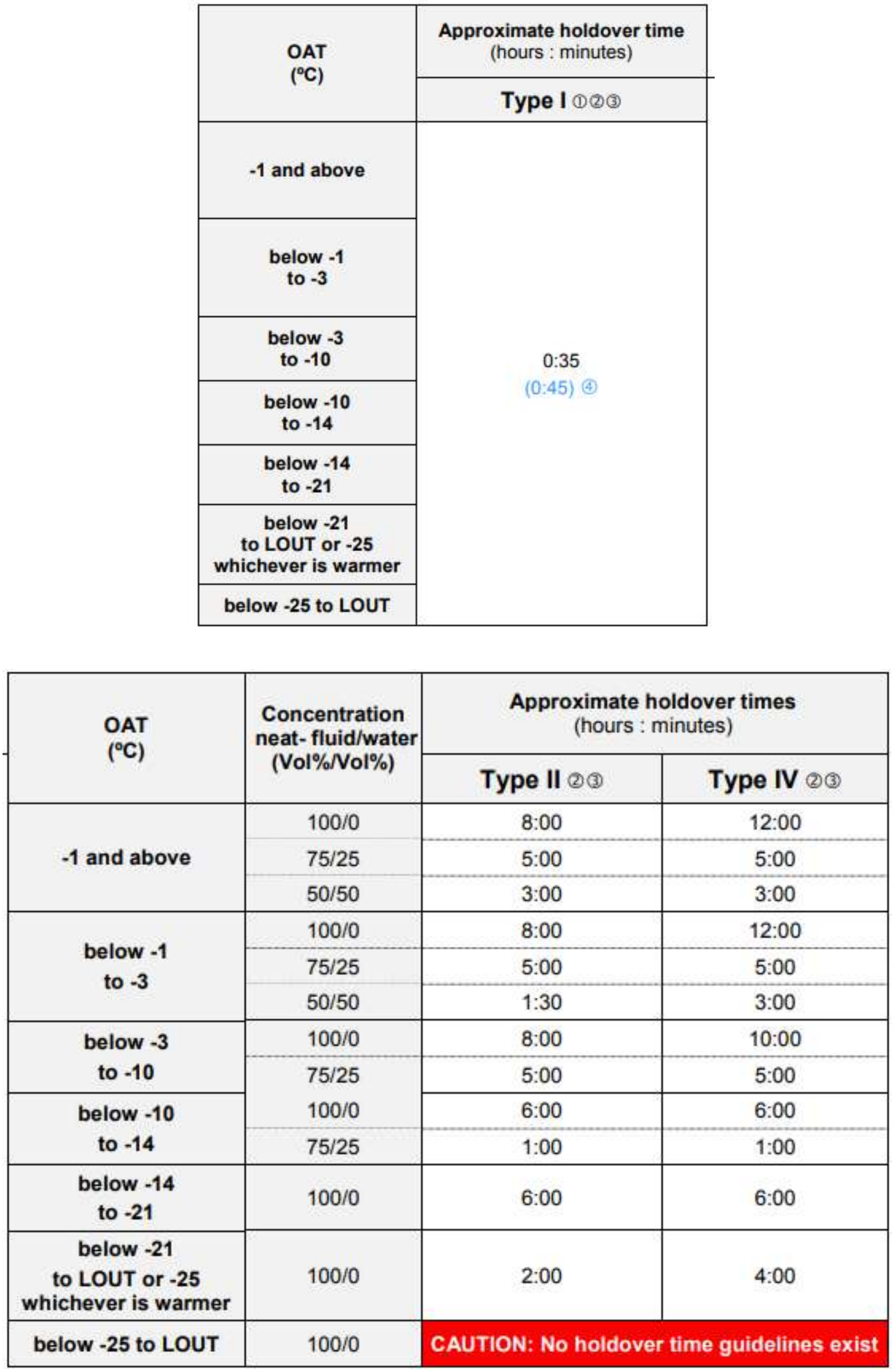


Fig.1.4.3.5. Comparison between Type I and Type II/IV de-icing fluids [18]

1.4.4 Holdover time tables

Holdover time (HOT) - the estimated time that deicing/anti-icing fluid will prevent the formation of frost or ice and the accumulation of snow on the critical surfaces of an aircraft.

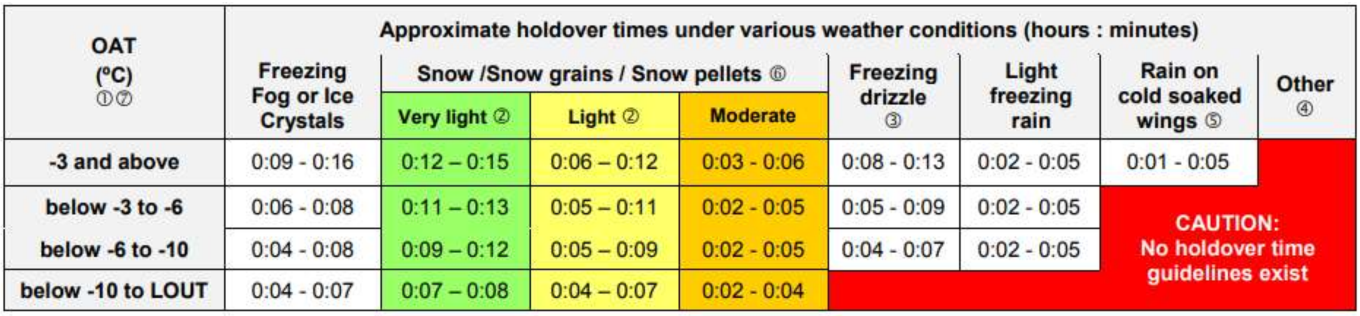
Holdover time begins when the final application of deicing/anti-icing fluid commences and expires when the deicing/anti-icing fluid loses its protection effectiveness. It is determined by the extent to which it is expected that applied fluid will remain active on the aircraft surfaces; active fluid must be able to provide protection from the accretion of frozen or semi-frozen contaminants in the prevailing conditions. Holdover Time begins at the start of the anti icing operation. If a two-step operation is used, then it begins at the start of the final (anti-icing) step. By definition therefore, holdover time will have effectively run out when frozen deposits start to form or accumulate on treated aircraft surfaces. [19]



OAT (°C)	Approximate holdover time (hours : minutes)
	Type I ①②③
-1 and above	0:35 (0:45) ④
below -1 to -3	
below -3 to -10	
below -10 to -14	
below -14 to -21	
below -21 to LOUT or -25 whichever is warmer	
below -25 to LOUT	

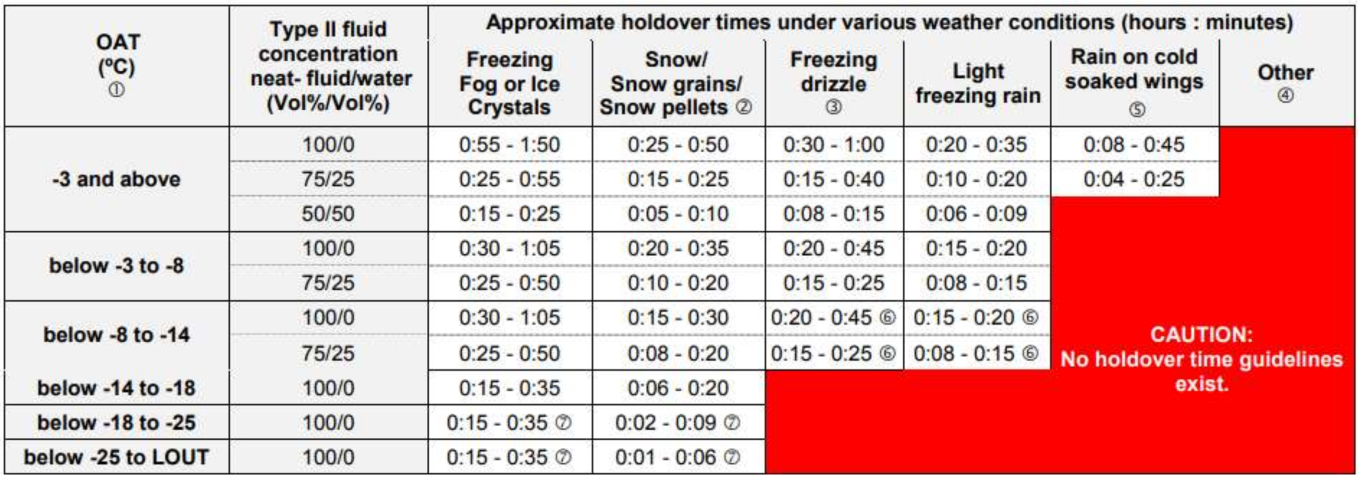
OAT (°C)	Concentration neat- fluid/water (Vol%/Vol%)	Approximate holdover times (hours : minutes)	
		Type II ②③	Type IV ②③
-1 and above	100/0	8:00	12:00
	75/25	5:00	5:00
	50/50	3:00	3:00
below -1 to -3	100/0	8:00	12:00
	75/25	5:00	5:00
	50/50	1:30	3:00
below -3 to -10	100/0	8:00	10:00
	75/25	5:00	5:00
below -10 to -14	100/0	6:00	6:00
	75/25	1:00	1:00
below -14 to -21	100/0	6:00	6:00
below -21 to LOUT or -25 whichever is warmer	100/0	2:00	4:00
below -25 to LOUT	100/0	CAUTION: No holdover time guidelines exist	

Fig.1.4.4.1 Active Frost Holdover Times for Type I, II and IV fluid mixtures. [20]



