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КАФЕДРА ПІДТРИМАННЯ ЛЬОТНОЇ ПРИДАТНОСТІ ПОВІТРЯНИХ СУДЕН

ДОПУСТИТИ ДО ЗАХИСТУ
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«_____»_______________2022 р.

КВАЛІФІКАЦІЙНА РОБОТА

(ПОЯСНЮВАЛЬНА ЗАПИСКА)

ЗДОБУВАЧА ОСВІТНЬОГО СТУПЕНЯ МАГІСТРА

ЗА ОСВІТНЬО-ПРОФЕСІЙНОЮ ПРОГРАМОЮ «ОБСЛУГОВУВАННЯ ТА РЕМОНТ ПОВІТРЯНИХ СУДЕН І АВІАДВИГУНІВ»

Тема: «Методологічні основи підтримання експлуатаційної надійності паливної системи пасажирського літака великої дальності з двома турбореактивними двигунами»

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Київ 2022

MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE
NATIONAL AVIATION UNIVERSITY
AIRSPACE FACULTY
AIRCRAFT AIRWORTHINESS RETAINING DEPARTMENT

ADMIT TO DEFENCE
Head of the Department
Ph. D., associate professor
___________ O.V. Popov
«____» __________ 2022

MASTER DEGREE THESIS
(EXPLANOTARY NOTE)

GRADUATE OF EDUCATIONAL DEGREE “MASTER”
FOR EDUCATIONAL AND PROFESSIONAL PROGRAMS
"MAINTENANCE AND REPAIR OF AIRCRAFT AND AIRCRAFT ENGINES»

Topic: “Methodological bases for maintaining the operational reliability of the fuel system of a long-range passenger aircraft with two turbojet engines”

Fulfilled by: ____________ **D.M. Hryshko**

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Kyiv 2022

NATIONAL AVIATION UNIVERSITY

Airspace Faculty

Aircraft Airworthiness Retaining Department

Educational Degree "Master"

Speciality 272 “Aviation Transport”

Educational and professional programs "Maintenance and repair of aircraft and aircraft engines»

APPROVED BY

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“_____”________________2022

Graduation Project Assignment

HRYSHKO DAVYD

1. Topic: “**Methodological bases for maintaining the operational reliability of the fuel system of a long-range passenger aircraft with two turbojet engines”** approved by the Rector’s order of “_29_”09__2022 №_1786/st.

2. The Graduation Project to be performed between: from September 26, 2022 till November 25, 2022

3. Initial data for the project: analysis of the fuel system structure, main requirements of the fuel system of a long-range passenger aircraft .

4. The content of the explanatory note: introduction, analytical part, structural design and description of the fuel system project part, scientific part, labour precaution, environmental protection, conclusions.

5. The list of mandatory graphic materials: general overview, data and characteristics of fuel system components, schemes of the fuel system.

6. Time and Work Schedule

#	Stages of Graduation Project Completion	Stage Completion Dates	Remarks
1	Literary review of materials according to the scientific direction of the thesis	26.09.22-29.09.22	Done
2	Reliability analysis of the engines	30.09.22-18.10.22	Done
3	Project part	19.10.22-22.10.22	Done
4	Scientific part	22.10.22-30.10.22	Done
5	Labour precautions	31.10.22-03.11.22	Done
6	Environmental protection	04.11.22-08.11.22	Done
7	Arrangement of explanatory note	08.11.22-12.11.22	Done
8	Peparing for project defend	12.11.22-25.11.22	Done

7. Advisers on individual sections of the project:

Section	Adviser	Date, Signature	
		Assignment Delivered	Assignment Accepted
Labour precaution	Ph.D., associate professor Kazhan K.I.		
Environmental protection	Ph.D., associate professor Pavlyukh L.I.		

8. Assignment issue date “_____”___________ 2022.

Degree work supervisor: _________________ O.V. Rugain.

(signature)

Assignment is accepted for fulfillment_________________ D.M. Hryshko

(signature)

ABSTRACT

Explanatory note to the thesis: "Methodological bases for maintaining the operational reliability of the fuel system of a long-range passenger aircraft with two turbojet engines":

90 pages, 35 figures,6 tables, 45 sources.

The object of study is the maintenance of the fuel system of a long-range passenger aircraft with two turbojet engines.

The subject of the study is the reliability of the fuel system of a long-range passenger aircraft with two turbojet engines.

The purpose of the thesis is to increase the operational reliability of the fuel system of a long-range passenger aircraft with two turbojet engines.

Research method – to solve the tasks, methods of analyzing the operation of aviation fuel systems of aircraft with turbojet engines were used to identify the causes of their failures, static, mathematical modeling.

The recommendations developed by the author can be proposed to improve the efficiency of interaction between the operator, the developer of aircraft and their components, as well as the state regulatory authority for aviation activities in order to ensure and maintain the operational reliability of the fuel system of a long-range passenger aircraft.

The materials of the thesis are recommended to be used in the educational process and practical activities of specialists of design bureaus.

AIRWORTHINESS, TURBOJET ENGINE, FUEL SYSTEM, RELIABILITY, MAINTENANCE

CONTENT

LIST OF TERMS, ABBREVIATIONS, TERMS

AE - AİRCRAFT ENGİNE;

AHS - AVİATİON HYDRAULİC SYSTEM;

AFS - AVİATİON FUEL SYSTEM;

AFD - AUTOMATİC FUEL DİSPENSER;

AC – AİRCRAFT;

APU - AUXİLİARY POWER UNİT;

NV - NON-RETURN VALVE;

EC – EXPENDABLE COMPARTMENT;

NGS – NEUTRAL GAS SYSTEM;

FT – FUEL TANK;

FS - FUEL SYSTEM;

ECP - ELECTRİC CENTRİFUGAL PUMP;

PP – PUMPİNG PUMP;

JP – JET PUMP;

FJP - FUEL JET PUMPS;

CTS - COMPLEX TECHNİCAL SYSTEM

SS – STEERING SYSTEM

EHS – ELECTROHYDRO SYSTEM

INTRODUCTION

The main purpose of the aircraft's fuel system is to ensure the timely delivery of fuel to the aircraft's engines. The aircraft's fuel system includes a fuel placement system in the aircraft, a fuel supply system for the engines, a fuel measurement system in the tanks, and a refueling system. Wings, which are hollow and divided into compartments, serve as a FT in most aircraft, and it also serves as a wing amplifier. From the inside, the entire surface of the FT is covered with a special sealing composition to prevent fuel leakage through the contact surfaces.

When the wings of the aircraft are made, this mixture is applied to the inner surface of the caisson when it is in a liquid state, then on a special stand, the caisson rotates in all planes, ensuring uniform spreading of the sealing compound over the entire inner surface. The principle of the power plant of all aircraft consists in the autonomous power supply of each engine from its own tank. Another feature of the FS is the cooling of engine oil, air conditioning systems, aggregates, radio-electronic equipment, aircraft balancing, generator constant speed drive, etc., and also as a working body in various automatic devices. For example, control of the inlet guide vanes and control of the jet nozzle flaps. The main requirements for aviation fuel systems are: reliability, survivability, fire safety, compliance with mass-dimensional characteristics, maximum simplicity of construction, maintainability and controllability, operational manufacturability, ensuring the necessary strength and vibration resistance of its elements.

Fuel systems of modern aircraft are a complex complex of a large number of interdependent subsystems: fuel supply to engines, fuel pumping, control of the order of fuel use from tanks, refueling and draining of fuel tanks, refueling and draining of fuel on the ground. and during flight cooling and control. Due to the large number of functional and structural connections in the fuel system during design, it is necessary to study and compare various design options, and apply optimal solutions that ensure the creation of the most profitable system for a specific aircraft. The analysis of fuel systems is the most important stage in the creation of an AFS, starting from the solution of external tasks and ending with design decisions in the system and its elements.

The analysis is carried out taking into account the requirements of AR25 airworthiness standards for AFS and aims to increase the reliability of AFS and fail-safe operation of the aircraft. The work considers the requirements for the design of the AFS, the main design requirements for the AFS, reliability, constructive measures to prevent AFS failures, a comparison of the reliability and failsafe of the AFS with aviation hydraulic systems (AHS), the prospects of alternative ways of increasing the reliability of fuel systems are also considered, and also developed recommendations for increasing the reliability of pipeline system components and pipeline systems in general based on the choice of design solutions.

The construction of AFS and AHS should be based on uniform principles that ensure the highest reliability and safety of flights. However, at present, this principle is not sufficiently followed and AFS significantly loses in reliability and safety failure in comparison with AHS. The proposed improvements through the application of redundancy of fuel system elements will significantly increase the reliability of the passenger aircraft fuel system, which will withstand up to 2 failures without serious consequences for the flight, and will be similar to the AHS in terms of reliability and fail-safe.

1 MAIN PART

1.1 Basic requirements for the fuel system of a passenger aircraft

Requirements for FS:

1. The system must ensure reliable fuel supply to the engines in all modes of their operation, as well as in all modes and altitudes of the aircraft flight and in the temperature range: from -60°C to 45°C [2].

2. Ensuring automatic production of fuel in a given sequence and with all possible operational variants of refueling, as well as ensuring the centering of the aircraft and keeping it within permissible limits. It should be possible to manually control the fuel supply in the event of a failure of the automatic fuel supply control for all possible combinations of working and non-working engines [2].

3. Ensuring safety, survivability and fire safety during flight and parking. This requires separate switching on and off of pumping stations, the possibility of cross-feeding fuel from any tank to any engine, redundancy of the most important units [2].

4. The internal volume of the aircraft tanks must ensure the placement of the necessary amount of fuel for the flight for the given maximum range or duration and the fuel reserve (navigator's reserve) for 45 minutes. Flights on all brands of fuel approved for operation on this type of ND. For aircraft of local airlines, the size of the reserve fuel balance must contain at least 15% of the maximum planned refueling [2].

5. Closed refueling of fuel tanks, if the capacity of the tanks is more than 3 m^3, with a fuel consumption of at least 25 l/s through all refueling points, at a pressure of no more than 0.45 MPa. With a smaller capacity, refueling is carried out through refueling guns. During refueling, dangerous discharges of static electricity should not be formed [2].

6. Provision of fuel draining in flight for aircraft with restrictions on landing mass and centering. The average consumption during a shower is up to 10 m3.

7. Ensuring complete draining of fuel from pipelines and units on the ground during repair work and maintenance of the aircraft. In this case, pumps are used to

accelerate fuel draining and reduce the number of drain points. The remaining fuel should not exceed 1% of the total capacity of the tanks.

8. When supplying fuel to engines from two or more groups of tanks, it is necessary to ensure uniform production of fuel. The unevenness of production should not exceed 5%. Many aircraft are equipped with leveling machines that provide the ability to automatically maintain even fuel production.

9. It is mandatory to have reliable drainage of fuel tanks to maintain the necessary pressure under any conditions and flight modes.

10. Provision of fuel filtration with cleaning corresponding to "RLE".

11. It is necessary to protect fuel system nodes from corrosion, icing and microorganisms, static electricity, overheating, which ensures durability and vibration resistance.

12. The fuel system must have a high level of manufacturability and, at the same time, adaptability to carrying out repair work in the shortest possible time with a minimum number of workers [2].

1.2. The influence of factors on the operation of the fuel system of a passenger aircraft

Factors affecting the operation of the fuel system are determined by its temperature, ambient air pressure, fuel consumption and speed, as well as its pressure near the nozzles. As the fuel temperature increases, its saturated vapor pressure increases and thermal stability decreases. When the temperature drops, the density of the fuel increases and at the same time there are significant losses of hydraulic pressure, the supply decreases and there is a threat of contaminating the filters with ice crystals. A decrease in atmospheric pressure leads to such a phenomenon as cavitation. With high fuel consumption, the charge of static electricity increases and the level of fire safety decreases. The choice of fuel type is determined by the type of engine [6].

This division is due to the specifics of the operation of each type of engine, different flight altitudes and many other factors.

The safety of the flight of the aircraft depends on the reliability of the power plant. Therefore, the fuel should ensure the best flow of combustion and mixture formation processes in the expected operating conditions and at the same time not cause overheating of the engine parts, its pollution and corrosion.

To fulfill these requirements, the fuel must have good energy characteristics, physical and chemical properties, and operational qualities. Energy characteristics are determined by high heat of combustion.

The necessary operational qualities require low hygroscopicity of the fuel, which is passive in relation to structural materials. It should not be poisonous, chemically and thermally stable.

The rate of evaporation of the fuel reflects its ability to change into a gaseous state. This significantly affects the ease of starting engines. The volatility of the fuel is estimated by the fractional composition and pressure of saturated vapors.

The highest vapor pressure created in the space above the fuel is called the saturated vapor pressure and is denoted Pt. Saturated vapor pressure affects the height of fuel systems.

When testing aviation fuels, the generally accepted ratio of vapor to liquid phase should be 4/1.

To characterize the saturated vapor pressure of liquids, a temperature of 37.8 ºC = 100 ºF is taken

At this temperature, the pressure is called the Reid pressure.

Fuel density is characterized by the kinematic density coefficient:

$$v_T = \frac{\mu_T}{\rho_T} \#(1.1)$$

Where μ_T – coefficient of dynamic density, kg/(m·s);

ρ_T – mass density, kg/m³.

The value of the kinematic density coefficient is expressed in stokes (1st=1cm²/s=10-4m²/s) and centistokes (1st=10-2cm²/s=10-6m²/s=1mm²/s).

Fuel density affects the operation of the fuel system and the quality of fuel atomization. The lower the density, the lower the hydraulic losses and the better the atomization of the fuel. The high density of fuel leads to a decrease in the throughput of filters, the load on fuel pumps increases, and the quality of combustion deteriorates.

Low density also has a negative effect, because the rate of wear of pumps for which the fuel is a lubricating element increases. Therefore, the fuel density is normalized.

Chemical stability is the resistance of fuel to oxidation during storage and use. Fuel stability depends on the availability of fuel with a minimum amount of resins.

The thermal stability of the fuel also plays an important role in the stability of the fuel system. When the fuel is heated, significant structural and chemical changes may occur in it, due to which sediment may form, which in turn quickly contaminates the fuel filters, which causes interruptions in the supply of fuel, or completely stops it. Fuel heating systems are provided for these purposes. The fuel temperature at the engine inlet is calculated using the formula [6]:

$$T_d = T_{rb} + \Delta T_H + \Delta T_p + \Delta T_\xi \#(1.2)$$

where T_{rb} – fuel temperature in the flow tank;

ΔT_H – fuel heating in the pumping pumps of the waste tank;

ΔT_p – fuel heating in the radiator;

ΔT_ξ – fuel heating in local supports of the fuel line.

The main criterion for evaluating the thermal stability of fuels is the amount of insoluble precipitates formed per unit mass of fuel, depending on its temperature. Insoluble precipitates are formed in fuel when the temperature rises as a result of oxidative thermal and catalytic processes and are the product of deep transformations in the oxidative environment of the least stable hydrocarbons, oxygen-sulfur and nitrogen-containing compounds [6].

The content of sulfur, minerals, acids and alkalis should be a minimum proportion of the fuel composition in order to reduce corrosion

The maximum allowable mass of mechanical impurities and impurities in the fuel should be no more than 0.0002%. The fuel purity class is regulated by DOST 17216-71 no worse than the 7th class

1.3. Overview of schemes and methods of fuel supply to the engine of a passenger aircraft

In general, the aircraft power system consists of three systems: starting, main and afterburner [5].

The fuel supply system includes:

- tanks or compartments of the aircraft, in which the fuel supply is placed;
- pumps supplying fuel from tanks to engines, pumps pumping fuel from one tank to another;
- fuel flow regulation valves (tank change);
- valves for emergency stop of fuel supply to engines (fire valves);
- taps for draining fuel sludge at various points of the system;
- fuel cleaning filters;
- system control devices;
- various pipes and many other elements and nodes.

There are several fuel supply schemes from the tanks to the engine: in series, in parallel, with a drain tank, etc.

According to the last scheme, fuel from other tanks is constantly pumped out or enters the spent tank, and from there it is already supplied to one or more engines during the entire flight. According to another scheme, fuel supply is carried out sequentially from several fuel tanks: as one fuel tank is emptied, fuel supply starts from the next fuel tank [5].

The choice of scheme is determined by the type of aircraft, its purpose, characteristics. An example of a fuel supply scheme with a partition is shown in Fig. 1.1.

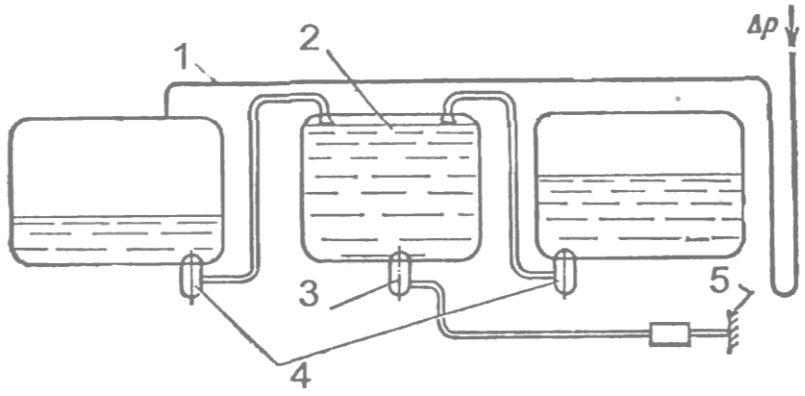


Figure 1.1 – Scheme of the fuel system with a discharge:

1 - drainage and inflation system; 2 - waste tank; 3 - pumping pump; 4 – transfer pumps; 5 – engine

Pumping of fuel from one tank to another in AC is carried out according to two schemes: radial and manifold. With a bundle scheme, fuel from each tank is pumped through a separate line equipped with a float valve that controls the supply of fuel to the waste tank. With the collector scheme, fuel from all tanks is pumped through a common main.Fuel supply to the high-pressure pumps of the engines to ensure their operation without cavitation is carried out with different degrees of pressure increase with the help of pumps (Fig. 1.2).

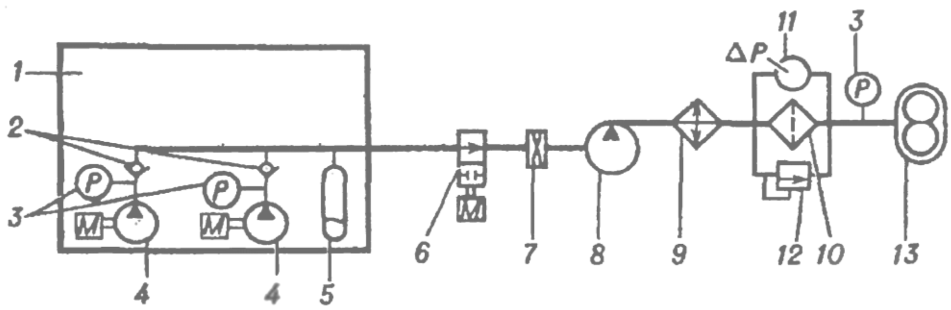


Figure 1.2 – Scheme of fuel supply from the fuel tank to the engine:

1 - waste tank; 2 - reversing valves; 3 - pressure sensors; 4 - tank bombs; 5 - fuel battery; 6 - bridge valve; 7 - flow sensor; 8 - pumping pump; 9 - fuel and oil radiator; 10 - filter; 11 - pressure drop sensor; 12 - bypass valve; 13- high pressure pump

First, the pressure is increased by the pumps located on the tanks, then the pump located on the main line, and only then the pump located directly on the engine.

Much attention is paid to the reliability of fuel supply. For example, the fuel system of the An-124 aircraft has four automated groups, each of which feeds "its" engine, but can supply fuel from any fuel group to any engine. When the plane's side is de-energized, fuel flows to the engines by gravity.

During long flights at high altitude, the fuel cools significantly, so the aircraft has a fuel heater on board to prevent ice crystals from clogging the pipes and filters.

The scheme of the fuel supply system to the engines is determined by the number of fuel tanks, engines and their location on the aircraft.

On single-engine aircraft, as well as some types of aircraft with two engines located according to the single-engine scheme, fuel supply schemes from one fuel tank are used (Fig. 1.3). In some types of aircraft, despite the spaced location of the engines, schemes with a single fuel tank are used.

In the diagram shown in fig. 1.3, fuel is supplied to the engine by a booster pump. The upper valve, installed in front of the engine, is used to stop the fuel supply to the engine in the event of a fire or to seal pipelines when replacing engines [6].

If the fuel tanks are above the engine pump, the aircraft is at a low altitude (up to 5000 m) and the fuel supply to the engine is relatively small, as in the case of low-power engines, then it is possible to pump fuel from the fuel tanks by gravity

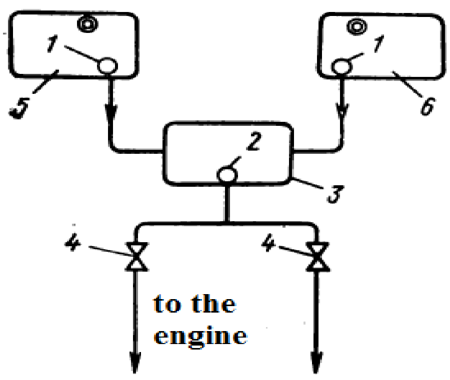


Figure 1.3 – Fuel supply scheme with a fuel tank:

1-transfer pumps; 2 - pumping pump; 3 dispenser tanks; 4 - bridge valve; 5 fuel tank #1; 6 fuel tank #2

When the layout of the engines is spaced by the aircraft, supply schemes with several consumable tanks are usually used (Fig. 1.4). In this case, each fuel tank provides fuel supply to one engine (Tu-124) or to a group of engines installed next to each other (Il-18). The presence of a ringing line with a ringing valve 8 in such schemes ensures the supply of fuel to any engine in the event of a failure in the pumping line of any fuel tank.

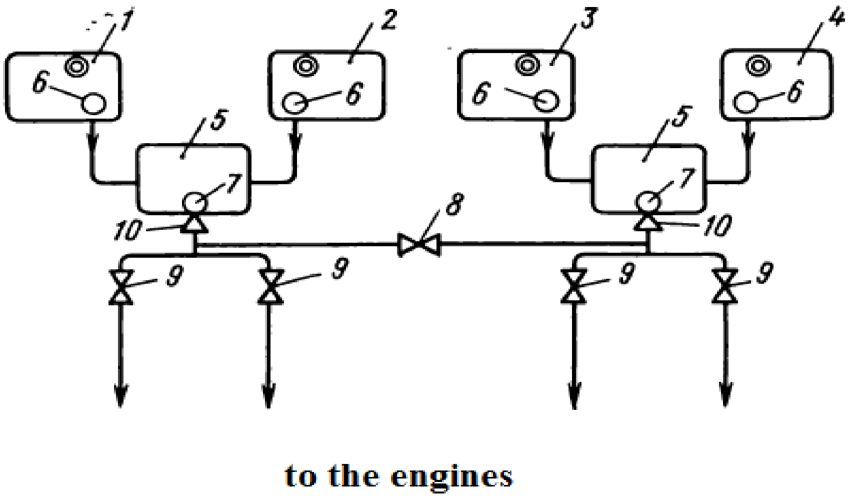


Figure 1.4 – Fuel supply scheme with two fuel tanks:
1 - Tank #1; 2-tank #2; 3-tank #3; 4-tank #4; 5-consumption tank; 6-pumping pump; 7-priming pumps; 8-ring tap; 9-overhead valve; 10-return valve.

On some types of aircraft, usually passenger or transport (Tu-104, "Trident", "Caravella", Short "Belfast", Short "Skyven", etc.), fuel is supplied to the engines from all tanks, i.e. all tanks are expendable (Fig. 1.5). The presence of a large number of expendable tanks on the plane makes it possible to use simple methods to achieve different options for the order of fuel production and to provide.

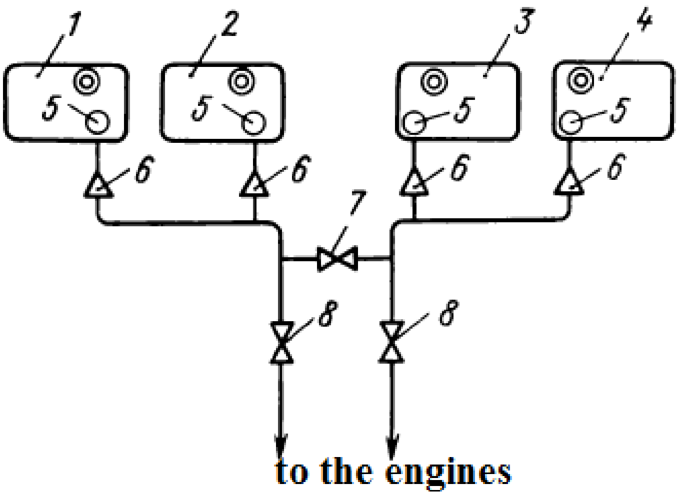


Fig. 1.5. Scheme of fuel supply to engines from all fuel tanks:

1 - Tank #1; 2-tank #2; 3-tank # 3; 4-tank # 4; 5-priming pump; 6-return valve; 7-ring tap; 6-overhead valve

Multivariate use of the aircraft, however, the mass of pumping systems, pipelines and their fittings increases, and the increase in the length of high-pressure pipelines causes additional difficulties in ensuring the reliability of the systems.

1.4. Overview of the main structural elements of the fuel system of a passenger aircraft

The fuel system of a modern aircraft includes the following main elements:

1. tanks or compartments of the aircraft in which the necessary fuel supply for the flight is placed;
2. supply control valves (reservoir switches); valves for emergency stoppage of fuel supply to engines (fire valves);
3. taps for draining fuel sludge from various points of the system; fuel cleaning filters;
4. pumps that supply fuel to engines and pump fuel from one tank to another;
5. devices for controlling the amount of fuel, its consumption and pressure; pipelines for supplying fuel to the engines, connecting the tanks to the atmosphere and returning the cut-off fuel.

1.1.1 Tanks

In modern airplanes, fuel reserves can reach several tens of tons. When flying over long distances, fuel is placed in a large number of tanks installed in the wing, less often in the fuselage.

Currently, three types of fuel tanks are used: hard, soft and sealed tank compartments.

Rigid tanks are made of light aluminum-manganese alloys, which provide deep stamping and stamping, good weldability, high elasticity and corrosion resistance. To give the tanks the necessary strength and rigidity, they have a frame made of partitions and longitudinal and transverse profiles. At the same time, transverse partitions serve to reduce shocks caused by the movement of fuel inside the tank during accelerated flight. Small tanks may have internal partitions.

Currently, soft tanks are widely used. They are easier to use, more durable and weigh less. Soft tanks are made of special rubber or kapron. Thin rubber reservoirs are glued to fabric blocks and one or two layers of synthetic polysulfide (thiocol) rubber. Rubber-metal fittings are glued to such tanks: flanges for fuel level sensors, filling nozzles, connecting nozzles, sockets for mounting locks, etc.

Fastening of thin-walled rubber tanks is carried out in containers inside the wing or fuselage.

The tank compartment is a properly closed internal volume of the wing part. The tank compartment is sealed with synthetic films. The rivet seam is hermetic, so the rivets are pre-coated with sealant. Final sealing is provided by multiple coating of the entire inner surface with a liquid sealant that hardens at room temperature.

The covers of the working hatches of the tank compartments are fastened with bolts with rubber sealing rings and hermetic (cap) nuts.

1.1.2 Valves

The taps installed in the fuel supply system allow you to control its supply to the engines from the corresponding tanks (or groups of tanks), as well as to block the fuel supply to the engine that has failed. By purpose, all mixers are divided into shut-off (overhead) and distribution. According to the control method, there are direct and remote control valves. By design, they can be cork, spool, valve, etc.

Remote control of valves is carried out with the help of electric mechanisms for closing the valve of the MNV type or compressed air.

1.1.3 Filters

The need to clean the fuel supplied to engines from foreign impurities is caused by the presence of solid particles in carburetors, direct injection units, and pumps with sizes ranging from tenths to thousandths of a millimeter. Despite the fact that the fuel poured into the tanks is filtered, and the tanks are protected from the ingress of mechanical impurities, during operation, the formation of corrosion products of pipelines and fuel system nodes, the ingress of pieces of rubber gaskets, etc. is possible. its corrosive properties and, in addition, can lead to clogging of pipelines in case of ice formation at low temperatures. Especially dangerous is the precipitation of moisture and the formation of ice in the pipelines of the fuel systems of modern high-altitude aircraft, which can gain a higher altitude in a short time, as a result of which the formation of condensate sharply accelerates.

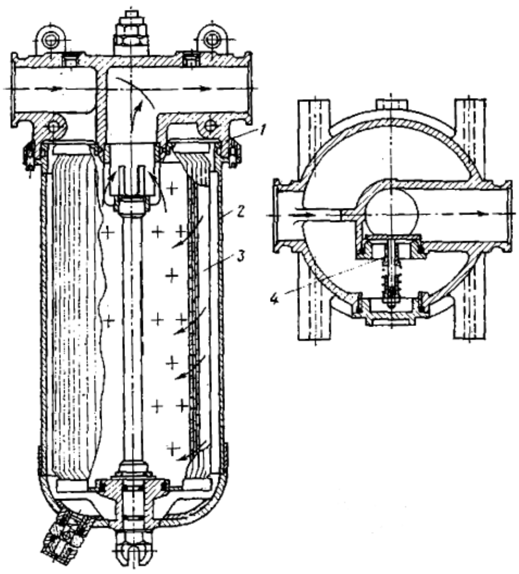


Figure 1.6 – Fuel filter

1 – cover; 2 – glass; 3 – filter element; 4 – bypass valve

In the fuel systems of aircraft, mesh metal, silk, slit, metal-ceramic, paper and mechanical filtering devices are used.

1.1.1 Fuel system pumps

Fuel system pumps serve to supply fuel to the engines in flight at all altitudes, from all tanks or groups of tanks.

According to their purpose, pumps are divided into pumping and discharge pumps, and according to the type of drive: with a drive from an aircraft engine and with an autonomous drive, as a rule, from an electric motor. Of the wide variety of different pump designs and types, the most common are low or low pressure centrifugal, high pressure and gear pumps.

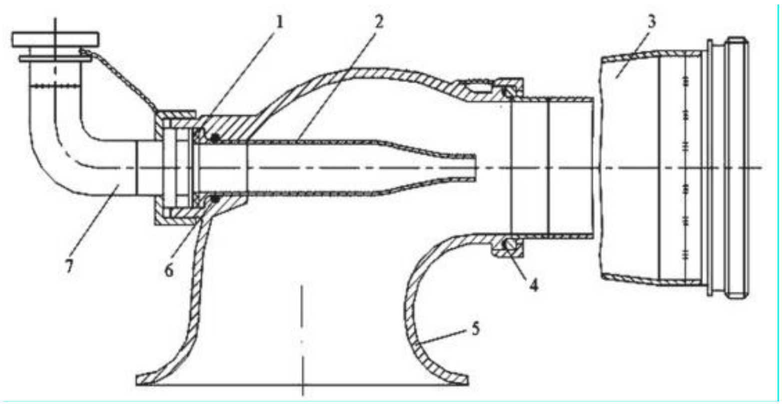


Figure 1.7 – Jet pump

1,4,6 – sealing rings; 2 – nozzle; 3 – diffuser; 5 – body; 7 – tube.

Modern airplanes usually have two priming pumps, one electrically actuated in the fuel tank or at the beginning of the fuel line, and the other, actuated by the aircraft engine, located at the end of the fuel line. pipe in front of the feed (high pressure) pump. Such an installation of pumps ensures a reliable supply of fuel to the engines.

Transfer pumps are designed to transfer fuel from the tanks, from which it must be obtained in the first place, to the feed tanks, that is, to the tanks from which the fuel is sent directly to the engines. The production of fuel from different tanks or their groups is dictated by the need to maintain a strictly certain centering of the aircraft during the entire flight and ensure the necessary unloading of the wing.

The pipelines of the fuel system, which provide fuel supply to the engines, connect the tanks with the atmosphere, are filled with fuel under pressure, are made, as a rule, of aluminum alloy and hoses with connecting fittings. The most common pipe connections: durite (flexible) in tension clamps and nipple (rigid).

Recently, flexible metal sleeves have become widely used, which withstand vibration loads well, are convenient for installation, and are relatively light.

The selection of fuel from the tanks is carried out with the help of aviation feed pumps, the pressure at the outlet of which must be higher than the minimum permissible (usually about 0.3 kg/cm2). A non-return valve is usually installed behind the priming pump, which prevents the reverse flow of fuel.

The fire valve blocks the fuel supply line when the engine is not running and in emergency flight.

Some aircraft have high hydraulic resistance in the line from the tank to the engine pump. This made it necessary to include in the fuel line an additional drive pump, pumping, which provides the necessary pressure to the main pump of the engine.

If the oil in the engine lubrication system is supposed to be cooled with fuel, then an oil cooler is installed in the fuel system.

As fuel is produced from the tank, the pressure in the tank drops, which can cause the tank to explode. To avoid this, fuel tanks communicate with the atmosphere through drain pipes.

In airplanes that fly at altitudes above 15,000-20,000 m, there is a risk of leaking a significant amount of fuel into the sewers. To eliminate this, it is necessary to create excess pressure in the tanks. This pressure is created by inert gases: nitrogen, carbon dioxide and others, which at the same time are a means of fighting fire.

A characteristic feature of the fuel systems of modern aircraft is the large capacity of their tanks. Refueling large quantities of fuel through the upper necks of conventional tanks is a difficult and time-consuming task, which is why the vast majority of modern aircraft have a lower pressure fueling system. These systems allow refueling in a very short time.

The refueling system of each aircraft consists of refueling nozzles (one or two), a refueling control panel, nozzles for fuel supply to refueling tanks or a group of tanks, refueling taps with an electric drive, safety float valves that exclude overflow of tanks. in the event of a malfunction of the fuel taps

To increase the range of fighters, some types can be refueled in the air from a specially equipped refueling aircraft.

A forced landing of a modern transport aircraft immediately after take-off, i.e. at maximum take-off weight, is in some cases unacceptable due to the limited strength of the chassis. Landing weight reduction in such emergency situations can be achieved by draining the fuel.

The system of emergency fuel draining in flight must meet the following requirements: Draining of a certain amount of fuel (which sufficiently lightens the aircraft) must be carried out within a limited time of approximately 10-15 minutes. At the same time, the centering of the plane should change somewhat. Spilled fuel must not enter the hot gas zone.

The emergency fuel drain system consists of taps, nozzles and drain control taps.

1.5. Technical requirements relating to passenger aircraft fuel systems

The basic requirements for the fuel system are contained in aviation rules (AR-25 or Western analogue Jar-25). In part of the fuel supply system to engines:

Each fuel system must be designed and manufactured in such a way as to supply fuel with consumption and pressure installed for the normal operation of the main and auxiliary engines in all expected operating conditions, requiring all maneuvers required by the certificate, and during which operation is allowed . Basic and auxiliary engines.

Each fuel system must be designed in such a way that the air flowing into the system may not cause combustion disruption in a gas turbine engine.