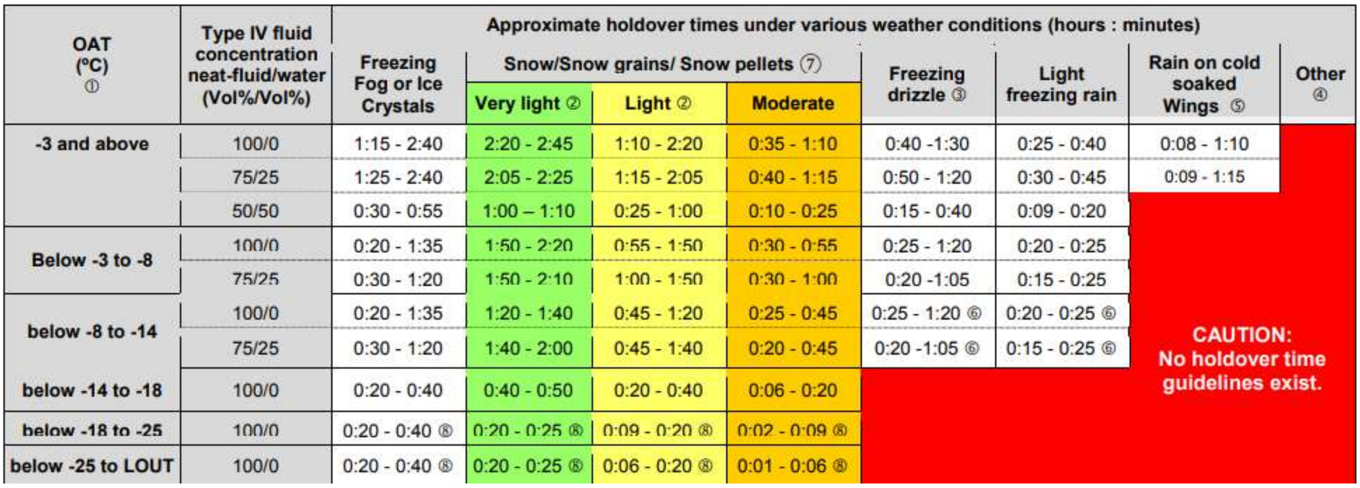
OAT (°C) ①⑦	Approximate holdover times under various weather conditions (hours : minutes)							
	Freezing Fog or Ice Crystals	Snow /Snow grains / Snow pellets ⑥			Freezing drizzle ③	Light freezing rain	Rain on cold soaked wings ⑤	Other ④
		Very light ②	Light ②	Moderate				
-3 and above	0:09 - 0:16	0:12 – 0:15	0:06 – 0:12	0:03 - 0:06	0:08 - 0:13	0:02 - 0:05	0:01 - 0:05	
below -3 to -6	0:06 - 0:08	0:11 – 0:13	0:05 – 0:11	0:02 - 0:05	0:05 - 0:09	0:02 - 0:05	CAUTION: No holdover time guidelines exist	
below -6 to -10	0:04 - 0:08	0:09 – 0:12	0:05 – 0:09	0:02 - 0:05	0:04 - 0:07	0:02 - 0:05		
below -10 to LOUT	0:04 - 0:07	0:07 – 0:08	0:04 – 0:07	0:02 - 0:04				

Fig.1.4.4.2 Holdover times for Type I fluid mixtures. [20]



OAT (°C) ①	Type II fluid concentration neat- fluid/water (Vol%/Vol%)	Approximate holdover times under various weather conditions (hours : minutes)					
		Freezing Fog or Ice Crystals	Snow/ Snow grains/ Snow pellets ②	Freezing drizzle ③	Light freezing rain	Rain on cold soaked wings ⑤	Other ④
-3 and above	100/0	0:55 - 1:50	0:25 - 0:50	0:30 - 1:00	0:20 - 0:35	0:08 - 0:45	
	75/25	0:25 - 0:55	0:15 - 0:25	0:15 - 0:40	0:10 - 0:20	0:04 - 0:25	
	50/50	0:15 - 0:25	0:05 - 0:10	0:08 - 0:15	0:06 - 0:09		
below -3 to -8	100/0	0:30 - 1:05	0:20 - 0:35	0:20 - 0:45	0:15 - 0:20		
	75/25	0:25 - 0:50	0:10 - 0:20	0:15 - 0:25	0:08 - 0:15		
below -8 to -14	100/0	0:30 - 1:05	0:15 - 0:30	0:20 - 0:45 ⑥	0:15 - 0:20 ⑥	CAUTION: No holdover time guidelines exist.	
	75/25	0:25 - 0:50	0:08 - 0:20	0:15 - 0:25 ⑥	0:08 - 0:15 ⑥		
below -14 to -18	100/0	0:15 - 0:35	0:06 - 0:20				
below -18 to -25	100/0	0:15 - 0:35 ⑦	0:02 - 0:09 ⑦				
below -25 to LOUT	100/0	0:15 - 0:35 ⑦	0:01 - 0:06 ⑦				

Fig.1.4.4.3 Generic holdover times for Type II fluid mixtures [20]



OAT (°C) ①	Type IV fluid concentration neat-fluid/water (Vol%/Vol%)	Approximate holdover times under various weather conditions (hours : minutes)							
		Freezing Fog or Ice Crystals	Snow/Snow grains/ Snow pellets ⑦			Freezing drizzle ③	Light freezing rain	Rain on cold soaked Wings ⑤	Other ④
			Very light ②	Light ②	Moderate				
-3 and above	100/0	1:15 - 2:40	2:20 - 2:45	1:10 - 2:20	0:35 - 1:10	0:40 -1:30	0:25 - 0:40	0:08 - 1:10	
	75/25	1:25 - 2:40	2:05 - 2:25	1:15 - 2:05	0:40 - 1:15	0:50 - 1:20	0:30 - 0:45	0:09 - 1:15	
	50/50	0:30 - 0:55	1:00 – 1:10	0:25 - 1:00	0:10 - 0:25	0:15 - 0:40	0:09 - 0:20		
Below -3 to -8	100/0	0:20 - 1:35	1:50 - 2:20	0:55 - 1:50	0:30 - 0:55	0:25 - 1:20	0:20 - 0:25		
	75/25	0:30 - 1:20	1:50 - 2:10	1:00 - 1:50	0:30 - 1:00	0:20 -1:05	0:15 - 0:25		
below -8 to -14	100/0	0:20 - 1:35	1:20 - 1:40	0:45 - 1:20	0:25 - 0:45	0:25 - 1:20 ⑥	0:20 - 0:25 ⑥	CAUTION: No holdover time guidelines exist.	
	75/25	0:30 - 1:20	1:40 - 2:00	0:45 - 1:40	0:20 - 0:45	0:20 -1:05 ⑥	0:15 - 0:25 ⑥		
below -14 to -18	100/0	0:20 - 0:40	0:40 - 0:50	0:20 - 0:40	0:06 - 0:20				
below -18 to -25	100/0	0:20 - 0:40 ⑧	0:20 - 0:25 ⑧	0:09 - 0:20 ⑧	0:02 - 0:09 ⑧				
below -25 to LOUT	100/0	0:20 - 0:40 ⑧	0:20 - 0:25 ⑧	0:06 - 0:20 ⑧	0:01 - 0:06 ⑧				

Fig.1.4.4.4 Generic holdover times for Type IV fluid mixtures [20]

Conclusions to the section

As a result of the analysis of information sources on the subject of master’s work, the following conclusions can be drawn:

1. De-icing/anti-icing technologies are one of the most important part when preparing an aircraft for the flight. This stage is an integral part of civil and military aviation. Primarily de-icing/anti-icing treatment should provides flight safety and economic efficiency, as well as maintaining of high aerodynamic characteristics, operability of controls, units, engines and reduction of aircraft take-off mass. Particular attention should be paid to which surface should be treated with de-icing and anti-icing.
2. De-icing vehicle namely “Safeaero 220” is the single operator deicer. With its wide operational radius and tight size, it’s the best special vehicle to provide deicing operations on aircraft ranging from small aircraft up to the Boeing 747. This special vehicle provides fast and high efficient maintenance.
3. Engineers who work on this special vehicle need to be especially careful from the beginning of the process of de-icing/anti-icing to the end. They must perform work stricly according to technology and move accroding to permissible maneuvering areas. Carry out timely special vehicles maintanance and certification of employees. Human life, the integrity of the aircraft, as well as the health of all people who are preparing the aircraft for departure depend on the accuracy of their actions.
4. According to Society of Automotive Engineers there are 4 different types of fluids which approved in aviation as de-icing/anti-icing fluids. Each of them has it’s own properties, composition and is used in a different weather condtions.
5. Holdover time also one of the most important thing during preparing aircraft to departure. This time are the calculated length of time that a given de-icing/anti-icing liquid will prevent the formation of frost or ice, or the accumulation of snow, on the critical surfaces of an aircraft so that the aeroplane can take-off safely.

SECTION 2

OPTIMIZATION OF AIRCRAFT DE-ICING/ANTI-ICING OPERATIONS

2.1 Recommended minimum amount of liquid

The amount of anti-icing fluid required will mainly depend on the volume and nature of the snow / ice deposits on the aircraft surfaces and the prevailing weather conditions during the treatment.

Weather conditions such as strong winds will affect how much de-icing fluid will be hit the surface of an aircraft.

Other factors affecting the amount of anti-icing fluid required may include be aimed at the work area with the jet of a jet engine, spray technique, visibility, color of liquids, presence on surfaces of the liquid applied at the first stage, available equipment, qualifications staff. Also, the specific properties of the anti-icing fluid itself may have an impact on its sprayed amount.

Precipitation gradually dilutes all types of anti-icing fluids until the applied layer of liquid will not freeze and ice formation will not begin. It is necessary to use such the amount of hot anti-icing fluid to take before flying out or applying anti-icing composition to prevent its possible freezing.

The amount of fluid used when performing snow / ice removal procedures should be be sufficient to completely clean all contaminated critical aircraft surfaces. Air surface the vessels after processing must be clean, damp, shiny, free from turbidity and lumps of applied liquids.

When performing de-icing treatment, you should be especially careful to ensure that after the completion of the surface treatment of the aircraft were covered with a continuous film of liquid. The presence of tears in the film liquid indicates that the liquid is applied unevenly and, under these conditions, a full-fledged protective has no effect. An insufficient amount of liquid leads to a decrease in the quality of processing and, accordingly, it is equal to a decrease in the time of protective action.