Each fuel system of the AMD aircraft must be able to operate for a long time throughout the fuel and pressure consumption range, receiving the maximum possible in the expected operating conditions, the amount of soluble and free water and cools to the most critical freezing temperature that can be faced during operation.

Each fuel system must satisfy the fuel supply to each engine in the system, regardless of which section of the system provides fuel supply to the second engine.

Each fuel system must provide fuel supply with a consumption of at least 100 % of the cost required by the engine at each intended mode of operation and maneuver.

The fuel is supplied to each engine under pressure and at temperature within the limits specified in the engine type.

Each main fuel pump must support each mode and position of the aircraft, and the corresponding emergency pump should be able to replace the main pump.

From which this engine is powered, it is produced during regular operation, and any other tank, from which fuel is normally supplied only to this engine, has a fuel reserve that is used.

The fuel supply should be provided under the worst condition:

- when the pumping pumps are pumped;
- when fuel is supplied to the engines from one tank with an open ring tank.

1.6. Features of maintenance of the fuel system of the passenger aircraft

When maintaining the fuel system of the aircraft, it is necessary to observe the safety rules with special care.

«Work on the replacement of units, pipelines and other works related to the possibility of open fuel supply to the ground or in the design of the aircraft must be carried out when the electricity supply of the aircraft is disconnected. It is allowed to supply fuel on the transmission line and the electrical equipment units.

Work in fuel caesons - tanks should be carried out in overalls with a mask or gas mask in the presence of an observer.

The overalls should be made of cotton fabric with fasteners or buttons that do not give sparks. The person responsible for observation must see the person who works in the tank and the signals they are given. During all work, take measures in the event of assistance signal. When working inside the tank, remove all unnecessary tools and personal belongings from the pockets, do not take metal objects with open edges.

To prevent the flash from filling the aircraft, it is necessary to grind the aircraft, filling hoses and fuels. Install the gasket under the wheel of the filler. It should be remembered that the source of ignition can be discharges of statistical electricity and sparks that result from strokes of metal objects about each other. Therefore, in order to avoid static electricity, it is forbidden to use woolen or textile materials when washing.

The neck of the caissons - tanks and other containers with fuel materials to open manually. Without hitting metal objects on them to avoid sparking. The friction and drawing of such - or metal objects (stairs, boxes, etc.) near the aircraft or under it with open fuel tanks is not allowed. It is not allowed to walk in shoes, stuffed with nails and metal plates, in the immediate vicinity of open tanks.

Main Fuel System Maintenance Work:

- check the condition of pipelines and nodes of the system:
- Checking the operation of pumping pumps, fuel pump of the Armed Forces:
- Checking the tightness of the power supply system of the main motors of bridge valves 1:
- work on refueling and fuel drain;
- Determining the performance of system blocks:
- antifreeze supply and pouring it.

During operation, it is necessary to carefully monitor the tightness and reliability of all pipeline connections. In the presence of leaks through the connection, replace the seals in them.

When disassembling the connecting metal couplings of the pipelines, it is necessary to drain the fuel from the pipeline and a special key to loosen the cape nuts, one loosen the nut, and the other completely distract.

Then slide the clutch towards the weakened nut. Remove the seal rings. When the earrings are removed, the inverted clutch should be mixed freely at the ends of the pipes.

When installing a connecting clutch of the nut, it is necessary to twist on a clutch without wrapping the rubber rings of the seals.

Details with dents, scratches and burrs on compacted surfaces are not tightened on the plane.

When connecting pipelines with a coupling, it is necessary to ensure tightness of pipelines at joints. The gap between the ends of the connecting pipelines should be 9+Zmm.

Examine the highways of the fuel and drainage system. There should be no dents, scratches and scuffs on the pipelines. Contact pipelines with elements of the aircraft housing is not allowed.

Make sure that there are no fuel leakage at the pipelines and their attachment to the units.

Check the integrity of metallic jumpers and their fastening.

To prevent corrosion, use only clamps with a galvanized ribbon.

When inspecting the nodes of the fuel system, it is necessary to make sure that there is no leak, cracks, dents, damage to the paint and varnish coating, weakening of bolts attachment and counteraction.

When inspecting the floats of the dispenser, pay special attention to the state of floats and their levers.

When carrying out work it is necessary to ensure that the caisson - containers, pipelines and units do not get foreign objects and water. snow. dirt.

To remove the pumps, you need to drain the fuel from the tanks. It is forbidden to lift pumps.

In case of installation of the pump, damage to the protective casing of the motor is not allowed.

Before assembling the nodes, it is necessary to check the integrity of the seals, to make sure that there are no branches, cuts, dents, deformation of aging nets on rubber rings. After installing the pumps, check their performance by turning them hand in the cab and listening to them.

After repair and disassembly of pipelines and units of the fuel system, but to monitor the cleanliness of the air of the air of the drainage system of fuel tanks.

The drain pipeline of the filling neck has no clogging, since the condensate in it can freeze, tore it, and through this break the fuel will flow from the tank.

Checking the operation of pumping pumps and tightness of the main engines power system is performed by alternate inclusion of the pumps of the cost tank.

To check the tightness of the main engines of the main engines, open the overlap of the valve and after 5 minutes (at least) the operation of the pumping pumps inspected the fuel lines and will be convinced of their tightness. In the presence of leaks on pipeline connections with each other and units, replace the rubber rings of seals.

Fuel refueling is carried out in accordance with the task for flight by means of pressure refueling. The main fuel for the engines of the aircraft and the Armed Forces engine is the kerosene of T-i brands. TC-1. RT and mixtures of these brands.

After about 15 minutes. After filling, drain the stops from the skin caisson - a tank of 0.5-1 liters into clean glassware through drainage fuel valves. The stove is drained with a special hose with a tip that attaches to the drain tank tap.

In the process of dressing, it is possible to walk the wing only in special shoes. There should be no dirt and sand on the hose used for dressing. Before starting the dressing, it is necessary to install a metallization between the tank's neck and a filling gun. The dressing can be done simultaneously with any number of pistols from one or two dressers [33].

1.7. Conclusions to the section

The following section was considered and analyzed the following factors of the fuel system of the aircraft:

- influence of factors on the operation of the fuel system of the passenger aircraft;
- inspection of the schemes and methods of fuel supply to the engine of the passenger aircraft;
- inspection of the main structural elements of the fuel system of the passenger aircraft;
- technical requirements for fuel systems of passenger aircraft
- peculiarities of maintenance of the fuel system of the passenger aircraft;

The materials that have been analyzed will help disclosure the topics of the diploma work in the following sections.

2 METHODOLOGİCAL BASES OF MAİNTAİNİNG THE OPERATİONAL RELİABİLİTY OF THE FUEL SYSTEM OF A LONG RANGE PASSENGER AİRCRAFT

2.1. System-directed and physical and information approaches to study the problem of ensuring and increasing the reliability of the fuel system functioning

Systematic approach is one of the main directions of the methodology of special scientific knowledge and social practice, the purpose and objective of which is to study certain objects as complex systems. The systematic approach contributes to the formation of appropriate and adequate formulation of the essence of the studied problems in the specific sciences and the choice of effective ways to solve them [34].

The methodological specificity of the system approach is that the purpose of the study is to study the patterns and mechanisms of system formation - a complex object, consisting of certain components (elements). At the same time, special attention is paid to the variety of internal and external connections of the system, the process (procedure) of combining basic concepts into a single theoretical picture, which allows to reveal the essence of the integrity of the system [34].

A systematic approach is a category that has no single definition because it is interpreted too wide and ambiguously. The literature provides the following interpretations or defining a system approach:

- integration, synthesis of consideration of different sides of a phenomenon or subject;

-an adequate means of research and development not of any objects, conditionally called the system, but only those that are organic;

- expressing procedures for presenting the object as a system and methods of their development;

- a lot of opportunities for obtaining a variety of statements and evaluations, which involve the search for different options for performing a certain work with the next choice of the best option [34].

Using the methods of system-oriented and physical-information approach, we will conduct a study of the main types and failures of the fuel system of the passenger aircraft.

During 2005, 389 incidents related to the refusal of aviation equipment in flight occurred with aircraft(45). The distribution of incidents related to the refusal and malfunctions of aviation equipment in flight by types of systems refused is presented in Figure 2.1.

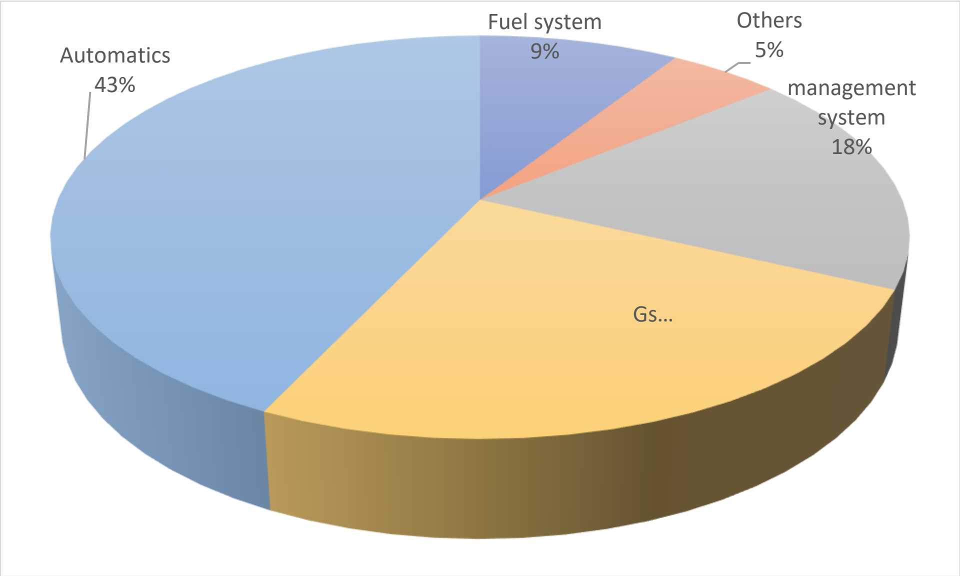


Figure 2.1-Distribution of incidents due to the refusal of aviation equipment on aircraft by types of systems, which refused in 2005.

In 2005, incidents with long-haul aircraft due to the refusal of aviation equipment in flight were mainly related to the design and production disadvantages of aviation equipment. This factor was noted in 41% of such incidents. However, there is also a significant number of failures related to violations of the inserted Rules of operation of PE (8 %) and poor repair (4 %).

The quality of aviation fuels largely determines the reliability of the Aviation Air Force and the safety of the Armed Forces GA. The analysis of aviation accidents for the period from 1995 to 2005, related to the quality of fuel, showed that during the specified period there were 96 events related to the refusal of the fuel system of the aircraft and engines in the process of preparation and flight. The most serious incidents occurred due to the sticking of fuel -regulating equipment (WA), fuel pumps that pump and pump.

Fuel system malfunctions can be caused by structural and production defects, as well as violations of the rules of its operation and maintenance. The characteristic failures and malfunctions of the system include the flow of fuel tanks, violation of tightness of pipelines, units and their connections, destruction of bearings of pumps that pump (pump) and their seals.

Table 2.1 shows a list of characteristic malfunctions of the fuel system of a passenger aircraft aircraft

Type of failure (defect)	Signs of failure (defect)	External manifestation of failure (defect) is possible
Violation of tightness of fuel tanks	Fuel sprinkling outside	Fire
The fuel fuel valve is unfinished	Sagging valve petals, fuel leakage	Fire
Contamination of the command fuel filter	Closing the fuel overflow valve	Engine stop
Destruction of pipelines	Pressure and performance drop at the engine inlet	Engine stop
Boost pump failure	Engine inlet pressure and performance drop	Fire
Boost pump failure	Pressure and performance drop at the engine inlet	Stopping the engine at high altitudes
Broken wiring at the fire hydrant switch	Formation of a false circuit and involuntary closing of the fire hydrant	Engine stop
Jamming of the impeller of the flow meter sensor	There are no flow meter readings	Stopping the engine due to complete fuel production
Failure of capacitive sensors	There is no fuel gauge reading	Stopping the engine due to complete fuel production

The analysis of characteristic malfunctions and failures of the fuel system makes it possible to identify the most common of them. The distribution of fuel system failures due to their causes is shown in fig. 2.2.

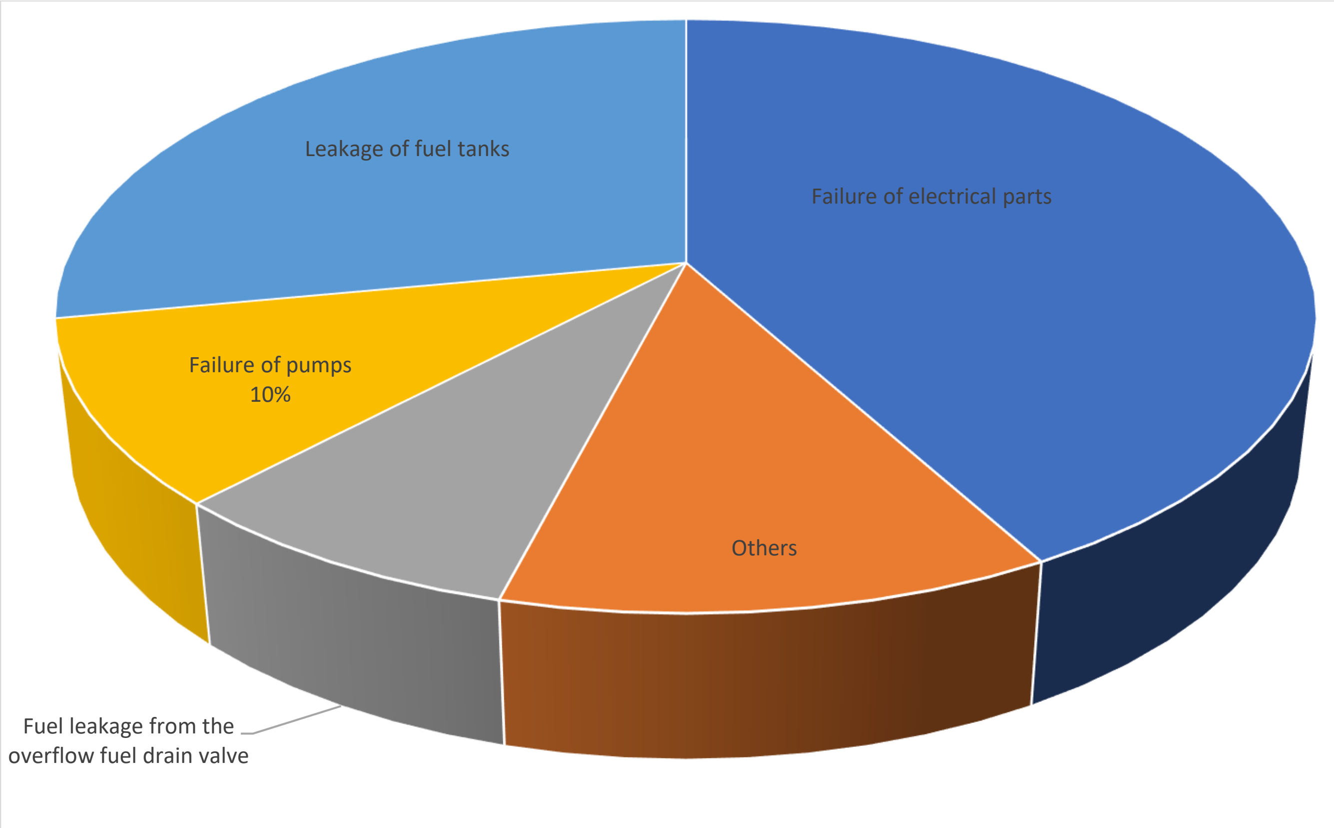


Figure 2.4 – Distribution of causes of fuel system failures

From fig. 2.4 shows that the main failures of the fuel system are:

– failure of the electrical part;

– leakage of fuel tanks;

– failures of pumping and transfer pumps;

– failure of the spilled fuel drain valve.

Operational reliability is the most important characteristic of any unit and system. It is necessary both to maintain it at a high level and to increase it. The methods of increasing the operational reliability of fuel systems include [45]:

– improvement of the system of control and management of the reliability of fuel systems of the armed forces;

– optimization of the scope and periodicity of performance of regulatory works

– ensuring the required level of operational manufacturability

– increasing the efficiency of fuel use in fuel systems.

The best result is achieved when applying a set of measures to increase the operational reliability of fuel systems.

2.2. Modeling the processes of functioning, ensuring and increasing the reliability of the fuel system of a passenger aircraft

Construction of models and mathematical modeling of the processes of the functioning of products (components) of the aircraft makes it possible to develop optimal schematic diagrams of systems at a higher level, to determine the characteristics of objects of operation in different modes of operation, to take into account the influence of operational factors.

The functioning of complex technical systems (CTS) in operating conditions, which involve prevention and preventive replacement of elements, maintenance, is described by a number of models that have a stochastic nature. The apparatus of controlled random processes is widely used to study these models.

At the same time, dynamic control tasks are investigated, when the decisions made depend on the previous history or, in the Markov case, on the state of the process at the current moment in time. When mathematically researching and building maintenance strategies, it is usually assumed that the number of possible restoration works in the system is known, and the task of choosing a maintenance strategy and the timing of their implementation is solved taking into account the objective characteristics of system reliability, the nature of failure indications, the presence of built-in performance monitoring, specific features of operating conditions, etc. .