2.2 Applying technologies that reduce the quantity of anti-icing fluid

Reducing the amount of anti-icing fluid used can have a positive impact on both the handling cost of the aircraft and the environment. Indicators such as outside temperature, amount and location of deposits on critical aircraft surfaces, meteorological conditions at the time of processing should always be considered by crew and ground personnel when choosing a processing method.

Currently, there are several alternative methods for removing aircraft ground icing, which are recommended to be used before using anti-icing fluids.

2.2.1 Mechanical de-icing

The mechanical de-icing method is especially effective for large quantities snow or slush on the aircraft. It allows you to remove not adhered to the surface the aircraft has snow and ice deposits, but does not provide protection against their re-formation. Carrying out anti-icing measures, limited only by the mechanical method, is not permissible. [21]

The method of mechanical de-icing is recommended to be used before applying anti-icing liquids or other available methods, especially in cases where the aircraft was on a long parking stand.

Manual snow removal techniques should be used where and when possible, if this does not create threats to flight safety. Moreover, at very low temperatures, the use of a liquid based glycol, according to the manufacturer's specifications, is limited by the rules of their use. Under these conditions, the use of a mechanical processing method may be the only possible one.

When removing icing by mechanical means, special attention should be paid to prevention of scratches on the lacquer casing and other damage to structural aircraft elements. Therefore, to perform this procedure, it is necessary to use only a special safe equipment.

Currently, a wide range of devices are used, which are advisable to use for removal of snow and ice deposits from aircraft, such as:

- Brooms;
- Brushes;
- Ropes;
- Scrapers.

Fig.2.2.1 Mechanical de-icing the surface of an aircraft with a broom [22]

When using hand tools to clean the aircraft from existing snow and ice deposits, special care must be taken to avoid damage to very sensitive and fragile sensors and navigation antennas. Full and static sensors are also very vulnerable pressure, angle of attack. When sweeping or pushing snow off the aircraft, care must be taken in the movement and avoid getting dirt into any voids on the fenders or stabilizers:

- Brooms and Brushes. Brooms and brushes are typically used to clean windows and other sensitive aircraft areas where the use of hot fluid is restricted or prohibited. Broomsticks also effective for removing accumulations of light and dry snow from the aircraft surface.
- Ropes. The ropes are used to clear large accumulations of snow from the wing or stabilizer. Rope usually is used in a reciprocating motion by two personnel, lightly touching the surface of the aircraft. The rope can also be used to remove condensed frost from the top of the wing or tail plumage. Special care must be taken to avoid damage to the paintwork aircraft and plating.
- Scrapers. Scrapers are especially effective for removing large accumulations of wet material from aircraft surfaces and heavy snow.

When providing mechancal de-icing critical areas of an aircraft, consideration should be given to he following points and limitations:

- Since the devices used often come into contact with the aircraft casing, to protect surfaces from damage, precautions must be taken. Whenever possible, it is recommended to use fully rubber attachments or attachments with handles and areas in contact with surface of the sun, covered with rubber or a similar soft material.
- It is necessary to pay special attention to personnel safety issues, especially when working in hard-to-reach places when ladders or other similar ancillary equipment is used. Slippery surfaces or unstable equipment can make it very dangerous to move around.
- Personnel sweeping snow from the wing or stabilizer are usually located on these surfaces. This an extremely unsafe practice with a high risk of slipping and falling. Also, many surfaces are not designed to support the weight of a person. For safety reasons, the sweeping of the wings and tail make the plumage from the cradle of the de-icing machine or from a high stepladder.
- Before performing mechanical cleaning of the wing, make sure that the aircraft controls are in neutral (slats, flaps and spoilers are retracted).

- Make sure the horizontal stabilizer is fully set to the NOSE DOWN position (leading edge in the extreme upper position).
- To prevent the aircraft from capsizing on its tail, the removal of heavy snow formation must start with the tail.
- When performing work, always clean from the front edge of the wing or stabilizer to the rear, and from top to bottom. If these rules are not observed, snow and ice formations can fall into free cavities of mechanization and, subsequently, damage them.
- Thoroughly remove any ice and snow deposits from controls, hinges, hinges and free cavities.
- After cleaning the aircraft with mechanical means, it is imperative that thorough check of the surface by touch. If during the verification process any frozen to the critical surface is a snow-ice deposit, it must be removed before departure. To obtain critical surfaces are completely clean, may need to continue cleaning with another available method.

2.2.2 De-icing with hot air

Removal of snow and ice deposits using hot air is quite effective and sometimes the only possible way to delete local icing. Positive result is achieved through a combination of heated air and low speed airflow, which melts and evaporates snow and ice deposits from the critical surfaces of the aircraft.

This method removes deposits, but does not provide protection against re-formation. It is impossible to completely de-icing the aircraft with hot air.

When using this method, special precautions must be taken. Water, formed as a result of the melting of snow-ice deposits, can get into the aircraft controls or other free cavities and, in the future, freeze. This in turn can lead to failure or that even worse, the malfunctioning of aircraft systems. Moreover, with the ongoing precipitation under the influence of hot air on warm and humid, due to melting, aircraft surfaces may, as a consequence, form ice or other snow and ice deposits.

The operator of the hot air installation must control the temperature and duration of exposure to aircraft surfaces in order to avoid overheating of the processed parts of the aircraft. Such attitudes give off enough heat to damage them.

Hot air is used mainly to remove snow and ice deposits from wheels, carbon components of chassis braking devices, input channels and output devices of motors, sensors, air pressure receivers and other parts of the aircraft, where the application of anti-icing liquids restricted or prohibited.

Fig.2.2.2.1 De-icing of aircraft by hot air flow [23]

When processing, special care must be taken not to direct the air stream directly into openings, including full and static pressure receptacles.

Removal of icing from the engine fan blades may only be carried out using hot air. If hot air is used to de-icing in the inlet ducts and fan blades of motors, it is necessary to strictly control the temperature and pressure of the air stream.

To avoid thermal stresses in the metal, when supplying hot air, the temperature must be increased gradually.

For certain types of motors using non-metallic materials, the temperature of the supplied hot air is substantially limited.

When hot air is used to remove icing from structural elements of the landing gear the temperature of the supplied air should not exceed 40°C. Work must be carried out from top to bottom until complete removal of all snow and ice deposits.

The supply air pressure must not exceed 5 Psi (0.35 Bar). Do not supply air to the fairings more than 1.5 Psi (0.1 Bar).

Do not direct pressurized air at:

- Gaskets for chassis drives;
- Bearing supports;
- Rotary drives;
- Articulated joints;
- Electrical wiring;
- Position sensors;
- Connectors.

High air pressure can squeeze grease out of bearings, assemblies, brakes and other lubricated machinery.

The use of hot air to remove icing from the fuselage is strictly prohibited.

2.2.3 De-icing with compressed air

Deicing with compressed air deicers is sufficient effective and compromise de-icing treatment. With this method, compressed air in the form of a high-speed air jet can be used either without liquid or together with anti-icing fluid.

Methodology for using compressed air to remove snow and other types of contaminants from critical surfaces of the aircraft is designed based on the need to reduce the consumption of anti-icing liquids for environmental and economic reasons. This is one of the promising areas of development anti-icing technology, although a compromise, but based on the latest research and development tests, this technique has significant potential.

Compressed air jet can be used in accordance with "Forced Air / Fluid Equipment for Removal of Frozen Contaminants "to remove snow and ice deposits from aircraft surfaces, both without liquid and together with liquid.

The use of compressed air is also subject to mandatory manufacturer approval aircraft.

This method allows both to remove snow-ice deposits, and, if applied anti-icing fluids, to provide the necessary protection against their re-formation.

The effectiveness of compressed air in removing contaminants from critical aircraft surfaces depends on a variety of factors, including airflow speed and temperature, operator training and experience, outdoor temperature, weather conditions, fluids used, etc.

When blasting with compressed air, always clean from the leading edge of the wing or stabilizer to the rear, and from the end to its base. If these rules are not followed, snow and ice formations can get into the free cavities of the mechanization and, subsequently, damage them.

The spray nozzle should be no closer than 1 meter from the aircraft surface. This limitation is associated with the possibility of damage to the structure of an aircraft manufactured with using composite materials. The compressed air jet must not be directed directly into motors, full and static pressure receiver openings or angle of attack sensors.

Avoid using compressed air near the cockpit glass wipers, surfaces made of rubber, plastic or other soft material, as this may damage them.

De-icing procedures using compressed air, depending on the applicable the moment of processing the conditions can be done in the following ways:

1. Compressed air only.

The use of compressed air only when treating is especially effective for removing dry, not frozen to snow plane surface. The compressed air supply must be at approximately the same temperature as the outdoor temperature. If the temperature of the compressed air is higher, snow / ice deposits can melt and, in the future, cause icing of the aircraft surface. After the completion of the work, the operator of the deicer must check by touch that the treated surface is clean and free of any form of contamination. If compressed air has not removed all contaminants from the treated surface or there is uncertainty about their complete removal, it is necessary to additionally treat with heated Type I anti-icing fluid.

2. Compressed air blasting with Type I anti-icing fluid.

In this method, heated Type I fluid is injected directly into the high-speed air flow. The main advantage of this method, compared to using only compressed air, is that the heated Type I fluid carries more thermal energy than just air flow. The heat of the liquid, in this case, is the main mechanism for removing impurities frozen to critical surfaces, therefore, this method is more effective for removing snow and ice deposits frozen to the surface aircraft.

3. Compressed air treatment using Type II or Type IV anti-icing fluids.

With this method, a Type II or Type IV fluid is either injected directly into the high-speed air flow, or sprayed over the air flow. A combination of anti-icing fluid and High-speed airflow has several advantages, although it has several serious disadvantages:

- When injected or sprayed over high velocity airflow, the liquid begins to act shear force. If the shear force exceeds the yield point of these fluids, they, by virtue of their characteristics, lose their viscosity and, accordingly, the time of protective action.
- The next most important problem is increased foaming, which also negatively affects on the protective characteristics of anti-icing fluids. When performing work, it is necessary to strictly adhere to and not allow violations of the rules for the use of used anti-icing liquids.

Removing snow and ice deposits using liquids in two stages:

In case of a large accumulation of snow and ice deposits on the surfaces of the aircraft, for minimizing the flow of anti-icing fluid a standard treatment procedure is advisable perform in two stages. This method is applicable when the weather conditions do not contribute to the icing of the aircraft and the protective action time is not critical.

In the first step, it is recommended to use water or Type I liquid mixed with water, heated at least than up to 60°C and not more than up to 82°C.

The concentration of the anti-icing fluid in the mixture for the first stage is selected from such a condition that the freezing point of the mixture is not more than at 3°C.

The temperature of the wing skin may be lower than the ambient temperature. Under these conditions, it may a mixture of liquids with a higher concentration of glycol is required to ensure sufficient supply freezing temperature of the mixture.

The second stage of treatment must be carried out before the liquid applied in the first stage, freeze (usually no more than 3 minutes). If the liquid freezes, the first step must be repeated.

Application of anti-icing fluid in the second stage of de-icing to a limited a period of time prevents the formation of ice, snow, slush or frost on critical surfaces aircraft before departure.

In the second step, it is recommended to treat with a mixture of Type I anti-icing fluid with water heated to not less than 60°C and not more than 82°C.

The concentration of Type I liquid in the mixture used in the second stage is selected from the condition that the freezing point of the liquid was at least 10°C below the outside temperature.

2.3 Alternative methods that reduce fluid use

Private jet pilots can avoid de-icing by arranging for the aircraft to stay in the hangar. However, at some airports, the cost of overnight stay in the hangar can be more expensive than the de-icing procedure. Many airports have no free hangar space for private jets, so the aircraft will be exposed to weather conditions prior to flight. [24]

A private jet can also be freed of ice by placing it for a shorter period in a heated hangar prior to departure. This less expensive option will help reduce or eliminate the need for de-icing treatment. Often, during an hour spent by an aircraft requiring de-icing treatment in a heated hangar, all the ice on the aircraft's surface has time to melt.

At some private jet airports, passengers can board a private jet in Angar before the plane is towed out. During the winter months, this is the advice we most often give to Private Fly members.

Fig.2.3.1 Staying the aircraft in the hangar for protection from snow and ice [25]

Deicing operator training is one of the main elements impacting glycol source reduction and operational efficiencies.

Increased operator proficiency will assist in mitigating:

- Overuse of deicing fluid;
- Misuse of deicing fluid performance capabilities;
- Long de/anti-icing times.

Training simulators provide:

- Emulates function and feel of actual de/anti-icing vehicles;

- No-risk, low-cost training environment;
- Train anytime, anywhere;
- Train without employing fuel, fluid;
- Significantly improves proficiency of de/anti-icing operators.

Both initial and annual recurrent training for ground employees should be conducted to provide that all such employees obtain and retain a thorough knowledge of aircraft de-icing/anti-icing policies and procedures, including new procedures and lessons learned.

Training success shall be proven by an examination/assessment which shall cover all training subjects laid down in section 2 hereafter.

The theoretical examination shall be in accordance with EASA (European Union Aviation Safety Agency) Part-66 or any equivalent requirements.

Only persons passing this examination can be qualified. The pass mark shall be 80%.

For staff performing the actual de-icing/anti-icing treatment on aircraft for the first time, practical training with an aircraft and the de-icing/anti-icing vehicles used at the station concerned must be included.

An aircraft is required in order to familiarize new trainees with the relevant typical aircraft surfaces/components and identification of no spray areas.

Prior to receiving final qualification, staff performing de-icing / anti-icing operations (driving and/or spraying) shall demonstrate competence in de-icing under operational conditions to a qualified supervisor.

For staff performing the actual de-icing/anti-icing treatment, practical training with the deicing/anti-icing vehicles used at the station concerned shall be included.

A practical assessment shall be performed as “a demonstration of skill” and only contains a fail /approve determination.

Records of personnel training and qualifications shall be maintained for proof of qualification.

For every de-icing/anti-icing treatment the following items must be listed:

- Aircraft registration and flight number.
- Date, starting time and end time of the treatment.

- Name(s) of person(s) who carried out the treatment.
- Name of person who carried out the post de-icing/anti-icing check and/or the check after preventive anti-icing treatment.

Kind of treatment:

- Preventive anti-icing or early de-icing.
- Standard de-icing/anti-icing including one-step/two-step method.
- Local clear-ice/frost removal.
- Type of technical de-icing.
- Anti-icing Code (when applicable).
- De-icing/anti-icing units used.
- Type, full brand name and quantity of the de-icing/anti-icing fluid used.
- OAT at the time of the treatment.
- Weather conditions at the time of the treatment.
- Quantity (litres) of de-icing and/or anti-icing fluid used.[26]

This information has to be saved at least until the start of the next winter period.

Fig. 2.3.2 De-icing trainers [27]

Fig.2.3.3 Employees are trained in deicing [27]

Fig.2.3.4 Elephant beta trainer [27]

Conclusions to the section

As a result of the researching oprimization of aircraft de-icing/anti-icing operations on the subject of master's work, the following conclusions can be drawn:

1. The amount of anti-icing fluid required mainly depend on the volume and nature of the snow deposits on the aircraft casings and the prevailing weather conditions during the treatment. Weather conditions such as strong winds will affect how much de-icing fluid will be hit the surface of an aircraft.
2. There are several methods with the help which we reduce the needed amount of de-icing/anti-icing liquid for deicing, such as; Mechanical(with the help of scrapers; brooms; brushes; ropes), Compressed air flow, Hot air flow.
3. Each of the staff who provides the de-icing/anti-icing treatment must pass the trainings and regularly confirm knowledge according to technologies.Who didin’t pass the exam not allowed to work.

4. But there are also more radical methods to reduce the usage and quantity of de-icing/anti-icing liquids, namely to stay the aircraft in the hangar.This method more suitable for small private Jets, than for bigger aircrafts like Airbus 380 or Boeing 747. Time in the hangar will cost more than anti-icing treatment.

SECTION 3

CALCULATIONS OF ELEMENTS OF HYDRAULIC SYSTEM OF THE SPECIAL VEHICLE

3.1 Determination of overall dimensions and performance characteristics of a round vortex brush

One of the conditions for the normal operation of the vortex brush is the complete pressing of its open working cavity to the treated surface (Fig. 3.1.1, Fig. 3.1.2). Therefore, to clean the surface of the aircraft with different curvatures, the end peripheral surface of the working head must have a seal.

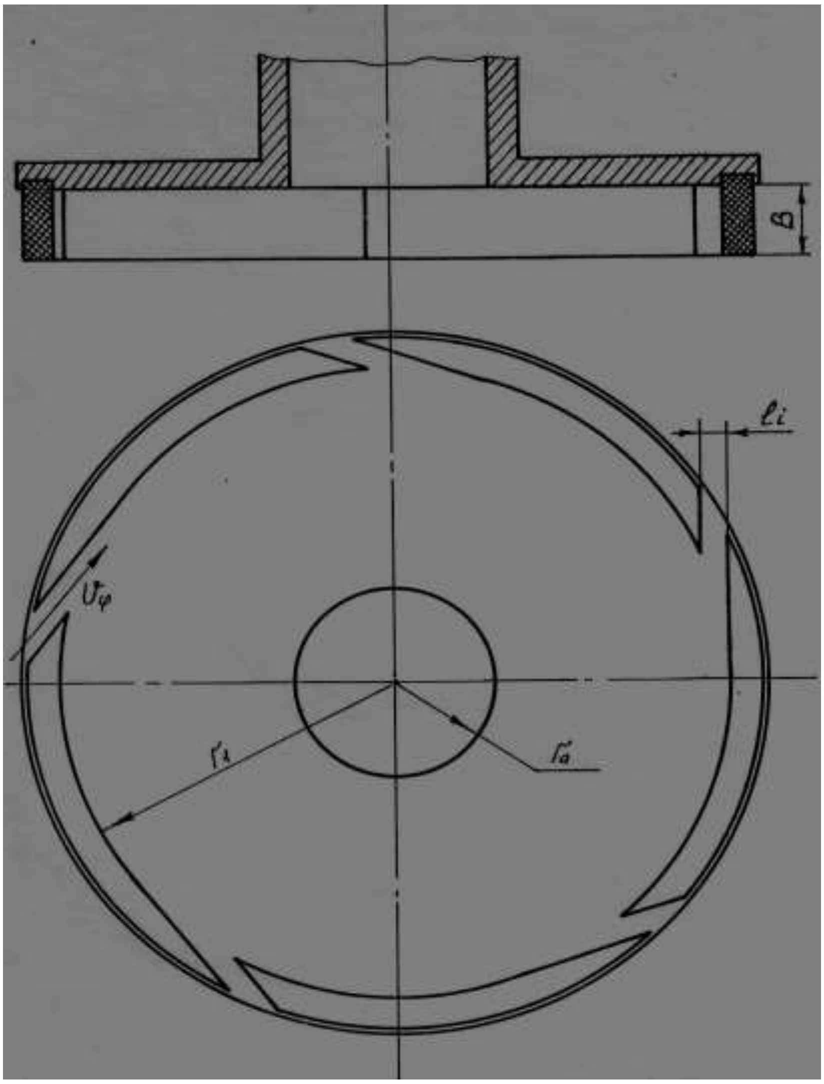


Fig. 3.1.1 Vortex brush of the special vehicle [28]

Fig. 3.1.2 Vortex brush of the special vehicle

The required amount of curvature compensation δ for the working brush ø 200mm we calculate by the formula:

$$\delta = R - \frac{1}{2}\sqrt{4 \times 1{,}9^2 - D^2} \qquad (3.1)$$

where:

R – radius of curvature of the surface;

D – diameter of the working brush.