To optimize the maintenance strategy, a quantitative criterion is set (a function that depends on the time distribution function of fault-free operation, the function of distribution time for repair work, etc.), the value of which can be used to judge the quality of the selected maintenance strategy. So, for example, V.A. Kashtaniv proved that if the process x(t), which describes the evolution of the system states over time, takes a finite set of values and is regenerating, then the functional J(G,Φ,F), which characterizes the quality of the system's work, has the form of a fine-linear functioned:

$$J(G,\Phi,F) = \frac{\iiint_0^\infty A(x,v,y)dG(x)d\Phi(v)dF(y)}{\iiint_0^\infty B(x,v,y)dG(x)d\Phi(v)dF(y)}$$

where F(x) – uptime distribution;

Φ(x) – distribution of time for independent manifestation of refusal;

G(x) – a function that determines the periodicity of maintenance.

The functions A(x,v,y) and B(x,v,y) contain conditional mathematical expectations of the process x(t) staying in the considered states during the regeneration period.

However, during the functioning of the CTS, the necessary characteristics are not always fully known, and decisions have to be made in conditions of incomplete information or in the absence of it.

When optimizing maintenance processes of complex objects of operation, difficulties arise with the multidimensionality of problems, the need to describe distribution functions according to normal or exponential laws, etc., which causes the need to introduce a number of assumptions and simplify the solution of problems.

If the flows of failures and restorations of technical devices are the simplest, and therefore the distribution of time intervals between failures and the moments of the end of restoration is exponential, then this allows the use of the apparatus of Markov random processes to build a reliability model of technical devices.

In the case when the process occurring in a physical system with a countable set of states and continuous time is Markov, then it is possible to describe this process using ordinary differential equations, in which the state probabilities Pi(t) are unknown. In general, such states include: work, recovery, waiting for use, control, prevention, etc.

In [18, 36], an approach to substantiating parameters of CTS service is considered. Models are used, for the construction of which a number of properties of Markov processes with continuous time are given. To create a model:

The number of states n in which the system is in operation is determined;

It consists of a state graph;

The initial state of the system is indicated;

For the flow intensity a_ij is determined for each possible transition that transfers the system from state A_i to state A_j.

The probability P_i of the system being in each of the states A_i is described by a system of differential equations, which is expressed in the steady state of operation in algebraic terms:

$$\sum_{j=1}^{n} a_{ij} \cdot P_j - \sum_{j=1}^{n} a_{ij} \cdot P_i = 0$$

Substituting *a*ij which depends on the service system, gives *P*j, corresponding to different combinations of service parameters.

In [37], Markov and semi-Markov models of the process of changing the quality of the functioning of AT products were proposed and methods of analysis of these models were developed based on the initial probabilistic characteristics of the streams of influencing obstacles. Probable characteristics of the fulfillment of the conditions of an operational state are determined from the solution of the Markov recovery equations:

$$\Phi_{ij}(t) = \delta_{ij} \cdot \psi_i(t) + \sum_{k=1}^{m} \pi_{ij} \int_0^t W_{ik}(\tau) \cdot \Phi_{kj}(t-\tau) \cdot d\tau \qquad i,j = \overline{1;M}$$

$$F_i(t_p) = \sum_j \int_0^t F_j(t_p - \tau) \cdot Q_{ij}(\tau) \cdot d\tau + \sum_j Q_{ij}(t) \qquad i = \overline{1;M}$$

where *M* – set of states of the process of changing the quality of product functioning q(t);

$\Phi_{ij}(t)$ – interval probabilities of transitions of the process q(t), characterizing the probability of the presence of the process;

$q(t)$ – at time t in the jth state, provided that at the initial moment of time he was in the ith state;

$F_i(t_p)$ – time distribution function t_p process q(t) in the subset of workable states M_p provided that at the initial moment of time it is in the i-th state. Other values are determined through matrix elements $[Q_{ij}(t)]$ from expressions:

$$\pi_{ij} W_{ij}(t) = \frac{dQ_{ij}(t)}{dt};$$

$$\psi_i(t) = 1 - \sum_{j=1}^{M} Q_{ij}(t).$$

Thanks to the use of these models, the reliability assessment can be carried out:

Coefficient of readiness

$$К_г = \sum_j \Phi_j$$

where Φ_j – interval transition probabilities of the process q(t);

- the average time of stay of the JSC product channel in the zone of workable working conditions;

- average recovery time.

Taking into account the TS of JSC products, we get the expression for the readiness factor:

$$К_g = \sum_{j=1}^{M} F_i P_{кф}$$

where $P_{kf} = \int_{q_{гр}}^{\infty} W(q_i) dq_i$

$W(q_i)$ – probability density.

The literature [38] describes a method for assessing the reliability of improved systems, based on the calculation of the increase in reliability for each of the specified characteristics instead of calculating the absolute values of the reliability indicator, which allows you to dramatically reduce the amount of calculations. Increased reliability:

$$G_p = \frac{P_c^*}{P_c} = \frac{P_j^*}{P_j}$$

where P_j^* та P_j – the probability of failure-free operation of the i-th element of the system after the increase in reliability and before it. Then *P* increasing system reliability

$$P_c^* = G_p \cdot P_c$$

For systems in which P(t) tends to 1, the failure probability amplification factor is used: $G_Q = \frac{Q_c^*}{Q_c}$

Reliability increase by availability factor $К_г^*$

$$G_{К_г} = \frac{К_г^*}{К_г} = \left[1 + К_г \cdot \left(\frac{\lambda_j^*}{\mu_j^*} - \frac{\lambda_j}{\mu_j}\right)\right].$$

Reliability improvement is defined for:

1) permanently included non-renewable system reserve;

2) a backup renewable system with one maintenance team;

3) reservation by replacement and different service priorities.

The proposed method simplifies calculations, allows you to calculate the reliability indicators of the new system in the presence of reliable data on the reliability of the old one, makes it possible to calculate the reliability of the CTS itself, if the latter are presented in the form of those that develop from simple ones.

The work [39] describes the functioning of technical devices with free laws of the probability distribution of the time of trouble-free operation and recovery of time elements using integral level systems. An approximate iterative method for the development of a level system solution is given, as a result of which the failure earnings, the average recovery time and the stationary availability coefficient are produced. For compiling integral levels, we offer a model in which 6 subsets of elements are defined for the k-th state of the device.

One of the methods of CTS research is a method based on the use of a bionic model [40]. Its essence is that it begins with the laws of distribution of the number of inoperable elements in different modes. In the case of compliance with their normal law, the coefficient of operational readiness is calculated.

However, the generally accepted methodology does not take into account inequalities beyond all elements in ensuring the quality of system functioning. It is proposed [41] to introduce weighting factors K_i for *i*-th level, which are either included in the technical tasks, or start experimentally. Then:

$$К_г = \prod_{i=1}^{n} F(\frac{m \cdot k_i - \overline{m_i} n}{n \cdot \sigma m_i})$$

where *n* – the number of levels of influence on quality;

m - the maximum number of inoperable elements, at which the nominal quality of the system is ensured;

$\overline{m_i}, \sigma m_i -$ mathematical expectation and root mean square deviation of elements at an arbitrary moment;

F(.) – normal distribution function.

When analyzing the reliability of CTS, it is not always possible to use Markov processes correctly. As a rule, this works until the recovery time or the failure flow, which are not the easiest. Construction of systems of equations describing non-Markov models is associated with great mathematical difficulties.

Taking into account the specifics of air transport, where the requirements for provision of power supply prevail, for the production of products of the FS when optimizing according to cost criteria, it is necessary to maintain the requirements of the specified levels of the power supply of the FS. In such conditions, the optimization criterion is equal to:

$$Q_{Ri}(t,\Delta t) \leq Q_{Ri}^{\cdot}(t,\Delta t),$$

$$C_{question.ex.} \rightarrow C_{\min}$$

або

$$K_{г} \rightarrow K_{г\,\max},$$

where $Q_{Ri}(t,\Delta t)$ – the level of probability of functional failure over time Δt;

$Q_{Ri}^{*}(t,\Delta t)$ – regulated level of probability of functional failure during flight time Δt;

$C_{question.ex}$ – питомі експлуатаційні витрати;

$К_{г}$ – readiness factor.

Relying on the fact that in SARP's ICAO regulated frequency of occurrence of events: special flight situations (SFS) and functional failures under the condition of limitation in the optimization of maintenance regimes allows to use the probability of SARP occurrence or functional failure leading to SFS (QRi(t)):

$$Q_{Ri}\,(t,\Delta t) \leq Q_{Ri}^{*}(t,\Delta t).$$

The set of control influences is considered optimal if the loss function is minimized under the conditions of ensuring regulated fail-safe levels.

Thus, to calculate the probability of functional failure of the system, it is necessary to obtain analytical features $Q_{Ri}(t,\Delta t)$ from the operational characteristics of the products and the maintenance kit:

$$Q_{Ri}(t,\Delta t) = f(\lambda_i,\Delta\tau_k,P_k),$$

where λ_i – failure intensity of the i-th element of the system;

$\Delta\tau_k$ – number of controls;

P_k – the probability of detecting a failure during maintenance.

To be used as an optimization criterion, it is necessary to obtain analytical dependencies that link the costs of implementing control influences and the amount of loss due to loss of operational capacity, with functional characteristics and parameters of the maintenance regime.

Specific operational costs associated with maintenance and elimination of the consequences of system failures will be equal to:

$$C_{question.ex.} = \frac{C_k}{\Delta\tau_k} + C_{yv}\cdot\lambda_c,$$

Where C_k – the cost of scheduled maintenance; Cuv – the average cost of eliminating the consequences of system failures;

λ_c – intensity of system failures.

Thus, the specific costs associated with maintenance depend on the object's failure-free operation, the maintenance regime, the cost of control operations and the costs associated with eliminating the consequences of failures:

$$C_{question.ex.} = f(\lambda_c, \Delta\tau_k, P_k, C_k, C_{yv}.)$$

So, for system elements that have a gradual nature of failures and a parametric type of vehicle control, the criterion can be given in the form:

$$Q_{Ri} = f(\lambda_{iv}, \lambda_{in}, \eta_i, \Delta Y, \Delta t_{di}, T_{\text{MPi}}),$$

$$C_{question.ex.} = f(\lambda_{iv}, \lambda_{in}, \eta_i, \Delta Y, \Delta t_{di}, C_{dept.i}, C_{dept.i}, C_{di}, T_{\text{MPi}}),$$

where $\lambda_{iv}, \lambda_{in},$ – the intensity of sudden failures and malfunctions, respectively;

$\eta_i,$ – the intensity of failures with a monotonous measurement of a parameter that has a determining character;

ΔY – permission to change parameters;

Δt_{di} – frequency of diagnosis;

T_{MPi} – inter-repair resource;

$C_{dept.i}, C_{carry.i}, C_{di}$ – the cost of eliminating failures, malfunctions and carrying out diagnostic procedures.

In order to increase the efficiency of the operation of the aircraft, it is necessary to increase the time shares that correspond to the operational state of the aircraft - why the maximum efficiency of readiness $К_г$ (minimum downtime ratio $К_{пр}$ during maintenance):

$$К_г \to К_{г\,max}\ (К_{пр} \to К_{г\,min}\ ).$$

Coefficient in simple large expression:

$$К_{пр} = К_{то} + К_{вп},$$

Where $К_{то}, К_{вп}$ – coefficients of downtime for maintenance and restoration of working capacity. Kto coefficient in a larger expression:

$$К_{то} = \frac{t_{то}}{Т_{то}},$$

Where $т_{то}, Т_{то}$ – duration and maintenance time.

With sufficient accuracy for practice, the Kvp coefficient is calculated based on the totality of:

$$К_{vп} = \lambda_{ser} \cdot Т_{в},$$

$$\lambda_{ser} = \frac{1}{T_{TO}} \cdot \int_0^{T_{TO}} \lambda(t)dt$$

$$К_{то} = \frac{t_{то}}{Т_{то}},$$

where $\lambda(t)$ – failure intensity;

$Т_v$ – average recovery time.

With any distribution of working hours before failure of the element, there is a dependence:

$$\int_0^{T_{TO}} \lambda(t)dt = -\ln P(T_{TO})$$

where $P(Т_{то})$ – the probability of maintaining working capacity.

Then the idle ratio $К_{пр}$ your expression:

$$К_{пр} = \frac{t_{TO}}{T_{TO}} + \frac{T_B}{T_{TO}}[-\ln P(T_{TO})]$$

If you examine the dependence of Kpr on the extremum, it is not important to make sure that there is an optimal speed of maintenance of the product, which ensures the minimum downtime ratio.

Unfortunately, the method does not solve the problem of grouping the composite elements of products according to the frequency of their maintenance and replacement. Most often, the following are accepted as service efficiency criteria: the probability of failure-free operation [43, 44]; readiness factor [44]; coefficient of technical use [18, 36]; service efficiency ratio [5]; maintenance costs [5], etc. The relevance and complexity of solving the tasks of analysis and synthesis of maintenance systems in order to increase the efficiency of the FS as an CTS leads to the fact that the number of studies in this field is increasing.

In order to comprehensively take into account the impact of controlling influences on the characteristics and properties of objects of operation, it is necessary to develop a new methodical approach to managing the state of JSC products, which allows determining the optimal controlling influences taking into account all operational factors.

2.3. Generalized scheme and characteristics of methods of alternative ways of increasing the reliability of the fuel system of a passenger plane

Let's analyze the scheme of a typical aircraft fuel system. What will happen to the aircraft in the event of calculated single failures and their combinations in the AFS: two electrical failures, as well as a mechanical and electrical failure?

Initially, in each engine of this aircraft there is only 1 main high-pressure fuel pump with a regulator in the form of a servo, spool and metering needle, which performs the function of a controlled throttle. The fuel system shall provide emergency pumps or an additional main pump to supply fuel to each engine in the event of failure of any main pump other than a direct fuel injection pump approved as part of the engine." Jamming of the spool, destruction of pump elements will lead to pump failure and engine failure. This corresponds to a complex situation (CS) according to the classification [35].

If a similar second failure occurs on the other engine, the second engine will shut down, causing the aircraft to glide to an off-strip landing. This is an emergency situation (ES), which is likely to turn into a catastrophic situation (CS).

In fig. 2.1 shows an example of a typical diagram of the fuel system of a twin-engine passenger aircraft.

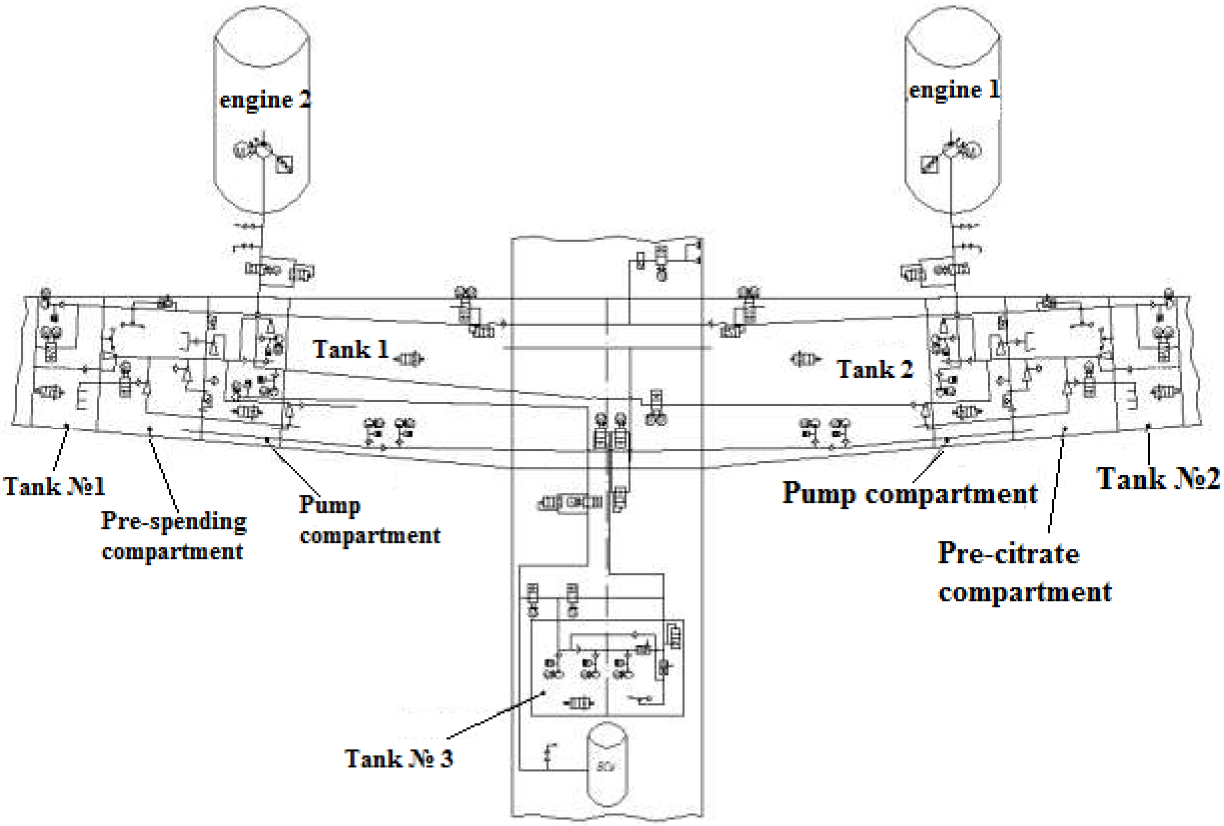


Figure 2.1 –Typical scheme of the fuel system of a twin-engine passenger aircraft

Compared to AHS and SS, fuel systems (AFS) significantly lose in terms of reliability and fail-safe both according to the requirements set forth in [35] and in implementation on airplanes.