At R = 1,9m and D = 0,2m.

$$\delta = 1{,}9 - \frac{1}{2}\sqrt{4 \times 1{,}9^2 - 0{,}2^2} = 0{,}00263\,(\mathrm{m}) = 2{,}6\,(\mathrm{mm})$$

The compensating capacity of the selected compaction material (pile) without loss of stability is approximately 20%, so to compensate for the curvature of 2.6 mm, it is necessary that the height of the pile B was:

$$B \geq \delta \frac{100}{20}$$

$$B \geq 2{,}6 \times 5 = 13\ (\mathrm{mm})$$

To ensure a small margin, take B = 15 mm.

According to the selected diameter equal to 2 r_1 = 20 cm = 0.2 m, the width of the pile B and the relative area of the nozzles $\overline{F_c} = 0{,}05 \ldots 0.1$, determine the area of the nozzles according to formulas [29]:

$$\overline{F_c} = \frac{\sum l}{2\pi r_1} \Rightarrow \sum l = \overline{F_c}\, 2\pi r_1 \tag{3.2}$$

If $\overline{F_c} = 0{,}07$, then:

$$\sum l = 0{,}07 \times 2 \times 3{,}14 \times 0{,}1 = 0{,}04398\ (\mathrm{m})$$

Round off $\sum l \approx 0{,}044$ m

At the length of one nozzle l_i = 0,01 m the number of nozzles will be equal to:

$$\Pi_c = \frac{\sum l}{l_i} = \frac{0{,}044}{0{,}01} = 4{,}4$$

Round the result to an integer and take $\Pi_c = 5$

Check the relative cross-sectional area of the nozzles:

$$\overline{F_c} = \frac{\sum_{i=1}^{5} l_i}{2 \times 3{,}14 \times r_1} = \frac{0{,}05}{0{,}628} = 0{,}0796$$

Find the total area of the nozzles by the formula:

$$F_c = \overline{F_c} \times 2\pi r_1 \times B \tag{3.3}$$

$$F_c = 0{,}0796 \times 2 \times 3{,}14 \times 0{,}1 \times 0{,}015 = 7{,}5 \times 10^{-4}\ (\mathrm{m}^2)$$

Determine the tangential velocity ($V\varphi$) of air entry into the annular channel of the vortex brush [29] for different ΔPa and r_a by the formula:

$$V_{\varphi}^{2}=\frac{2\times\Delta P_{a}\times\overline{r_{a}^{2}}}{\rho\left(1+\overline{F_{c}^{2}}\right)} \tag{3.4}$$

so:

$$V_{\varphi}=\sqrt{\frac{2\times\Delta P_{a}\times\overline{r_{a}^{2}}}{\rho\left(1+\overline{F_{c}^{2}}\right)}}$$

where $\Delta P_a = P_1^{*} - P_a$; the pressure difference at the entrance to the annular channel of the educational brush and its axis, Pa;

$\overline{r_a^2}=\frac{r_a}{r_1}$ - dimensionless radius of the inlet of the diaphragm of the vortex brush;

$\rho = 1.29$ kg/m^2 - air density.

To determine the force of compression and displacement of the vortex brush, it is necessary to know the pressure distribution in the annular channel and the coefficient of friction of the sealing material (pile) on the treated surface.

The distribution of static pressure in the annular channel of the vortex head is determined by:

$$P=P_{1}^{*}-\Delta P_{a}\left(\frac{r_{a}}{r}\right)^{2} \tag{3.5}$$

The pressing force (separation) is determined by the integration of expression (3.5).

The pressing force (separation) is equal to:

$$P_{від}=\pi r_{a}^{2}\times\Delta P_{a}+\int_{r_{a}}^{\overline{r_{1}}}2\pi\times\Delta P_{a}\times r dr \tag{3.6}$$

$$P_{від}=\pi\times\Delta P_{a}\times r_{a}^{2}\left(1+2\ln\frac{1}{\overline{r_{a}}}\right).$$

From this formula it follows that the separation force increases with increasing pressure drop and the radius of the diaphragm hole r_a.

The shear force during anti-icing treatment of the aircraft is determined:

$$P_{зр} = P_{від} \times f \tag{3.7}$$

where f = 0.23 - coefficient of friction - sliding of pile on a paint and varnish covering.

The specific pressing force per unit area of the vortex brush is calculated by the formula:

$$\overline{P_{пит}} = \frac{P_{від}}{\pi \times r^2} \qquad (3.8)$$

According to the specific pressing force, knowing the specific load on the glider, determine the area of support.

Air consumption ($G_{пов}$) is determined by expressing through the tangential velocity of air entry:

$$G_{пов} = F_c \times \rho \times V_\varphi \qquad (3.9)$$

According to the calculated air flow rate and the relative flow rate of anti-icing fluid

$$\overline{G_{рід}} = \frac{G_{рід}}{G_{пов}} \qquad (3.10)$$

determine the absolute consumption of anti-icing fluid. From the literature [29] , the optimal relative consumption of anti-icing fluid $\overline{G_{рід}} = 0,05$

so,

$$G_{рід} = G_{пов} \times 0,05$$

The data obtained during the calculations are given in Table 3.1

Table 3.1

The data obtained during the calculations

Indexes	**Differential pressure, ΔPa Pa**	**Relative radius $\overline{r_a}$**				
		0,2	**0,3**	**0,4**	**0,5**	**0,6**
Tangential velocity , V_φ	$5x10^3$	16,6	26,5	34,2	42,5	51,7
	$1x10^4$	23,9	36,3	47,7	62,8	74,2
	$1,5x10^4$	30,8	44,2	60,1	75,8	90,9
	$2x10^4$	33,0	51,9	74,4	86,0	104,6

Continuation of Table 3.1

Compressive force, $P_{від}$, N	$5x10^3$	23,5	45,9	73,1	91,2	112,5
	$1x10^4$	56,2	92,3	140,0	185,4	226,5
	$1,5x10^4$	76,2	142,0	211,4	284,0	345,1
	$2x10^4$	102	195,4	287,6	373,5	459,2
Shear effort, $P_{зр}$, N	$5x10^3$	5,8	12,8	15,7	22,0	24,8
	$1x10^4$	14,1	25,1	35,9	44,2	53,5
	$1,5x10^4$	20,2	31,9	50	66,0	75,8
	$2x10^4$	23,2	44,0	64,1	82,0	107,2
Specific pressing force $\overline{P_{пит}}$, N/M	$5x10^3$	845	1529,6	2260,1	2991,9	3641
	$1x10^4$	1645,6	3055	4529,2	5956,7	7281,9
	$1,5x10^4$	2529,3	4589,7	6800,2	8989,2	10859,9
	$2x10^4$	3275	6126,3	9089,3	11989,5	14569,0
Consumption of anti-icing fluid (kg/f) 10^{-3} $G_{рід}$	$5x10^3$	0,75	1,2	1,4	2,0	2,1
	$1x10^4$	1,2	1,5	2,1	2,9	3,3
	$1,5x10^4$	1,4	2,1	2,6	3,5	4,2
	$2x10^4$	1,5	2,4	3,2	4,0	4,7

According to the received data we make the table and we make the analysis of work of a vortex brush. It follows from Table 3.1 that the main influence on the air inlet velocity is the pressure drop ΔP_a and the relative radius of the diaphragm hole $\bar{r}_a$.

As it increases, the total pressure level in the vortex brush noticeably decreases.

Analyzing the table, we can say that to increase the intensity of the circular motion of the air in the vortex brush, it is advisable, at a given pressure drop ΔP_a, to increase the relative radius of the outlet. But its increase leads to a marked increase in the force of pressing the vortex brush to the surface to be treated. Therefore, the choice of value $\bar{r}_a$ is made taking into account these two opposing factors and there is a compromise between them. Also, with increasing radius of the outlet significantly increases the consumption of air and anti-icing fluid. With increasing pressure drop ΔP_a from 5x103 to 2x104 Pa, at constant, the flow of air and anti-icing fluid increases by about 2 times.

Based on the above, the following dimensional and operational parameters of the vortex brush are accepted:

- to ensure the productivity of anti-icing fluid up to 600 m^2 / hour, the diameter of the vortex brush is 200 mm;
- to increase the range of curved surfaces treated by the vortex brush is taken as the height of the seal B = 15 mm;
- from the obtained calculations it is seen that the average values are formed at a relative radius of the outlet of 0.3, thus $\bar{r}_{ш}$ = 30 mm. It is at this radius that it is possible to use a vortex brush to process the aircraft over the entire range of pressure drop;
- to exclude the displacement of contaminants with a vortex brush tangential nozzles in the seal have a rectangular cross section and is open from the treated surface. The size of one nozzle is assumed to be 15x10 mm;
- a brush is installed inside the vortex head to intensify the processing and improve its quality.

3.2 Calculation of overall dimensions of the brush

Activation of the processing process when using a brush, due to the combined effect of fluid and mechanical brush. The brush rotates due to the kinematic energy of the vortex and occupies some part of the width of the annular channel. Given the significant increase in productivity and quality of cleaning is the calculation of the overall dimensions of the brush:

Research data are used for calculation.

The radius of the brush is equal to:

$$r_{щ} = 0,9 \text{ x } r_1, \tag{3.11}$$

then:

$$r_b = 0,9 \text{ x } 100 = 90 \ (mm).$$

The height of the brush ($в_b$) is equal to:

$$в_b = B \text{ x } 0,8 \tag{3.12}$$

then:

$$в_b = 15 \text{ x } 0,8 = 12 \ (mm)$$

For flat and uneven surfaces, flat-type brushes with spring-loaded suspension are used. But since the surface of the glider has a different curvature, two-element brushes are used. (Fig This design allows the brush bristles to take a normal position to the tangent in this area. The role of the spring in this case is an elastic rocker.

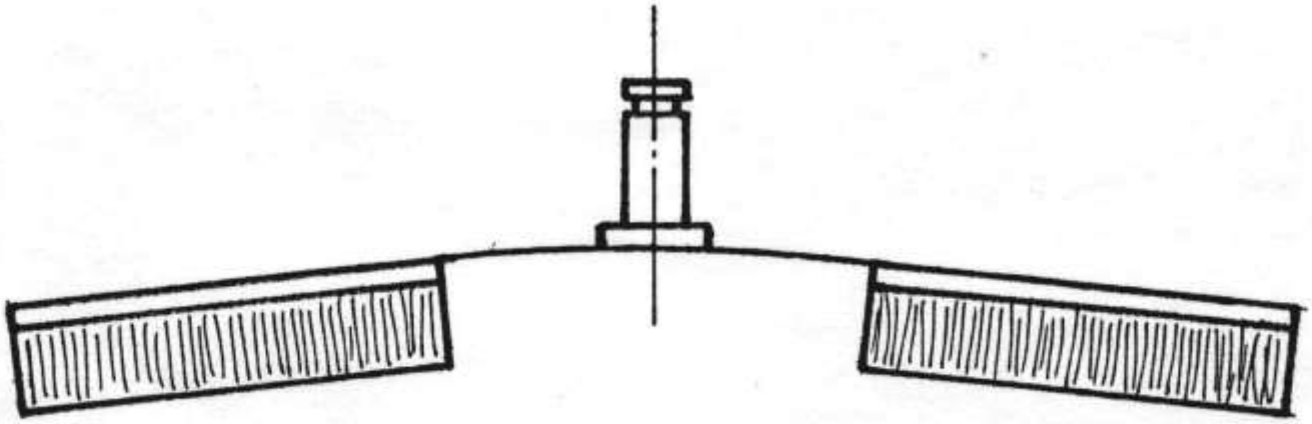


Fig. 3.2.1 Scheme of a spraying brush

3.3 Development of the design of the spray unit. Drive calculation

The spray unit consists of a telescopic support frame, a block of spray heads (three vortex spray heads), a worm gearbox with a plate - rotor hydraulic motor, a hydraulic cylinder for controlling the telescopic frame, a parallelogram transmission and pipelines.

The bearing telescopic frame is made of light aluminum alloy Al-7 and is a square section design. To reduce the effort to extend (assemble) the telescopic frame, as well as reduce the wear of the telescope cavities at the working ends of the telescopic booms, load-bearing frames are installed that eliminate friction inside the telescopic frame.

The block of spray heads consists of three vortex spray heads located at an angle of 120^0 relative to each other and cleaned surfaces that provide cover, except for gaps.

To ensure the self-orientation of the vortex brush on the treated surface, the vortex spray head mounting has two degrees of rotation whose axis is located at an angle of 90^0. The brushes are attached to the vortex brush unit frame and have a spring suspension that acts as a damper. The worm gearbox receives the drive from the plate-rotor hydraulic motor by means of non-front connection. The gearbox housing is the supporting frame of the telescopic boom, has a groove for a large telescope. The large telescopic boom is inserted into the groove of the gearbox housing and held there by welding. The worm gearbox is located on the work platform shaft and is mounted on two ball bearings. The worm wheel is rigidly attached to the work platform shaft. The worm reducer is necessary for simplification of processing, and also for possibility of work of a spray knot at any positions of arrows, irrespective of the mechanism of stabilization of working platforms. Another advantage of the worm gear is that it is self-braking and this reduces problems in the transport position of the special vehicle and when processing the aircraft.

The hydraulic cylinder of the telescopic boom control has a working stroke of 400 mm and when working on the retraction of the rod, to exclude damage to the aircraft, a safety valve is installed in the hydraulic system.

Parallelogram transmission is required to control a telescopic boom, with a large stroke, a hydraulic cylinder with a small stroke. To ensure the operation of the parallelogram transmission, it is necessary to fix one end of the transmission to the hydraulic cylinder, the other to the small boom of the telescope and the next central node of the transmission to the large boom of the telescope. The parallelogram transmission, consisting of six sections with a length of connecting strips of 500 mm during the stroke of the hydraulic cylinder 400 mm provides the extension of the telescopic boom by 2000 mm. This extension is sufficient to ensure the normal operation of the spray unit. The connecting strips are hinged at the ends and in the center.

3.4 Calculation of the drive of the spray unit

The drive of the spray unit in the proposed design is a worm gearbox with a plate - rotor hydraulic motor “Г16-11М” with a torque of 63 Nm.

The calculation of the bending moment on the output shaft is done with the telescopic boom fully extended, when the moment will be maximum. Assume that the weight of a telescopic boom with a block of spray heads is a distributed load equal to P = aq = 600 N, the length of the telescopic boom a = 3 m.

According to the formula of material resistance, the moment on the output shaft:

$$T_2 = \frac{a^2 \times q}{2} = \frac{a \times P}{2}$$

$$T_2 = \frac{3 \times 600}{2} = 900 \quad \textit{(Nm)}$$

Initial data for the calculation of worm gear:

T_1 = 63 Nm, T_2 = 900 Nm, n_1 = 1500 min$^{-1F[}$

Take $i = 30$, $z_1 = 1$, so $z_2 = i \text{ x } z_1 = 1\text{x } 30 = 30$

In the first approximation, we estimate the sliding speed V_s:

$$V_s = 4{,}5 \times 10^{-4} \times \Pi_1 \sqrt[3]{T_2} \tag{3.13}$$

$$V_s = 4{,}5 \times 10^{-4} \times 1500 \times \sqrt[3]{900} = 6{,}3 \quad \textit{(m/s)}$$

Take $\sigma_в$ = 200 MPa.

The allowable stresses for tin bronzes in polished and polished worm is

$$[\sigma_н] = (0{,}85 \div 0{,}9)\, \sigma_в$$

$$[\sigma_н] = 0{,}87 \text{ x } 200 = 174 \; \textit{(MPa)}$$

Material of a worm steel 40X, hardened to HRC 54, turns to grind and polish.

Pre-assigned q = 10, in this case:

$$\frac{q}{z_2} = \frac{10}{30} = 0{,}333 \, ;$$

which is within the recommended limits.

The wheelbase is determined:

$$a_w = 0{,}625\left(\frac{q}{z_2} + 1\right)\sqrt[3]{\frac{E_{пр} \times T_2}{\sigma_н^2\,(q/z_2)}} \tag{3.14}$$

where $E_{пр}$ – the modulus of elasticity of materials of a worm and a wheel is resulted.

$$E_{np} = \frac{2E_1 \times E_2}{(E_1 + E_2)} \tag{3.15}$$

where:

E_1 – the modulus of elasticity of the worm (for steel 2,1 x 10^5 MPa);

E_2 – the modulus of elasticity of the worm wheel (for bronze E_2 = 0,9 x 10^5 MPa).

$$E_{np} = \frac{2 \times 2{,}1 \times 10^5 \times 0{,}9 \times 10^5}{2{,}1 \times 10^5 + 0{,}9 \times 10^5} = 1{,}26 \times 10^5 \text{ (MPa)}$$

The wheelbase will be equal to:

$$a_w = 0{,}625(0{,}33 + 1)\sqrt[3]{\frac{1{,}26 \times 10^5 \times 900 \times 10^3}{174^2 \times 0{,}33}} = 166{,}9 \text{ (mm)}$$

The result obtained is rounded to the number of R_a 40 and accepted:

$$a_w = 160 \text{ mm.}$$

The worm gear module is calculated by the formula:

$$m = \frac{2a_w}{q + z_2} \tag{3.16}$$

$$m = \frac{2 \times 160}{10 + 30} = 8 \text{ (mm)}$$

Take m = 8 mm.

The required shear factor is equal to:

$$X = \frac{a_w}{m} - 0{,}5(q + z_2) \tag{3.17}$$

$$X = \frac{160}{8} - 0{,}5(10 + 30) = 0$$

The main parameters of worm transmission are determined.

The main dimensions of the worm:

- the diameter of the dividing circle

$$d_1 = q \times m \tag{3.18}$$

$$d_1 = 10 \times 8 = 80 \ (mm)$$

- diameter of vertices

$$d_{a1} = d_1 + 2 \text{ x } m \tag{3.19}$$

$$d_{a1} = 80 + 2 \text{ x } 8 = 96 \ (mm)$$

- diameter of depressions

$$d_{f1} = d_1 – 2{,}4\ m \tag{3.20}$$

$$d_{f1} = 80 – 2{,}4 \text{ x } 8 = 60{,}08 \ (mm)$$

- the width of the worm at the displacement coefficient $X = 0$ and the number of measures 1 is equal to

$$в_1 \geq (11 + 0{,}06\ z_2)\ m \tag{3.21}$$

$$в_1 \geq (11+ 0{,}06 \text{ x } 30) \text{ x } 8 = 102{,}8 \ (mm)$$

but for polished worms $в_1$ increase at $m < 10$ mm for 25 mm., the length of the worm will be:

$$в_1 \geq 102{,}8 + 25 = 127{,}8 \ (mm)$$

The length of the worm is $в_1 = 128$ mm.

The main dimensions of the worm wheel:

- dividing diameter

$$d_2 = z_2 \text{ x } m = 30 \text{ x } 8 = 240 \ (mm)$$

- diameter of vertices

$$d_{a2} = d_2 + 2\ m = 240 + 2 \text{ x } 8 = 256 \ (mm)$$

- diameter of depressions

$$d_{f2} = \alpha_2 – 2{,}4\ m = 240 – 2.4 \text{ x } 8 = 220{,}8 \ (mm)$$

- worm wheel width

$$y_2 = 0{,}75 \text{ x } d_{a1} = 0{,}75 \text{ x } 96 = 72 \ (mm)$$

- the largest diameter of the worm wheel

$$d_{aM2} \leq d_{a2} + \frac{6m}{z_1 + 2} \tag{3.22}$$

$$d_{aM2} \leq 256 + \frac{6 \times 8}{1+2} = 272 \quad (\text{mm})$$

Conclusions to the section

According to subject of masters’ work, the following calculations were made:

1. Determination of overall dimensions and performance characteristics of a round vortex brush;
2. Calculation of overall dimensions of the brush;
3. Calculation of the drive of the spray unit.