Similar considerations can be made with fire hydrants that close the fuel supply to the engine in the event of a fire at the command of the crew. However, the fire hydrant will shut off the fuel supply to the engine and with one false electrical signal, the engine will fail, and with the second false electrical signal, the second engine will fail with the consequences specified above. Other situations are also possible when calculation failures occur in the AFS, which lead to complication of flight conditions, SS, emergency situationaccording to the classification [35], while when similar calculation failures occur in the AHS, the flight conditions either do not deteriorate at all or are affected much more mildly during the flight and safer.

Let's consider possible improvements of the AFS from the example of a typical fuel system (Fig. 2.2), which will allow to increase the reliability and safety of the AHS level.

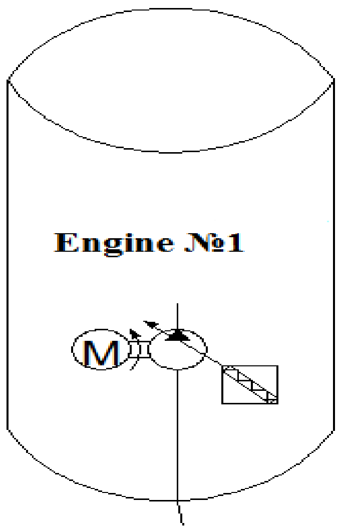


Figure 2.2 - Main fuel pump with in-engine regulator

Fig. 2.3 shows only one main fuel pump, which, according to [35], is approved as part of the engine, but its single failure leads to engine failure, a change in the flight plan, which causes a complex situation (CS) according to the qualification [35], and the failure of the second pump - the failure of the second engine, which qualifies as an emergency situation (AS), which turns with a high probability into a catastrophic situation (CS).

It is suggested to put a second pump in the engine in parallel with the first one, which will work in case the first one fails for some reason. The second pump can be driven, like the first one, from a box of aircraft units (PLA) or from an additional electric motor and turn on after the failure of the first one.

The fuel supply system to the engine consists of a thermal valve and a fire cock, which is closed in flight only in one case: if the engine caught fire and it is necessary to urgently cut off the fuel supply to it. From the point of view of safety failure, in comparison with AHS, this scheme does not stand up to any criticism: with one electrical failure (false signal), the system will fail and the engine will stop. Figure 2.4 shows the fuel supply system to the engine in the area of the fire hydrant.

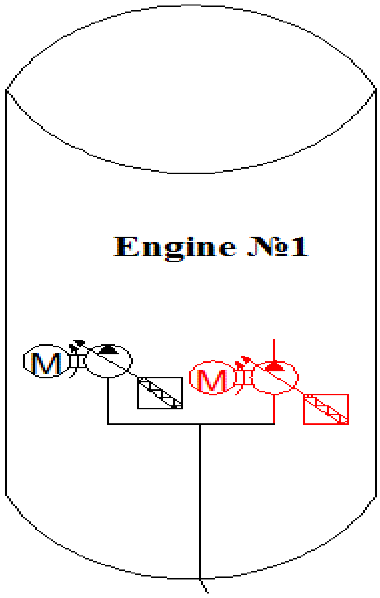


Fig. 2.3 Proposed improvements - installation of a second (reserve) fuel pump with a regulator

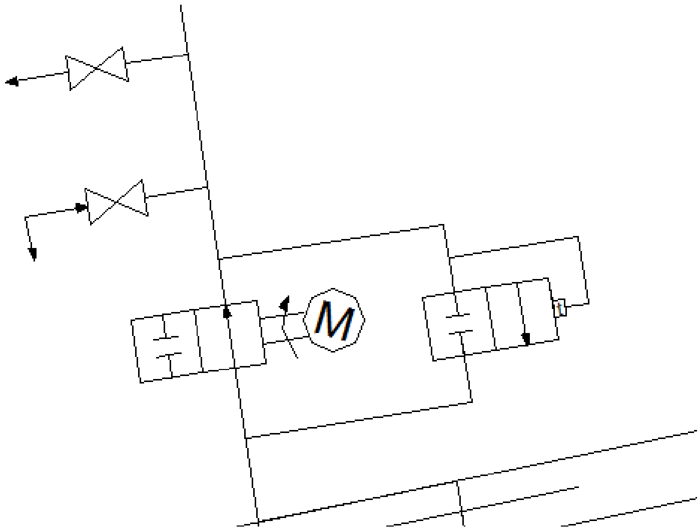


Figure 2.4 – Fuel supply system to the engine in the area of the fire valve

In Fig. 2.5 an improvement in the fuel supply system to the engine in the area of the fire valve is proposed. It is proposed to make a fire hydrant with 2-circuit control (that is, it works only when both contacts are closed), also to add the same fire hydrant in parallel and in series again the same, but two-motor and two-chain fire valve, and also to put a single-motor double-chain valve in parallel with it. This scheme will withstand 2 electrical failures without consequences, which include: the failure of the electric motor for various reasons, which leads to the supply of a false electrical signal to one or two contacts.

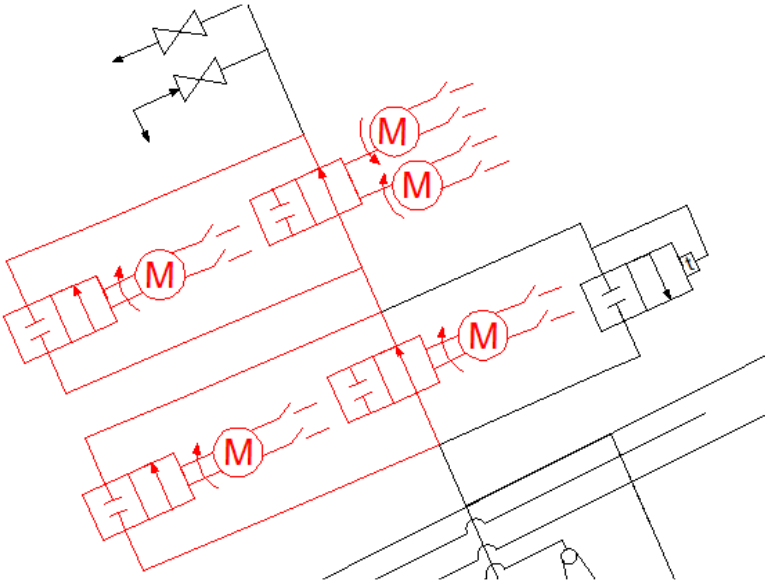


Figure 2.5 - Proposed improvements to the engine fuel supply system in the fire valve area.

Let's consider tank №2 in detail from the point of view of fail-safe. If the electric motor that drives the priming pump fails, and the float valve that allows fuel to drain into the pre-spend compartment by gravity in the event of a pump failure, then the fuel will remain in tank №2 “under lock”. That is, this scheme cannot withstand a combination of one electrical and one mechanical failure.

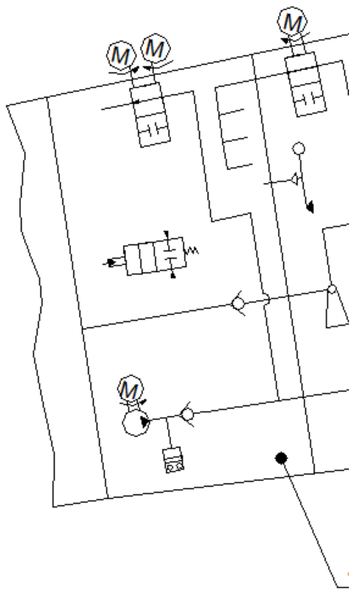


Figure 2.6 – Tank №2

To prevent the situation described above, it is suggested to put a second pumping pump, similar to the first one, in tank №2. Then, in case the first pump fails and the float valve breaks, the second pump will pump fuel into the pre-consumer compartment.

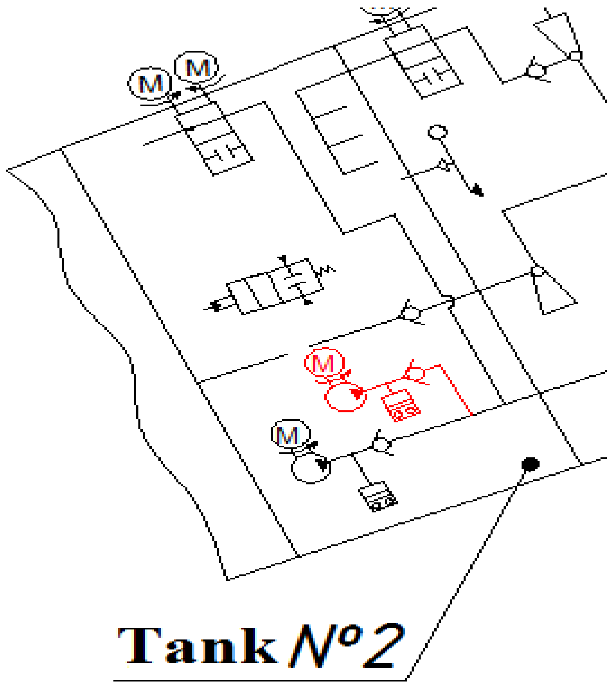


Figure 2.7 – Suggested improvements in tank №2.

In fig. 2.8 shows the diagram of the pre-consumer compartment, where the fuel comes from tank №2 and from where it enters the pump compartment. Having analyzed the pre-expenditure compartment, we can conclude that its scheme does not need any improvements

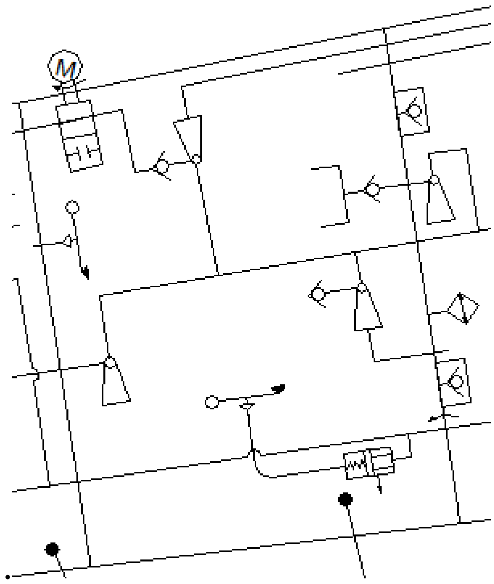


Figure 2.8 - Dispensing compartment

In fig. 2.9. the diagram of the pump compartment is shown, where the fuel comes fromthe pre-consumer and from where it comes through the fire hydrant to the engine.

After analyzing the pump compartment, it can be concluded that its scheme does not need any improvements.

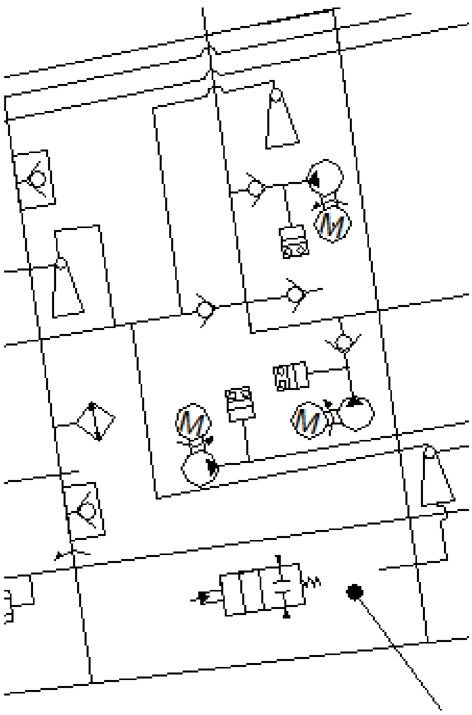


Figure 2.9 – Pump compartment.

In fig. 2.10 shows the layout of the pumping pumps in tank №1. These pumps pump fuel into the pump compartment. In addition, the pump located on the right pumps fuel into tank №3 for balancing pumping. Having analyzed this scheme, it can be concluded that in case of failure of both pumping pumps, located closer to the root part of the wings, balancing pumping from tanks №1 to tank №3 will cease to be possible, which according to the classification of AP25 standards will cause SS or AS, while in AHS, two electrical failures lead only to CFC- complication of flight conditions.

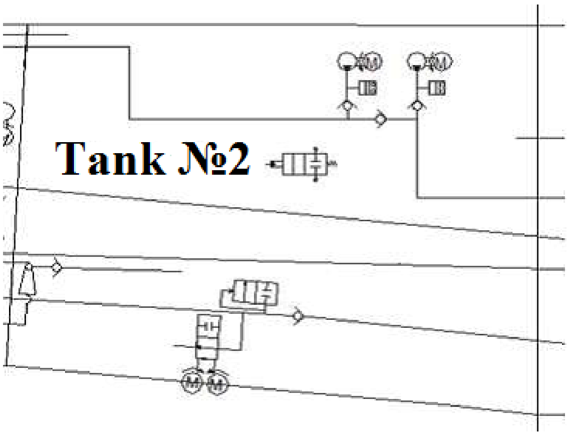


Figure 2.10 - Pumps of the pumping tank №1.

In order for this system to withstand two electrical failures, it is suggested to install a single-circuit in-tank valve in both half-wings parallel to the non-return valve. Then, in case of failure of both "balancing" pumps, this valve will allow fuel to be pumped into tank №3 by the other two pumps of tanks №1 bypassing the non-return valve. In fig. 2.11 Proposed improvements to increase the reliability of balancing pumping from tanks №1 to tank №3 are presented.

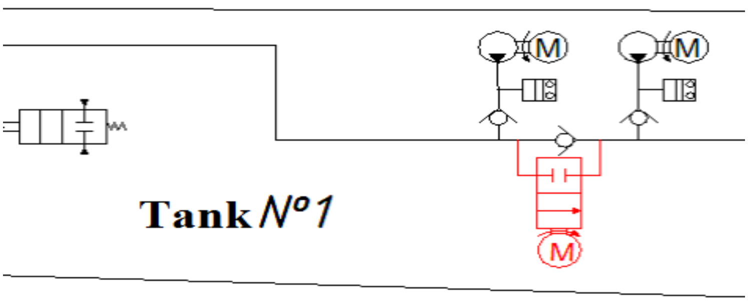


Fig. 2.11 Proposed improvements to increase the reliability of balancing pumping from tanks №1 to tank №3

In this fuel system, there is no such balancing pumping between console tanks №2 directly. This pumping is carried out by pumping fuel from tank №2 to the pre-spend compartment, and from there by jet pumps to tank №1, where the fuel, thanks to the equalizing pipeline, is evenly distributed among tanks №1.

The installed non-return valve does not allow fuel to be directly pumped from tank No. 2 to the opposite half-wing through the refueling pipeline. In fig. 2.12 shows the refueling pipeline of tank №1.

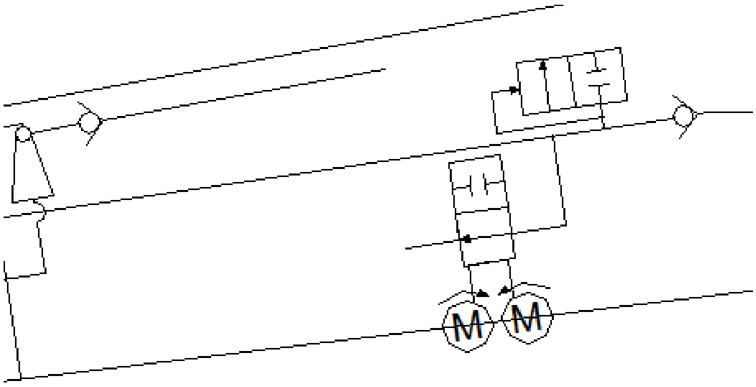


Figure 2.12 – Filling pipeline of tank №1.

If you put an internal overlapping double-chain valve parallel to the non-return valve, then you can pump fuel from one tank №2 to another, bypassing this non-return valve. At the same time, this valve must be duplicated in the same way as it was done in the fuel supply system to the engine, so that this system can withstand 2 electrical, as well as 1 electrical and 1 mechanical failure. Balancing pumping will be carried out by turning off the boost pumps in the tank where the fuel enters. Fig. 13 shows the proposed improvements for balancing pumping between tanks №2.

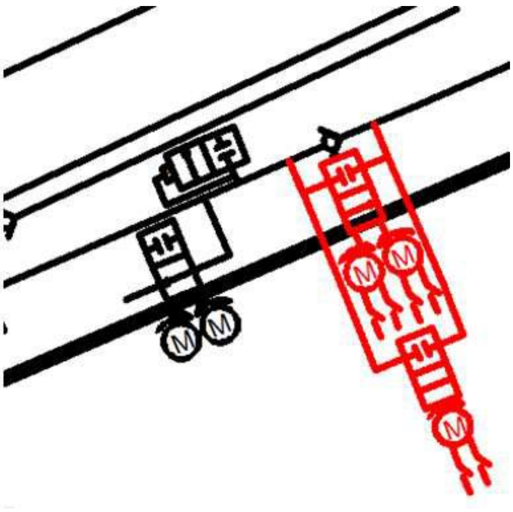


Figure 2.13 - Proposed improvements for balancing pumping between tanks №2.

The proposed scheme will withstand 2 failures, while if 2 false electrical signals are given and either clans will operate without immediate need for it, and fuel will begin to flow from one wing floor to the other, disturbing the centering of the aircraft, then this can lead to catastrophic consequences. In order to prevent such a situation, it is proposed to successively already existing valves, only in one half-wing, to put a similar schematic solution, but already with single-chain valves. On Fig. 2.14 presents the proposed improvements in the other half wing for carrying out pumping of the balancing fluid between tanks No. 2.

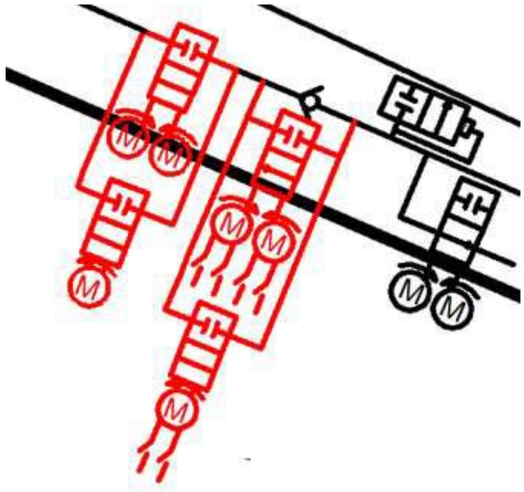


Figure 2.14 - Proposed improvements in the other half-wing to provide balancing pumping between tanks № 2.

Let us now consider the diagram of a part of the fuel system located in the fuselage of the aircraft. There are 3 internal tank taps from left to right: a tap responsible for balancing pumping from tanks №1 to tank №3, similar to it, but responsible for pumping in the opposite direction, and a cross-feed valve that allows you to feed the engine with fuel from the opposite side if necessary half wings After analyzing this diagram, we can conclude that none of these faucets can withstand 2 failures.

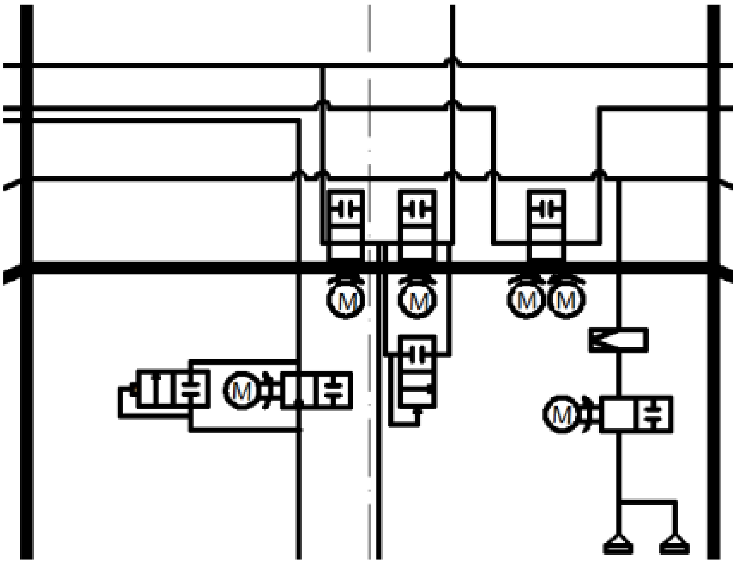


Figure 2.15 – Fuselage part of an airplane wing.

In order to bring the fuel system closer to reliability and fail-safe AHS here, it is proposed to apply a schematic solution similar to the balancing pumping between tanks No. 2, while the taps responsible for the balancing pumping from tanks No. 1 to tank No. 3 should be double-chained so that 2 false electrical signals do not led to the beginning of uncontrolled balancing pumping and, accordingly, the loss of centering of the aircraft.

In fig. 2.16 presents the proposed improvements in the fuselage and half-wing of the fuel system.

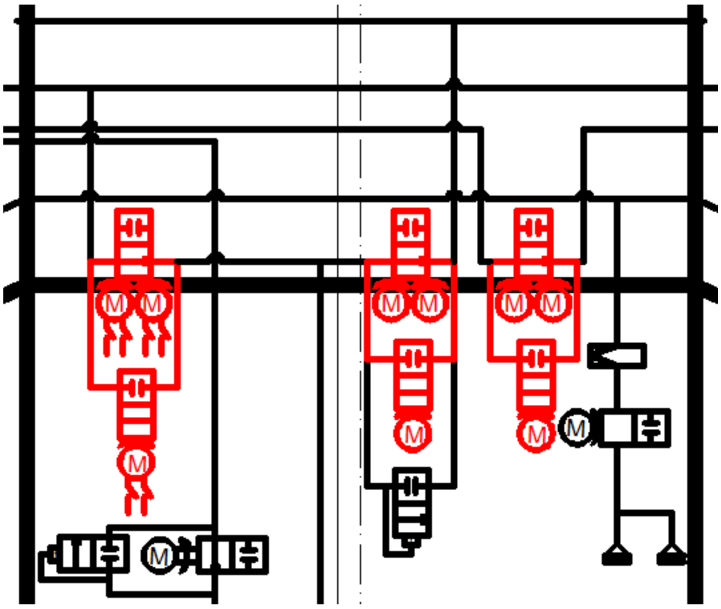


Figure 2.16. Proposed improvements in the fuselage and half-wing of the fuel system

Let's now consider the scheme of balancing pumping from tank №3 to tanks №1. From fig. 2.17, it can be seen that the valve (right), which is responsible for this pumping, will fail in case of one or two failures.

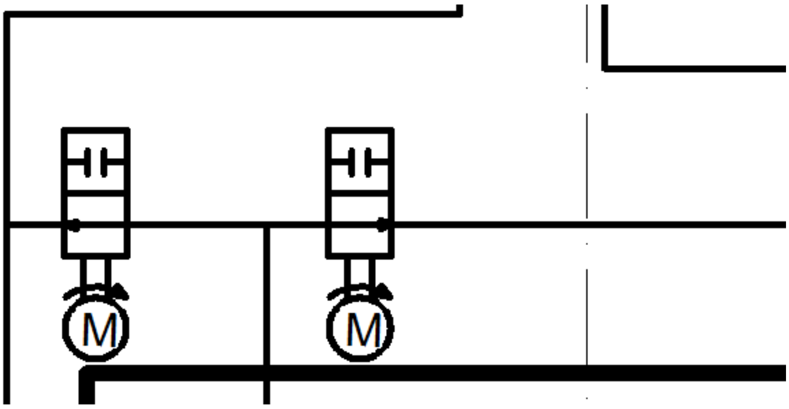


Figure 2.17 – Fuel taps responsible for balancing and supplying fuel to the APU.

It is proposed to install a two-motor valve instead of a single-motor valve, increasing the reliability of this system.

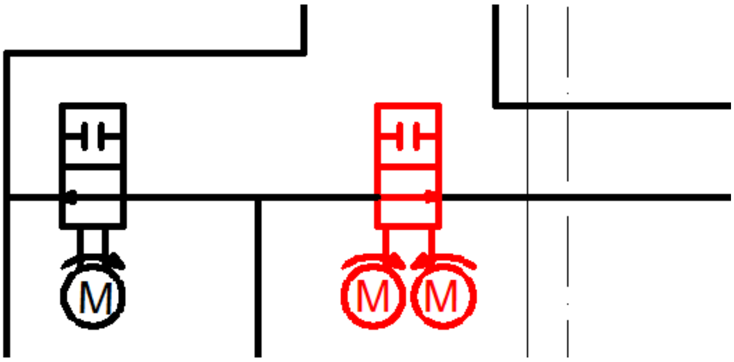


Figure 2.18 - Proposed improvements in balancing pumping from tank №3 to tanks №1.

Let's now consider tank No. 3 itself (Fig. 2.19). It is equipped with 3 booster pumps, each of which is single-circuit, therefore, at one false signal, it will start to work.

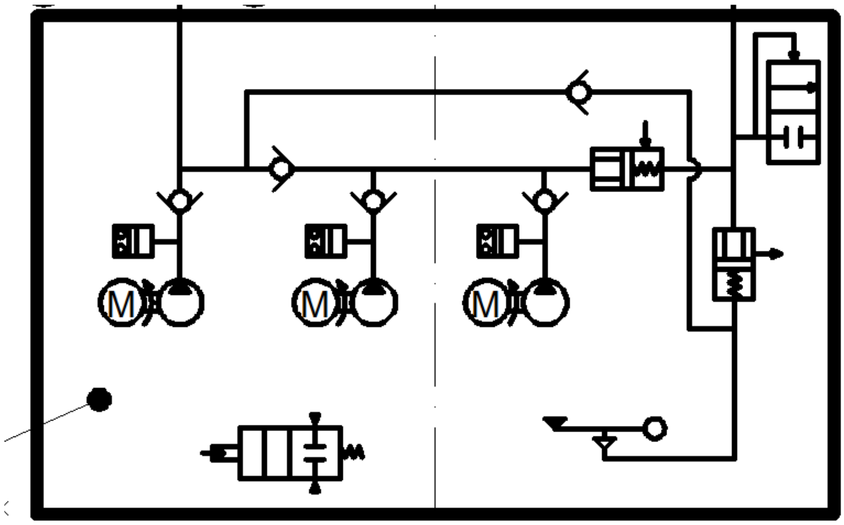


Figure 2.19 – Tank No. 3.

In order to increase the reliability and fail-safe of this scheme, it is proposed to make the control of the electric motors of each of these pumps double-chain, which will increase the probability of its failure at an inappropriate moment, while maintaining the ability to withstand two electrical failures. In fig. 2.20. proposed improvements to tank №3 are presented.

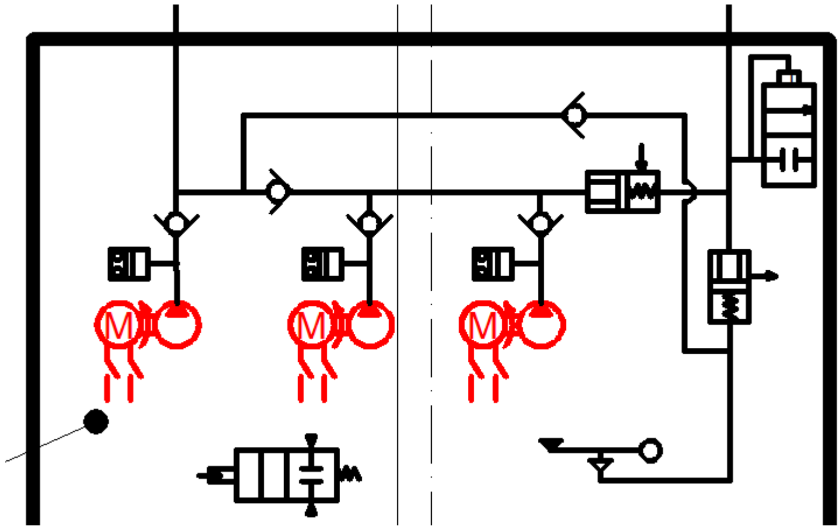


Figure 2.20 - Suggested improvements in tank №3.

In order to improve the reliability and failsafe of the fuel system and bring it to the level of reliability and failsafe of the AHS, it is advisable to increase the level of AFS redundancy to the level of redundancy used in the AHS, adopting the proposals outlined in Table No. 1 and shown in Fig. 21.

The proposed improvements through the use of redundancy of fuel system elements will significantly increase the reliability of the fuel system of the passenger plane, which will now withstand up to 2 failures without serious consequences for the flight, in terms of fail-safe it will be similar to SS and EHS, however, these improvement measures will lead to an increase in the total weight of the fuel system by approximately 80-100 kg. It should be noted that the use of triple redundancy of SS and EHS ensures high reliability and failure, meets the requirements of AP25 standards, but this requires an increase in the weight of these systems by hundreds of kg compared to single-channel AHS. However, this does not stop designers and currently 3-channel or more AHS are widely used, which ensure high reliability and flight safety of modern passenger aircraft.

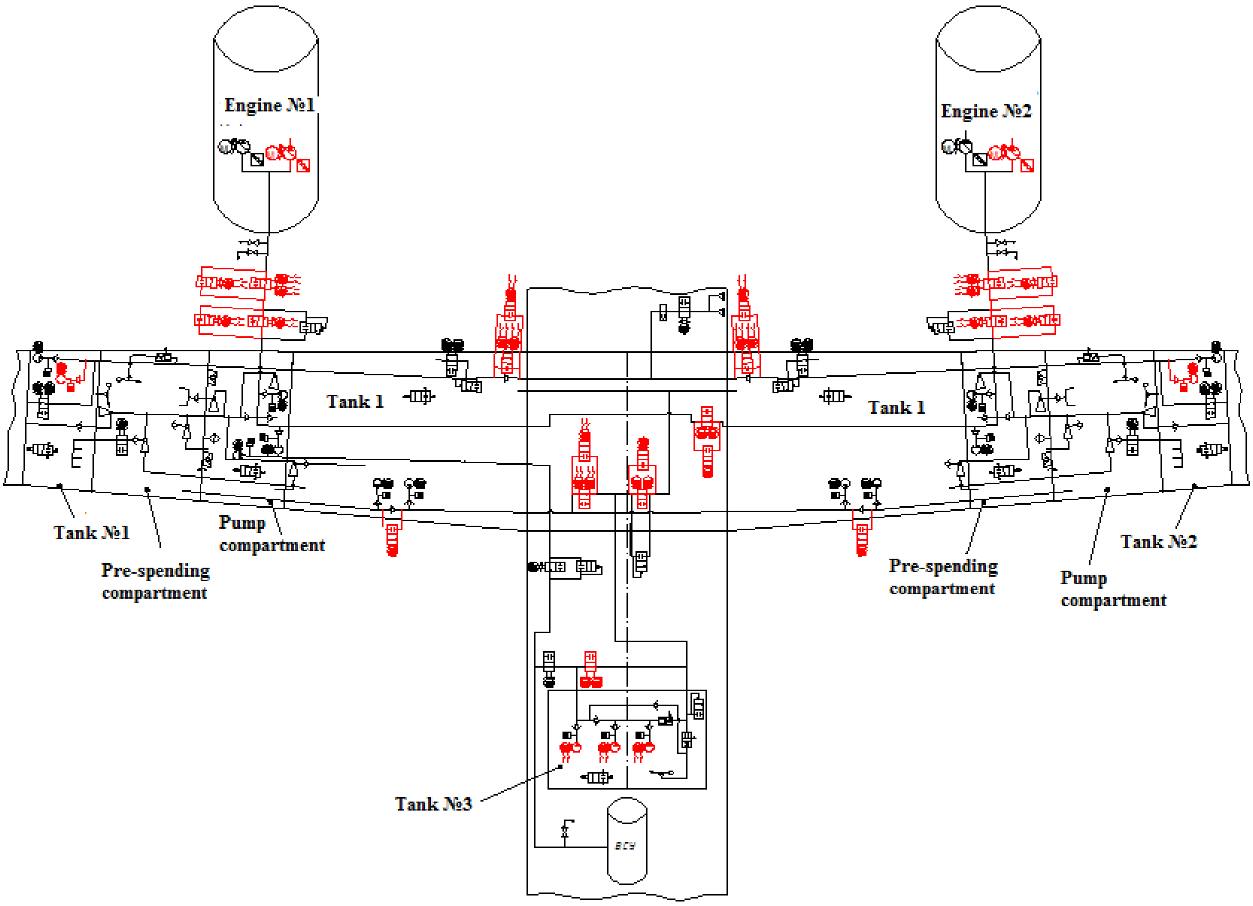


Figure 2.21 – Typical fail-safe enhanced fuel system

2.4. Conclusions to the section

The proposed improvements through the application of redundancy of fuel system elements will significantly increase the reliability of the passenger aircraft fuel system, which will withstand up to 2 failures without serious consequences for the flight and will be similar to AFS, SS and EHS in terms of reliability and failsafe, however, these improvement measures will lead to an increase in the total mass of the fuel system for approximately 80-100 kg.

It should be noted that the use of triple redundancy of SS and EHS ensures high reliability and failure, meets the requirements of AP25 standards, but this requires an increase in the mass of these systems (SS and EHS) by hundreds of kg. However, this does not stop the designers and currently 3 or more channel SS and EHS are widely used, which ensure high reliability and safety of the flight. Proposed improvements to the fuel system - install a second pump on the engine in parallel with the first one, which will work if the first one fails for some reason.

The second pump can be driven, like the first, from the box of aircraft units (CSA) or from an additional electric motor and turn on after the failure of the first; Make a fire hydrant with 2-chain control (that is, it works only when both contacts are closed), also add the same fire hydrant in parallel and the same again in series, but with a two-motor and two-chain fire hydrant, also put a single-motor double-chain faucet in parallel with it; Increase the safety margin of pipelines and units of the fuel system by pressure to three, as provided for in the AHS

3 LABOR PROTECTION

3.1General provisions

The main legislative acts on labor protection are: Constitution of Ukraine, Laws of Ukraine "On labor protection", "Code of laws on labor of Ukraine", "Basics of legislation of Ukraine on health protection", "On guarantees of sanitary and epidemiological measures". Welfare of the population ", "On fire safety", "On the use of nuclear energy and radiation safety", "Rules of normalization of working time and rest time of civil aviation aircraft crews".

3.2. Dangerous and harmful production factors during maintenance of the fuel system of a passenger aircraft

Safety measures during aircraft maintenance are regulated by: state and industry standards; systems of labor safety standards; flight instructions, aircraft maintenance; maintenance programs and regulations; repair technology, labor protection manuals and instructions, etc. Dangerous and harmful factors of production are described in GOST 12.0.003-74 SSBT "Dangerous and harmful factors of production". Thus, during aircraft maintenance, there are, for example, dangerous and harmful production factors:

- increasing or decreasing air humidity;
- increase or decrease in air mobility;
- increased level of static electricity;
- lack or insufficient natural lighting;
- insufficient lighting of the working area;
- increased level of vibration;
- increased noise level at the workplace;
- increasing or decreasing the air temperature of the working environment;

- moving machines and mechanisms; unprotected moving parts of production equipment; move products, blanks, materials.

Increase or decrease in air mobility. This factor can be observed in the following conditions: increased air mobility - sudden gusts of wind, emission of exhaust gases from working engines may occur during aircraft maintenance on open areas; reduced air mobility is observed in closed parts of the aircraft (wings, technological hatches and canopies), where air access is limited.