Thanks to these calculations, we can improve the de-icing/anti-icing technology at the airports , reduce the quantity of de-icing/anti-icing fluids. During de-icing technology brushes with nylon fiber bristels are used.

Nylon brushes are used to avoid scratches on the surface of aircraft, which can negatively influence on aerodynamic characteristics of the aircraft. this material was chosen because it can withstand heavy loads, does not tear and has good wear resistance. Even after long-term use, it does not lose its main properties. And it also has a soft pile, which is very important in this topic.

SECTION 4

LABOR PROTECTION

According to DSTU 2293:2014 among the various factors of production distinguish a dangerous (production) factor, the impact of which on the employee under certain conditions leads to injuries, acute poisoning or other sudden deterioration of health or death, as well as the harmful (productive) factor, the influence of which, under certain conditions, may lead to disease, reduced capacity for work and / or negative impact on the health of descendants [30].

The subject of work is the workplace, where the de-icing/anti-icing procedure takes place. In this chapter we will considered the working conditions at technical operation of the special vehicle with anti-icing fluid, prevention of dangerous and harmful production factors during operation of the deicer and also we will calculate the grounding device of the special vehicle.

4.1. Hazardous and harmful production factors during operation of the de-icing/anti-icing vehicle

During maintenance of the special vehicle (SV) equipped with anti-ice installation, the following dangerous and harmful production factors will be observed:

- increased dust and air pollution of the working area. The source of this factor are the aircrafts that take off, land, refueling and starting the aircraft engines;
- increased noise level in the workplace. The source of noise are working aircraft engines, vehicles and mechanisms, as well as increased noise in the workplace due to the operation of the engine of a SV and additional units. According to DSTU EN 1915-4: 2013 the standard defines the presence of noise as a hazard and establishes methods for measuring and reducing noise levels of ground support equipment (GSE) [31]. Another purpose of this standard, despite the diversity of GSE, is to obtain data on noise generation that can be reproduced and compared with the noise level of this category of equipment;

- the increased level of static electricity because of high speed of air-liquid force on pipelines during anti-icing. In accordance with DSTU 7237:2011,dangerous and harmful effects on people of electric current, electric arc and electromagnetic fields are manifested through electric shock in the form of electric injuries and occupational diseases [32];
- moving vehicles and mechanisms; during the operation of the SV near the aircraft parkings there are a movement of aircraft, special vehicles and mechanisms in the area of work unprotected moving elements of aircraft (rotating turbines, propellers, chassis) and special vehicles (lifting and lowering cab, hatches);
- increased or decreased air temperature of the working area. The main influence is made by climatic conditions and change of seasons;
- location of the workplace at a significant height relative to the ground surface. The influence of this factor is due to the fact that during the anti-icing of the aircraft, operator is at a height of 13 m from the ground during the anti-icing technology.

4.2. Prevention of dangerous and harmful production factors during operation of the special vehicle

One of the most important tasks of labor protection is to ensure the safety of employees, that is to ensure a state of working conditions in which the impact on workers of dangerous and harmful factors is excluded. To ensure the safety of workers, it is necessary to service all working bodies of the special vehicle equipped with the distribution unit in accordance with the schedule.

During the regular inspection of the vehicle, before leaving the line, a special place should be given to the serviceability of components, units and systems that affect traffic safety and safe operation of special equipment. Special vehicles with malfunctions are not allowed to operate until all detected faults are completely eliminated. The engineer must report all malfunctions of vehicles and equipment to the head of the column and make an entry in the log of reception - transfer of change.

Officials who control the entrance (exit) of a special vehicle to the aircraft are obliged to control the movement of the special vehicle in the service area of the aircraft in accordance with the scheme of the approach with the help of clear signals.

To reduce air pollution of the working area, it is necessary to strictly control the engines of the base chassis and special equipment for toxicity and emissions of harmful substances into the atmosphere with the help of "Infralit" devices.

After the entrance of the special vehicle to the aircraft, before deploying it to the working position, it must be grounded to remove static electricity.

In order to ensure the safety of the driver and operator in the design of the special vehicle provides:

- for work at night, the car is equipped with two rotating headlights, two headlights of the main light and position lights operated from the car of the operator;
- to ensure communication with the command and control point, the special vehicle is equipped with a receiving and transmitting radio station;
- the operator's workplace is equipped with a fence, a safety belt and a rope ladder in case of rupture of the pressure head pipeline of hydraulic systems;
- according to departmental regulations, the noise level at the workplace of the driver and operator of special vehicles should not exceed 85dBA. But due to the fact that the maintenance of the aircraft by a special machine takes place in the parking stands of the aircraft, the noise level may exceed the allowable value. To protect the driver from the effects of noise and low temperatures, the cab of the machine is equipped with a heater and insulated with sound-absorbing material;
- according to regulations, the noise level at the workplace of the driver and operator of special vehicles should not exceed 85 dBA. But due to the fact that the maintenance of the aircraft by a special vehicle takes place in the parking stands of the aircraft, the noise level may exceed the allowable value. To protect

the driver from the effects of noise and low temperatures, the cab of the machine is equipped with a heater and insulated with sound-absorbing material.

The operator is protected from noise by means of individual means of protection: headphones and helmet.

For work in the winter the operator is provided with warm uniform, and in the conditions of the raised temperatures installation over a workplace of the operator of a tarpaulin awning is admissible.

4.3. Providing fire and explosion safety during maintenance of special vehicle

Fire safety of parking lots is determined mainly by the possibility of explosion of petroleum products, low-temperature anti-icing / washing liquids. The main causes of fire are:

- sparks that occur during the operation of the main engine and heater during operation of the special vehicle;
- sparks arising from shocks and friction at the entrance of the special vehicle to the aircraft;
- sparks of wiring of the equipment and lighting devices;
- discharges of static and atmospheric electricity;
- leaks in the fuel system and lubrication system;
- accumulation on the engine and its crankcase of dirt mixed with fuels and lubricants;
- places of refueling with fuel and oil;
- presence of flammable agents near the exhaust pipes and the heater;
- leakage of electrolyte from the battery case.

For fire prevention it is necessary to:

1) The lubrication system and the fuel system were sealed.
2) There was no leakage of exhaust gases.
3) Exhaust gases from the crankcase must be given to the inlet of the air cleaner in addition to the accumulation of gases in the crankcase space.

4) Muffler pipe - tightly connected to the exhaust manifold of the engine.

It is forbidden:

1) Work of the special car without a spark flame arrestor on exhaust pipes and a heater.
2) Use faulty power supply devices, electrical appliances and wiring cables.
3) It is forbidden to operate a special vehicle without grounding

In the event of a fire on a special vehicle should be fire extinguishers. In the event of a fire, the machine is removed from the buffer zone to a safe place. The driver reports what happened to the dispatcher and the fire brigade, and the operator begins to extinguish the fire. After the report, the driver comes to the aid of the operator and extinguishes the fire with existing means.

4.4. Calculation of the grounding device of the special vehicle

In the process of de-icing/anti-icing of the aircraft by a special vehicle equipped with a vortex spray unit, static electricity may occur, which is associated with high air flow and rotational force inside the anti-icing brush head. Therefore, during the operation of the special vehicle it is necessary to remove static electricity.

According to departmental documents, the grounding device must have a resistance of not more than 100 Ohms.

For the calculation we choose the specific resistance of the soil (sand), which is equal to $\rho = 7 \cdot 10^2$ (Ohms) [33].

Initial data:

Single steel rod d = 400 mm;

l = 3 m;

hammered to a depth of $H_o = 1.0$ m from the ground.

Find the depth of the foundation:

$$H = H_o + 0.5\, l \tag{4.1}$$

$$H = 1 + 0.5 \cdot 3 = 2.5\ (m)$$

The resistance of a single ground is calculated by the formula [34] :

$$R_{on} = 0,366\frac{\rho}{l}\left(\lg\frac{2l}{d} + \frac{1}{2}\lg\frac{4H+l}{4H-l}\right) \tag{4.2}$$

$$R_{on} = 0.366\frac{7\cdot 10^2}{3}\left(\lg\frac{2\cdot 3}{0.04} + \frac{1}{2}\lg\frac{4\cdot 2.5+3}{4\cdot 2.5-3}\right) = 197\,\text{(Ohms)}$$

Since the resistance of a single ground is greater than the normal, requires several groundings connected in parallel, and located from each other at a distance *a*
(take *a* = 2l= 6 m).

Determine the number of groundings by the formula:

$$n = \frac{R_{on}}{r_з \cdot \eta_{cm}} \tag{4.3}$$

where: R_{on} - single ground resistance, Ohms;

$r_з$ - normal resistance of the grounding device, Ohms;

η_{cm} - single rod grounding factor, (η_{cm} = 0.75).

$$n = \frac{197}{100\cdot 0.75} = 2.62$$

Take the number of groundings equal to 3, to connect the rods using connecting strips.

Calculate the resistance to current flow from the strip:

$$R_{см} = 0,366\frac{\rho}{l_{см}}\cdot\lg\frac{2\,l_{см}^2}{в\cdot H_{см}} \tag{4.4}$$

where: $l_{см}$ - the length of the connecting strip, m;

в - band width, m;

$H_{см}$ - depth of laying the strip, m.

At $n = 3$, $l_{см} = n \cdot a = 3 \cdot 6 = 18$ (m).