Absence or insufficient natural lighting and insufficient lighting of the work area. The absence or insufficient natural lighting during the refueling of an aircraft (in the dark or during the transitional period of the day) significantly worsens the working conditions and can lead to mistakes by the personnel in the performance of their duties. functions.

Higher vibration and higher noise. As a rule, these factors are caused by the operation of the engines of both the aircraft being serviced and the aircraft and its maintenance facilities located nearby.

An increase or decrease in the air temperature of the working environment. It should be noted here the influence of the ambient temperature at different times of the year (high temperature in summer, low temperature in winter); an increase in surface temperature in conditions of high solar radiation, as well as an increase in the temperature of the surfaces of exhaust systems or autonomous engines; Lowered surface temperature when working with the trunk lid and its mechanisms.

Mobile machines and mechanisms; unprotected moving parts of production equipment; move products, blanks, materials. This group of dangerous and harmful production factors includes: self-propelled and manual refueling equipment - refueling stations of the "CZL" system, fuel nozzles, fuel tanks of cars, filtering refueling stations, aviation refueling stations, manned aircraft; unprotected moving parts of aircraft, rotating propellers for moving to landing sites, use of aviation in the national economy; movable distribution sleeves with distribution taps; etc.

3.3Technical and organizational measures to reduce the level of exposure to dangerous and harmful production factors during maintenance of the fuel system of a passenger aircraft

In order to eliminate or reduce the impact of dangerous and harmful factors of production in accordance with the requirements of NPAOP 63.23 - 1.06-98 and GOST 12.4.026-76 of SSBT, the following measures have been developed:

- in order to reduce the level of exposure to dangerous and harmful production factors, the employee who carries out technical maintenance of the aircraft is obliged to comply with the rules of the internal work schedule in accordance with the approved work schedule.

- before starting work, the employee must wear special clothes and, if necessary, obtain and prepare for use personal protective equipment, as well as check the serviceability of work tools, devices and other equipment used in the maintenance of the enterprise. plane.

- when carrying out maintenance work on elevated parts of the aircraft, in all cases, only specially provided stairs and ramps should be used. Works carried out at a height of 1.3 meters or more from the ground (floor), from stairs or other equipment, as well as from structural elements of the substation at a distance of no more than 2 meters from unfenced drops and when working in special Objects of the SPO-type 15M are carried out with the help of safety belts, carabiners and special cables that are attached to fastening nodes.

- it is forbidden to carry out work at a height during a thunderstorm, ice, with a wind speed of 15 m/s or more. Work on moving vertical panels must be stopped at a wind speed of 10 m/s or more.

- it is necessary to use only functional portable electric lamps with a protective grid and a maximum operating voltage of 24 V DC or 12 V AC.

- To protect against chemicals and special liquids used during maintenance, it is necessary to use personal protective equipment: rubber gloves, aprons, bandages, glasses, respirators. Barrier ointments should be used to protect exposed areas of the skin.

- in order to avoid accidental activation of flaps, rudders, ailerons and other moving elements of the aircraft during maintenance, it is necessary to turn off the electric current, release the pressure in the hydraulic system, and set warning flags on the controls.

- to reduce the level of noise exposure, it is necessary to use personal protective equipment; the walls of the repair area must be sheathed with sound-absorbing material.

- to avoid electric shock, a neutral wire is used in the wiring system.

- the lack of natural lighting is compensated by portable or stationary artificial lighting.

- after finishing the work, remove the used equipment; remove, thoroughly wash (clean) and store personal protective equipment used during work; observe hygiene measures, wash hands and face with warm water and detergent, if possible take a shower.

3.4. The procedure for certification of workplaces according to working conditions

Attestation of workplaces is aimed at:

- identification of factors and causes of unfavorable working conditions;

- sanitary and hygienic study of the factors of the production environment, determination of the severity and intensity of the labor process at the workplace;

- a comprehensive assessment of the factors of the production environment and the nature of work and compliance of their characteristics with labor safety norms, construction and sanitary norms and rules;

- determination of the degree of harmfulness and danger of work and its nature according to hygienic classification;

- justification for assigning the workplace to the category with harmful (especially harmful) working conditions;

- determination (confirmation) of employees' right to preferential pension provision;

- analysis of implementation of technical and organizational measures aimed at optimizing the level of hygiene, nature and safety of work.

Attestation is carried out in accordance with the Procedure and Methodological recommendations for the attestation of workplaces according to working conditions (hereinafter - recommendations), approved by the Ministry of Labor and Health Protection of Ukraine.

According to clause 6 of the Procedure, certification of workplaces provides for:

- Establishment of factors and causes of unfavorable working conditions;

- Sanitary and hygienic study of the factors of the production environment, difficulties and tensions of the labor process at the workplace;

- Comprehensive assessment of the factors of the production environment and the nature of work for compliance of their characteristics with labor safety standards, construction and sanitary standards and regulations;

- Determination of the degree of harmfulness and danger of work and its nature according to hygienic classification;

- Justification of assigning the workplace to the category with harmful (especially harmful) difficult (especially difficult) working conditions;

- Determination (confirmation) of the right of employees, professions and positions to preferential pension provision of employees;

- Studying the compliance of working conditions with the level of technical and technological development, improving the procedure and conditions for establishing benefits and compensations;

- Analysis of the implementation of technical and organizational measures aimed at optimizing the level of labor protection.

The Resolution of the Cabinet of Ministers of Ukraine dated August 1, 1992 No. 442 "On the Procedure for Attestation of Workplaces by Working Conditions" approved the Procedure for Attesting Workplaces by Working Conditions (hereinafter referred to as the Procedure). .

The results of the certification are used by enterprises and organizations regardless of the forms of ownership and management, as well as for the implementation of measures to improve working conditions, establish benefits and compensations provided for by current legislation.

The periodicity of certification is established by the enterprise independently in the collective agreement, but at least once every 5 years. Extraordinary attestation is carried out in the event of a fundamental change in working conditions at the initiative of the owner or a body authorized by him, a trade union committee, a labor collective or its elected body.

According to the results of the attestation, urgent measures are determined to improve working conditions and safety, which do not require the involvement of third-party organizations and specialists for their development and implementation.

When working with a personal computer (PC), workers can be negatively affected by the following dangerous and harmful production factors:

- increased level of electromagnetic radiation;
- increased level of ionizing radiation;
- increased level of static electricity;
- increased intensity of the electrostatic field;
- increased or decreased air ionization;
- increased brightness of light;
- increased voltage in the electrical circuit, the shorting of which can occur through the human body;
- static overload of the musculoskeletal system and dynamic local overload of the muscles of the hands;
- visual analyzer overvoltage;
- mental overstrain;
- emotional overload;
- monotony of work.

Measures for the prevention of occupational pathology include the conduct of hiring and periodic medical examinations at all enterprises, compliance with the work and rest regime, job instructions, and taking measures to create safe working conditions.

In order to ensure protection and achieve standardized levels of computer radiation, it is necessary to use short-range filters, local light filters and other means of protection that have been tested in accredited laboratories and have an annual hygiene certificate.

When equipping the workplace with a laser printer, the parameters of laser radiation must meet the requirements of DSanPiN 3.3.2.007-98.

Organization of the workplace of details capable of creating glare. The keyboard is placed on the surface of the table in such a way that the space in front of the keyboard is sufficient for the support of the employee's hands (at a distance of at least 300 mm from the edge facing the employee).

To ensure the convenience of visual observation, quick and accurate reading of information, the plane of the monitor screen is located below the level of the worker's eye, preferably perpendicular to the normal line of sight of the worker (normal line of sight is 15 degrees below the horizontal).

To exclude the influence of increased levels of electromagnetic radiation, the distance between the monitor screen and the worker should be at least 500 mm (optimally 600-700 mm).

The movable stands for documents (lecterns) used are placed in the same plane and at the same height as the screen.

The work chair (armchair) must be stable, the seat must be adjustable in height, and the back of the seat must be adjustable in height, angles of inclination, as well as the section of the back from the front edge of the seat. Adjustment of each parameter should be independent, easy to perform and have reliable fixation.

For those who find it convenient, use a footrest. The workplace is placed in such a way that natural light falls from the side (preferably to the left).

The area for one workstation with a PC should be at least 6.0 m2, and the volume at least 20.0 m3.

Premises with PCs must be equipped with heating, air conditioning and effective air ventilation systems.

Location of workplaces in basements is not allowed.

For the interior decoration of PC rooms, it is necessary to use diffusion-reflective materials with a reflection coefficient for the ceiling of 0.7-0.8; for walls - 0.5-0.6; for the floor - 0.3-0.5.

Adjustable blinds or thick curtains are used to reduce brightness in natural lighting.

Luminaires of general and local education should create an appropriate contrast between the screen and the surrounding environment, taking into account the work and the visibility requirements of the employee. The illumination of the table surface in the area where the work document is placed should be 300-500 lux.

Possible reflections and glare on the monitor screen and other installations are eliminated by appropriate placement of the screen, installation, location of local lighting fixtures. When working desks are arranged in a row, it is not allowed to place monitor screens facing each other due to their mutual reflection. To ensure the safety of workers at adjacent workplaces, the distance between desktops with monitors (from the back side of the surface of one monitor and the screen of the other monitor) should be at least 2.0 m, and the distance between the side surfaces of the monitors should be at least 1.2 m.

Screen protective filters are used to reduce the level of electrostatic field intensity. When using a protective filter, it must be firmly installed on the monitor screen and grounded. To ensure optimal microclimate parameters during regular ventilation and daily wet cleaning of the room.

When working with a PC, it is necessary to ensure access of employees to primary fire extinguishing equipment, first aid kits.

When working with PCs, employees, taking into account the influence of dangerous and harmful production factors, are provided with individual protection in accordance with typical industry norms for the relevant professions and positions.

When working with a PC, employees must:

- to be supported by the regime of work and rest, established by legislation, the rules of the organization's internal labor regulations, labor discipline, to comply with the requirements of labor protection, personal hygiene rules;

- comply with fire safety requirements, know the procedure in case of fire, to be able to use primary means of extinguishing fire;

- know the methods of providing first aid in case of accidents at work;

- about equipment malfunctions, cases of death of a manager or other persons familiar with the maintenance of equipment.

Not allowed:

Perform work while in a state of alcohol intoxication or in a state caused by the use of narcotic drugs, psychotropic or toxic substances, as well as drink alcoholic beverages, use narcotic drugs, psychotropic or toxic substances at the workplace or during working hours; install the system unit in closed niches, at the same time on the floor; use sockets, extension cords that do not have a ground contact to connect the PC.

Employees who do not meet the requirements of the valid Instructions are held liable in accordance with current legislation.

Determination of the required number of grounding devices and the length of the connecting strip in the fuel system maintenance barn to protect against static electricity and electric shock

At the aircraft parking lot where fuel system maintenance takes place, it is important that all electrical appliances located near the service area are grounded, this will protect the service personnel from possible electrocution and the occurrence of an electrostatic arc, which can lead to the ignition of aircraft fuel vapors.

Let's make a calculation according to the method given in [30, 31].

For grounding electrical equipment, steel strips are used for connection, which are welded to steel round rods with a diameter of d = 38...50 mm and a length of l = 2...3 m or to steel hot-dip galvanized corners of 50x50x5 mm. The strips are welded horizontally to the rods at a depth of h = 0.5...0.8 m from the upper surface of the rod or a corner from the ground surface. Specific resistance of the soil is given in table 3.1. Resistance to current spreading from a single grounding of a rod or angle [30, 31]:

$$R_{cm} = 0.366 \cdot \frac{\rho}{l}\left(\lg\frac{21}{d} + \frac{1}{2}\cdot\lg\frac{4h+1}{4h-1}\right), [\text{Ом}] \#(3.1)$$

where ρ – soil resistivity (table 3.1) in $\text{Ом} \cdot \text{м}$;

l – rod length, m;

d – rod diameter, m;

h is the distance from the soil surface to the middle of the rod, m.

Table 3.1 - Soil resistivity.

Soil	Specific resistance, ρ, Ohm·m
Sand	700 (400...700)
Sandstone	300 (150...400)
Black soil	20 (9...53)
loam	100 (40...150)
Clay	40 (8...70)
Peat	20 (1...30)
River water	50 (10...100)
Sea water	1 (0.2...1)

– the value of soil resistivity is given at a moisture content of 10...20%;

– in parentheses are the limit values of the variation of the specific resistance depending on the humidity.

Soil resistivity in Ом х м:

$$\rho = \rho_{\text{вим}} \cdot k_c \#(3.2)$$

Where k_c – coefficient of increase in specific resistance (seasonality coefficient).

$$d = 0{,}95\ b_1 \#(3.3)$$

Where b_1 – corner side, m.

$$h = h_o + 0{,}5 \cdot l \#(3.4)$$

Where h_o – depth of steel plate laying, m. Resistance to the spread of current for steel strips, with a cross section of at least 100 mm and a thickness of 4 mm, laid in the soil parallel to the ground at a depth of 0.5...0.8m:

$$R_{stripes} = 0.366 \cdot \frac{\rho}{l_1} \cdot \lg \frac{2 \cdot l_1^2}{b \cdot h_0}, [\text{Ом}] \#(3.5)$$

Where *l1*– strip length, m;

b– lane width, m.

$$l_1 = (n - 1) \cdot a\#(3.6)$$

where n – number of rods, pcs.;

a – the distance between the rods, m, (if $n = 2$ then $l_1 = a = l$).

Number of grounding devices, units:

$$n = \frac{R_{cm}}{r_H \cdot \eta_{cm}} [unit.], \#(3.7)$$

Where $r_H -$ normalized resistance value of the grounding device, Ohm;

$\eta_{cm} -$ the utilization factor of a single rod grounding device.

The resistance of a rectangular loop grounding device from rod or corner grounding devices with connecting strips in ohms:

$$r_{\text{кз}} = \frac{R_{cm} \cdot R_{stripes}}{R_{cm} \cdot \eta_{stripes} + n \cdot R_{stripes} \cdot \eta_{cm}} \#(3.8)$$

where $\eta_{pol} -$ utilization ratio of a single grounding device with a strip;

$\eta_{\text{ст}}$ – coefficient of use of a single rod grounding device (Table 3.2).

Table 3.2 – Utilization factor of a single grounding device

The number of rods (corners) in the contour	$\eta_{angle}, \eta_{\text{ст}},$	$\eta_{\ stripes}$
3	0,75	0,50
4	0,65	0,45
6	0,60	0,40
10	0,55	0,35
20	0,50	0,25
40	0,40	0,20

We will generate the initial data for the calculation of grounding at the aircraft parking place where scheduled maintenance is carried out:

- soil resistivity $\rho_{vum} = 100$ Ом · м;

– coefficient of increase in specific resistance $k_C = 1{,}4$;

– grounding device – galvanized steel rod: $l = 3$ м, $d = 0{,}040$ $h = 2$ м;

– strip steel in width $b = 0{,}1$ м;

– utilization ratio of a single grounding device $\eta_{\ stripes} = 0{,}45$;

– utilization ratio of the grounding rod device $\eta_{\ st} = 0{,}65$;

– the norm of resistance of loop grounding $r_H = 4$ Ом.

The main parameters of the circuit device that grounds aircraft in the parking lot for protection against static electricity are shown in Figure 3.1.

– soil resistivity according to the formula (3.2):

$$\rho = 100 \cdot 1{,}4 = 140 \text{ Ом} \cdot \text{м}$$

– the resistance to current flow from a single steel rod according to the formula (3.1):

$$R_{st} = 0.366 \cdot \frac{140}{3}\left(\lg\frac{21}{0{,}040} + \frac{1}{2} \cdot \lg\frac{4 \cdot 2 + 1}{4 \cdot 2 - 1}\right) \approx 47\ [\text{Ом}]$$

– the depth of laying the steel plate according to the formula (3.4):

$$h_0 = 2 - 0{,}5 \cdot 3 = 0{,}5 \text{ м}$$

– determine the resistance of the current spreading in the ground from the steel strip according to the formula (3.5):

$$R_{\text{смуги}} = 0.366 \cdot \frac{140}{3} \cdot \lg\frac{2 \cdot 3^2}{0{,}1 \cdot 0{,}5} \approx 44 \text{ Ом}$$

– the number of grounding devices according to the formula (3.6):

$$n = \frac{47}{4 \cdot 0{,}65} = 18$$

– the resistance of the grounding circuit device according to the formula (3.8):

$$r_{кз} = \frac{47 \cdot 44}{47 \cdot 0{,}45 + 18 \cdot 44 \cdot 0{,}65} = 3{,}9 \text{ Ом}$$

The parameters of the grounding circuit are shown in Figure 3.1.