Take *в* = 30мм, $H_{см}$ = 0,6 м, then:

$$R_{см} = 0,366\frac{7\cdot 10^2}{18}\lg\frac{2\cdot 18^2}{0.03\cdot 0.6} = 64.9\,\text{(Ohms)}$$

The resistance of the grounding circuit device is determined by the formula:

$$r_{кз} = \frac{R_{оп} \cdot R_{см}}{R_{оп} \cdot \eta_{см} + n \cdot R_{см} \cdot \eta_{оп}} \tag{4.5}$$

At $n = 3$ and $\frac{a}{l} = 2$ the band usage factor is equal to $\eta_{см} = 0{,}55$.

$$r_{кз} = \frac{197 \cdot 64{,}9}{197 \cdot 0{,}55 + 3 \cdot 64{,}9 \cdot 0{,}75} = 50{,}3\,\text{(Ohms)}$$

The obtained value of the resistance of the grounding circuit device is less than the normalized ($r_{кз}$ <100 Ohms), so we take the number of groundings 3, and the length of the connecting strips 18 m.

Conclusions to the section

In the section on labor protection we considered workplace, where the de-icing/anti-icing technology takes place. Working conditions at technical operation of the special vehicle with anti-icing fluid, prevention of dangerous and harmful production factors during operation of the deicer.

Desribed dangerous production factors and ways to prevent it. The dangerous factors of production are: increased dust and air pollution, increased noise level, level of static electricity, moving vehicles and mechanisms, increased or decreased air temperature.

Also we calculated the grounding device of the special vehicle to remove static electricity. According to documents, the grounding device must have a resistance of not more than 100 Ohms. It was found that the obtained value of the resistance of the grounding circuit device is less than the normalized (50,3 < 100 Ohms) , so we take the number of groundings 3, and the length of the connecting strips 18 m.

SECTION 5

PROTECTION OF THE ENVIRONMENT

5.1. Factors of negative impact on the enviroment during de-icing/anti-icing. Methods of reducing it.

The greatest pollution of atmospheric air comes from power plants running on hydrocarbon fuels (gasoline, kerosene, diesel fuel, fuel oil, coal, natural gas and others). The amount of pollution is determined by the composition, the amount of fuel burned and the organization of the combustion process.

The main sources of air pollution are vehicles with internal combustion engines (ICE). Motor transport is a source of air pollution, the number of cars is constantly growing, especially in large cities; and at the same time the gross emission of harmful products into the atmosphere is growing.

Toxic emissions of ICE are exhaust and crankcase gases, fuel vapor from the carburetor and fuel tank. The main share of toxic impurities enters the atmosphere with gases from the ICE. Studies of the composition of exhaust gases, ICE show that they contain several dozen components. Sulfur dioxide (SO_2) is formed in the exhaust gases when sulfur is contained in the source fuel (diesel fuel) [35].

The amount of harmful substances entering the atmosphere as part of the exhaust gases depend on the general technical condition of cars and especially on the engine - the source of the greatest pollution. So, at infringement of regulation of the carburetor CO emissions increase in 4 - 5 times.

Another method of exhaust gas disposal is recirculation, ie re-suction into the cylinders (along with a portion of the new fuel mixture), in order to burn CO and CH and reduce the amount of nitrogen oxides directly in the engine cylinders.

In the near future, reciprocating ICE will remain the main type of automobile engines, and diesel ICE should be greatly developed. Diesel ICE began to be widely used after the

Second World War on heavy-duty trucks. But in recent years, the advantages of diesel engines, such as lower specific fuel consumption (30-35%) and lower toxicity of exhaust gases, have led to their widespread use not only on trucks of large and medium capacity, buses, but also on cars.

The main directions in solving environmental problems are the improvement of technological processes and the development of new equipment with lower emissions and waste into the environment, the replacement of toxic waste with non-toxic and unused waste with recycled waste.

An important measure to protect the environment is the rational placement of sources of pollution; device of sanitary protection zones; removal of industrial enterprises with harmful emissions outside the city; accounting for "wind rose", etc. Environmental quality control is of great importance.

The main factors of adverse effects of civil aviation on the environment are: aviation noise; emissions of harmful substances from ground sources and aircraft engines; soil pollution by sewage and solid waste.

To reduce the degree of pollution it is necessary to take the following measures:

- daily control of emissions and toxicity of exhaust gases of all special vehicles coming to the line from the park;
- to make timely maintenance of special vehicles;
- do not allow the use of fuels (gasoline grades) not provided for this engine;
- anti-ice treatment of aircraft, special vehicles and mechanisms to be done on sites equipped with a reservoir and treatment facilities;
- to do maintenance of the aircraft only on the sites provided for these purposes;
- reduce the operating time of aircraft engines and special vehicles in parking stands;
- collecting, cleaning, reuse solutions and anti-icing fluids «Arctic», «TYPE- I» and «TYPE-II».

5.2. Calculation of the contaminated area during de-icing of aircraft

Depending on the climatic conditions (presence and intensity of precipitation, humidity, pressure, ambient temperature, fog or other meteorological phenomena), one aircraft may be treated several times [36]. As a consequence - repeated drying, which leads to the accumulation of dry residues. The main part of the anti-icing fluid flows down to the ground during aircraft handling (75-80%) or is blown away by the wind. The discharge of the remainder on the surface of the aircraft occurs during takeoff. Water-saturated residues of de-icing fluids crystallize on the apron, which leads to the death of microorganisms located within the airport. The anti-icing fluid contains wetting agents - tensides. They degrade slowly in the environment and are toxic to aquatic life.

Mixing with snow, metal dust and other chemicals on the apron, the solution can enter the groundwater through the airport's existing drainage system. It should be noted that part of the surfaces of parking stands and taxiways consists of concrete slabs with joints filled with loose soil, which can potentially lead to the ingress of pollutants into the soil aquifers.

The minimum flow rate for Type I fluid is one liter per square meter of aircraft surface. According to Association of European Airlines the recommended minimum flow rate of anti-icing fluid is 1.3 - 1.6 liters per square meter of surfaces to be treated [37].

During the entire autumn-winter period, aircraft are processed. Liquid consumption depends on the following parameters:

- from the type of aircraft;
- the total mass of snow-ice deposits and the mass of snow-ice deposits frozen to the casing;
- from process technology, processing and technique;
- from the qualifications of the operator performing de-icing treatment.

Per day, depending on weather conditions, at a large airport, at least 20% of all departing aircraft are processed. It is worth noting the fact that the distribution of waste fluids on the territory of the airfield is uneven.

Let us calculate the area of a contaminated area when servicing one aircraft, which can be covered with a formed film from an anti-icing liquid with a thickness (H) of 1 mm, provided that the density is constant. It is this height of the liquid column that is enough to almost completely stop gas exchange between the upper horizon of the soil and the near-surface layer of air.

Let's consider 2 cases: with bad weather conditions (rainfall, strong wind and low temperatures) and good weather conditions comfortable for aviation navigation (with temperatures close to zero and cloudless weather).

In a one-stage treatment, an average of 120 liters of water and 60 liters of anti-icing fluid Type I are consumed.

S = V/H ,

where V – total volume of liquid used, H – film thickness.

So 1 L = 1 dm^3, 1 mm = 0.01 dm, then S = 180 dm^3 / 10^{-2} dm = 180 m^2.

In a two-stage treatment, 240 liters of water and Type I - 120 liters and Type IV - 120 liters are consumed.

So S = 480 dm^3 / 10^{-2} dm = 480 m^2.

Thus, in the minimum case, the potentially polluted area is several times larger than the area of the airfield, and if we take into account the intensity of processing at peak loads at airports, the total pollution becomes large-scale.

To reduce the negative impact on the environment and, above all, human health, a set of measures is required. Liquid organic components must be added to the deicing fluid formulation, which could:

1. Have great solubility and completely absorb (dissolve in itself) inorganic salt content of antifreeze anti-icing fluid;
2. Due to low volatility, they are not only non-drying, but also hygroscopic;
3. By their nature, they additionally possess structuring or inhibiting properties.

Conclusions to the section

Having considered the issue of protection of the environment on the subject of master's work, the following conclusions can be drawn:

1. The greatest pollution of atmospheric air comes from power plants running on hydrocarbon fuel, vehicles with internal combustion engines and other. The number of vehicles is constantly growing and at the same time the gross emission of harmful products into the atmosphere is growing.
2. The main directions in solving environmental problems are the improvement of technological processes and the development of new equipment with lower emissions and waste into the environment, the replacement of toxic waste with non-toxic and unused waste with recycled waste.
3. The priority task is to create specialized areas on the apron for handling aircraft, which will have its own system for removing waste fluids. The system must be closed and have pollutant deactivators. The injection units need to be modernized for spot spraying of solutions over the fuselage surface.
4. According to the calculations the potentially polluted area is several times larger than the area of the airfield, as a result, it negatively affects the soil around the airport, wastewater, and also affects the health of people who work at the airport.

CONCLUSION

De-icing/anti-icing treatment of aircraft is one of the key tasks of the modern period. This procedure is necessary not only for the smooth and safe flight of the aircraft. That is why the optimization of the process of de-icing/anti-icing treatment of aircraft at the airports of Ukraine is an urgent problem, as our industry does not produce special vehicles for these types of work that meet modern requirements of labor protection and the environment.

In this work, a special vehicle for de-icing/anti-icing treatment was used, most suitable for equipping it with a vortex spray unit designed to remove ice, snow and frost from the surfaces of the aircraft. This special vehicle involves all de-icing/anti-icing operations performed by one employee of the ground service, which reduces the cost and processing time of the aircraft.

The aim of the work was to equip the special vehicle with a special de-icing/anti-icing unit to increase efficiency and reduce costs, ensure disposal and reuse of waste fluid to protect labor and the environment, as well as improve the quality of de-icing/anti-icing treatment of aircraft.

To achieve the aim in the work the following tasks are solved:

1. Carrying out of information search of sources concerning features of a design and technical characteristics of modern anti-ice vehicles.
2. Development of constructive improvement of the vortex head.
3. Calculation and selection of the main elements of the hydraulic system of the special vehicle.
4. Development of technology for anti-ice treatment of aircraft with the involvement of the special vehicle.
5. Development of sections on occupational safety and environmental issues in the operation of anti-icing special vehicles.

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