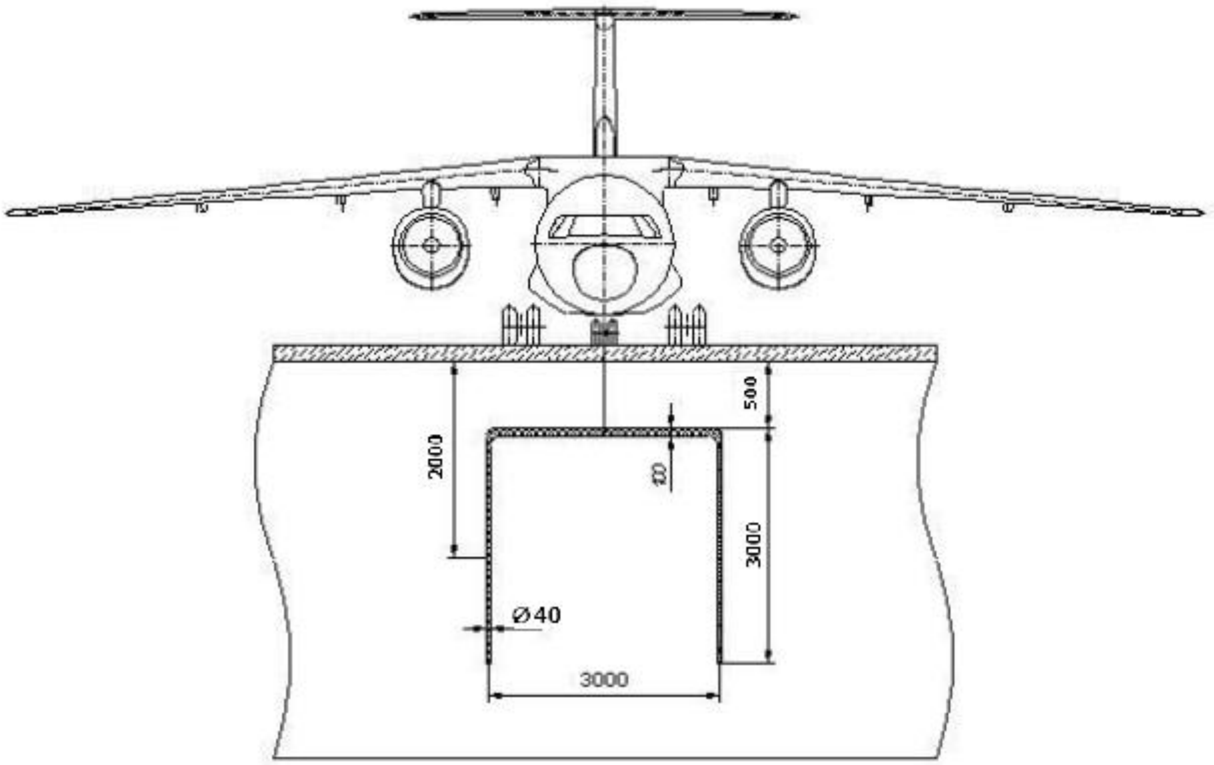


Figure 3.1 - Main parameters of the circuit device grounding aircraft in the parking lot for protection against static electricity

The obtained value of the resistance of a rectangular contour grounding device made of rods with a welded connecting strip is $r_{кз} = 3{,}9$ Ом, this resistance is less than the normative one $r_H = 4$ Ом, it can be concluded that this circuit meets the standards and can be used for grounding. There are n = 18 grounding devices in this grounding circuit.

3.5.Conclusions to the section

The obtained value of the resistance of a rectangular contour grounding device made of rods with a welded connecting strip is $r_{кз} = 3{,}9$ Ом, this resistance is less than the normative one $r_H = 4$ Ом, it can be concluded that this circuit meets the standards and can be used for grounding. There are n = 18 grounding devices in this grounding circuit.

Thus, the entire development minimizes the possible impact of the harmful and dangerous factor of electric shock and the occurrence of a static current arc that can lead to the ignition of fuel vapors.

It should also be noted that noise and chemically aggressive factors have a significant impact on the technical personnel who serve the AT, chemicals have a special impact on the skin, eyes and oral cavity.

To ensure the safety of personnel during technical work on the aircraft, it is necessary not only to establish labor protection standards, but also to apply new methods of automating maintenance.

The procedure for conducting attestation of workplaces according to working conditions is determined in accordance with the resolution of the Cabinet of Ministers of Ukraine "On the procedure for conducting attestation of workplaces according to working conditions" and "Methodical recommendations for conducting attestation of workplaces according to working conditions".

4. ENVIRONMENTAL PROTECTION

4.1 Consideration and analysis of pollution factors

The rapid development of air transport and the growth of its role in human life could not but affect the environment (NS). The main impact of aviation on the environment is acoustic pollution, as well as the emission of gases into the atmosphere, which leads to climate change and air pollution [20-22]. A feature of emissions of harmful substances during the operation of air transport is altitude (as is known, airplanes currently fly at an altitude of 8–13 km). As a result, the composition of the atmosphere changes in various ways, both directly and indirectly. Direct impact: emission of carbon dioxide, nitrogen oxides (NO_x), water vapor, unburned hydrocarbons (benzene, propane, ethane, acetylene, methane, etc.), sulfate particles and soot. Indirect impact: the formation of ozone (O_3) as a result of a chain of chemical reactions similar to the formation of smog.

In the lower layers of the atmosphere, ozone is a harmful substance that contributes to global warming. Exhaust gases from aircraft engines contribute to the formation of ozone holes. A huge amount of water vapor is released into the upper layers of the troposphere and the lower stratosphere. From 10 to 30 tons of water vapor is released into these layers of the atmosphere every day. Nitrogen oxides react with stratospheric ozone, which leads to the destruction of this layer, which protects the biosphere from harsh ultraviolet solar radiation. In turn, an increase in the humidity of air masses contributes to the appearance of clouds, and in the surface layer at low negative temperatures - the formation of fog (smog) [20].

Water vapor emitted from an aircraft engine mixes with the surrounding air under the influence of turbulent exchange, which leads to condensation and sublimation of water vapor at low temperatures and high humidity. In the presence of inversion layers, the volume of rising water vapor spreads, contributing to the formation of a large curtain of spherical clouds. Initially, the cloud trail has a width of several hundred meters, but as it spreads, it increases to several kilometers. That is, water vapor released into the atmosphere can increase the number of cirrus clouds and their vertical power. Such a change in cirrus clouds occurs, as a rule, during intensive flights and leads to a change in the traditional mode of solar radiation. That is, an increase in the number of cirrus clouds leads to an increase in air temperature.

Pollution of the lower layers of the stratosphere above the tropopause (height above 9-11 km) affects the physical and chemical composition of the stratospheric air. Particles thrown to an altitude of 14 km remain in the stratosphere for up to one month, and at an altitude of 22 km - up to two years. This leads to a decrease in the density of atmospheric ozone and, accordingly, affects the weather conditions and climate of the Earth, causes natural disasters. Depletion of the ozone layer is also a negative factor for the ecology of the animal and plant world, and human health.

From an ecological point of view, a modern airport (aerodrome) can also be considered as a complex of electromagnetic energy radiations that have a harmful effect on emergency services and people. Radiation sources include radars, communication devices, etc.

Waves of decimeter, centimeter, and especially millimeter ranges have the greatest biological activity. Medical and biological studies of the effect of microwave radiation on living organisms have shown that it can disrupt (suppress) the activity of the central nervous system, destroy protein molecules contained in the blood, and change the functions of human endocrine organs [20].

The negative impact of electromagnetic radiation is amplified by the noise factor. The increase in the carrying capacity of aircraft and the intensity of flights has also led to an increase in the noise level in the areas where airports (airfields) are located. This is far from a complete list of environmental problems that arise during anthropogenic activity as a result of JSC operation.

Almost all types of transport are developing in Ukraine: aviation, railway, automobile, sea, river, pipeline and electronic. All types of transport complement each other and, together with transport routes, form a transport complex (Fig. 4.1) [20]. Therefore, certain positive dynamics are observed in the development of air legislation of Ukraine. This applies not only to the number of norms included. By the way, if the Air Code of

Ukraine from 1993 had only two articles aimed at protecting atmospheric air from the negative impact of aircraft [21], the new Air Code already contains a special chapter X "Protection of the natural environment" [22].

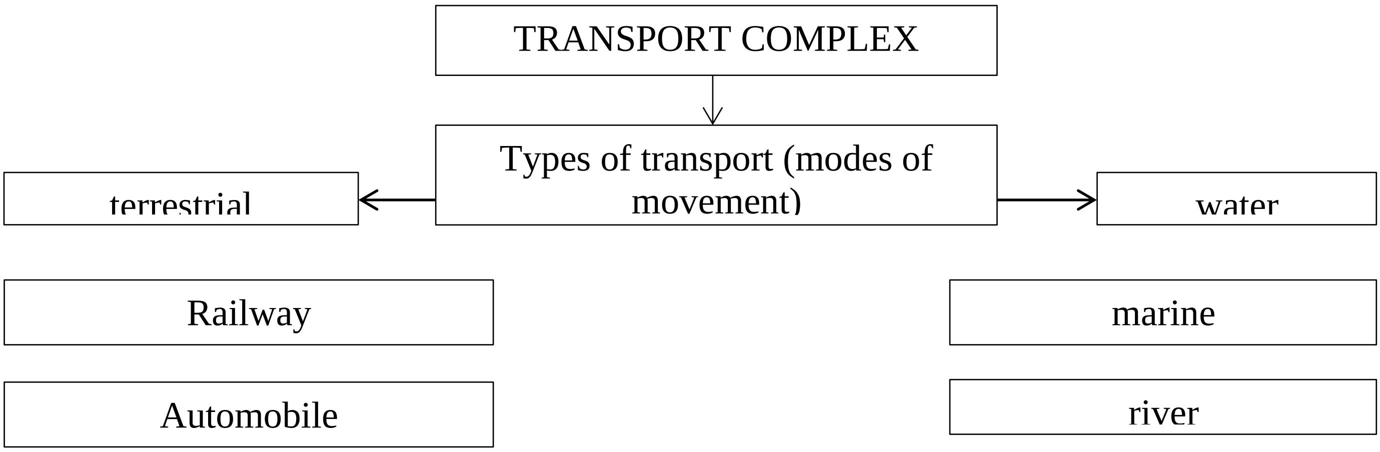


Figure 4.1 – Structure of the transport complex

Given the scope of regulation of such norms, it extends not only to the choice of emergency protection from the harmful effects of civilian aircraft, protection of the population from the harmful effects of pollutant emissions (emissions), noise, electromagnetic radiation, the risk of aviation events during the operation of aircraft, and and for the registration of civil aircraft, the airworthiness of a copy of a civil aircraft, etc. There are about 20 positions in total [23].

For example, with regard to aircraft certification, the new Air Authority already clearly states that CA authorities may refuse to register a civil aircraft if the aircraft does not meet the requirements for airworthiness, emergency protection or other restrictions established by the authorized authority. CA; while the previous Air Code did not provide for such a condition at all. Also new is the provision of the new Air Code that, from the placement of the established responsibility of the Air Force to the regulations in the field of emergency protection, the authorized body on CA issues a certificate of the Air Force regarding noise in the area.

Analyzing the state of legal protection of atmospheric air against the negative impact of CA, it should also be avoided that one of the main factors of the negative impact of CA on the natural environment is aviation noise (ASH).

In this connection, it should be noted that the regulation of harmful physical effects on the atmosphere, in particular noise reduction, is one of the directions of legal measures for the protection of atmospheric air. Busy air transport has a significant place in the noise regime of populated areas. Aviation power plants with gas turbine and piston engines are the sources of AS on the territory of aviation enterprises and adjacent areas; aircraft auxiliary power plants and launch units; special airfield service machines for various aviation purposes, including thermal and wind machines, created on the basis of engines that use up the flight resource. Acoustic environment in the area of the airport by the local mode of operation of the airline; types of aircraft operated at the airport; the current arrival and departure routes of the aircraft; the location of residential buildings thanks to the runway, as well as measures taken by the airport to reduce the adverse impact of AS on the environment. Therefore, the object of the negative influence of the CA is not only the National Assembly, but also the population. It should be noted the increased attention to this important problem in the air law of Ukraine.

Thus, in the new Air Code of Ukraine, it is clearly defined that the maximum permissible level of air pollution during the operation of the aircraft, emissions of aircraft engines and electromagnetic radiation of objects of aviation activity should not exceed the maximum permissible level established by the aviation rules of Ukraine; and in the event that the noise level during the operation of a civil aircraft has reached the established maximum permissible level of AS, the authorized body on CA issues has the right to limit or prohibit the flights of such an aircraft [22].

Measures aimed at reducing the noise level at the airport and near it based on a balanced approach to air pollution regulation may include: spatial zoning of the area around the airport taking into account air pollution conditions and other adverse environmental factors; implementation of operational measures during aircraft take-off and landing; appropriate organization of air traffic with a reduction in the impact of AS, etc. [22]. The legislation of Ukraine lays down obligations in the context of achieving an effective problem not only on aviation companies and aviation authorities, but also on executive power bodies, local self-government bodies, enterprises, institutions, organizations and citizens who comply with Art. 24 of the Law of Ukraine "On Ensuring the Sanitary and Epidemic Welfare of the Population", when carrying out any type of activity with the aim of avoiding and reducing the harmful impact on the health of the population of noise, non-ionizing radiation and other physical factors, it is obligatory to take measures that are not allowed to continue receiving excesses levels noise, established by sanitary standards at protected facilities.

Noise at protected facilities during the implementation of any type of activity should not exceed the levels established by sanitary regulations for the relevant time. As for the owners of airfields, operators, commanders and crew members of aircraft, they are obliged to prevent noise or reduce it to a minimum during the operation of aircraft on the ground and in the air. In this connection, attention should be paid to the fact that in modern conditions, two different approaches are used for the normalization of AS:

- when permissible levels are established taking into account sanitary and hygienic requirements, provided that there is no unpleasant effect of noise on a person (sanitary and hygienic regulation);

- when noise regulation establishes aircraft noise standards, taking into account modern researched and technically sound methods of air transport processes. If the adverse effects of AS during the day and at night are different, permissible values are set separately for day and night in the direction of reducing the coefficient of the noise level in the territory of residential buildings at night.

Current legislation provides for administrative liability for this violation of the norm. The noise of modern subsonic aircraft with gas turbines is primarily regulated by the ISAO international standard, as well as national standards. Current regulations on noise clearly regulate not only permissible levels of noise, but also methods of its measurement, flight modes during certification tests, as well as processing of results and bringing them to initial conditions to ensure the protection of the environmental rights of citizens and the prevention of offenses in the field of airspace use by aviation transport . . It is worth paying attention to the role and place of the institute of legal responsibility in the interdisciplinary mechanism of legal regulation of environmental security problems of the CA. In this connection, it should be noted that legal liability, such as administrative and disciplinary liability, to a much lesser extent – civil liability, and in special cases – criminal liability are established from the above-mentioned issues. At the same time, the legal norms aimed at the protection of atmospheric air, as a rule, have a responsible nature in terms of liability. Therefore, in each specific case, a differentiated application of special legislation is required to establish specific legal responsibility. For example, administrative responsibility is implied in Article 11 of the Law of Ukraine "On Atmospheric Air Protection", which establishes a permit for the system of regulating emissions into the atmosphere, in violation of which . relevant legal consequences [23]. The Law of Ukraine "On the Protection of Atmospheric Air" also explicitly prohibits the deliberate release of fuel into the atmosphere during faulty engine start-up or after shutdown [23]. Violation of this norm entails administrative responsibility.

Article 3 of the Law of Ukraine "On Protection of the Natural Environment" requires collection of a fee for pollution of natural resources and reduction of the quality of natural resources [24]. Be sure to pay attention to the fact that this issue is also addressed in the new Air Code of Ukraine. Thus, the Code stipulates that during the operation of the aircraft on the ground and in the air, the subjects of aviation activity are obliged to maintain the established standards for the content of hazardous substances in the exhaust gases and the influence of physical factors, and to take measures to reduce the number of emissions (emissions) of pollutants and the level AS, electromagnetic and radiation radiation, as well as the discharge of substances, waste and materials harmful to human health and the natural environment from the aircraft is prohibited, except in an emergency situation and the performance of aviation chemical works. Persons guilty of such actions are liable according to the law [22].

In addition to the legal measures for the protection of atmospheric air, it is also necessary to establish fines for emissions into the atmosphere by stationary sources, including enterprises of the CA. Thus, in accordance with Article 11 of the Law of

Ukraine "On Atmospheric Air Protection", hazardous waste emissions into the atmospheric air by stationary sources can be used after obtaining a permit, which is issued by a territorial body of a specially authorized central executive body on ecology and natural resources in agreement with a territorial body specially the authorized central body of the executive power for health care [23]. As for the nature of the established liability, the law ensures that persons guilty of hazardous waste emissions into the atmospheric air without the permission of specially authorized executive authorities are liable in accordance with the law [23].

It should be emphasized that the permit for emissions of hazardous substances into atmospheric air by stationary sources is the legal document that provides legal legitimacy for the legality of the use of natural resources. Thus, in accordance with Article 12 of the Law of Ukraine "On Atmospheric Air Protection" and "Procedure for restriction, temporary prohibition (suspension) or termination of the activities of enterprises, institutions, organizations and objects in the event of their violation of the legislation on the protection of the natural environment", such activity the enterprise is limited or temporarily prohibited (stopped).

The actions of officials of territorial bodies of the authorized body of state power may be appealed to higher management or in court. As for civil liability, it is meant, for example, in Article 34 of the Law of Ukraine "On Atmospheric Air Protection", which provides for compensation for damage caused by violation of the legislation on atmospheric air protection [22]. In this connection, it should be emphasized that the aviation legislation of Ukraine for the first time provides for civil liability for subjects of aviation activity, which are obliged to compensate citizens for damage caused to their health and property as a result of aviation activity, in accordance with the law [24]. Summarizing the above, it is necessary to state that at the current stage in Ukraine, a certain interdisciplinary regulatory and legal mechanism has been created that regulates the environmental aspects of the security of the CA.

But, as you can imagine, it needs further improvement for practical use; in particular, through the development of precautionary measures in this area in accordance with global international requirements and standards, it is worth noting the increase in the norms of environmental direction in the air legislation of Ukraine. But despite the positives stated in the new Air Code of Ukraine, the mechanism of bringing legal responsibility for violations of environmental norms demonstrated in it will not yet contribute to awareness of the importance of the environmental component of CA security. The main requirements of SARP's ICAO on the protection of emergencies from the operation of the air transport system are given in documents [25-28].

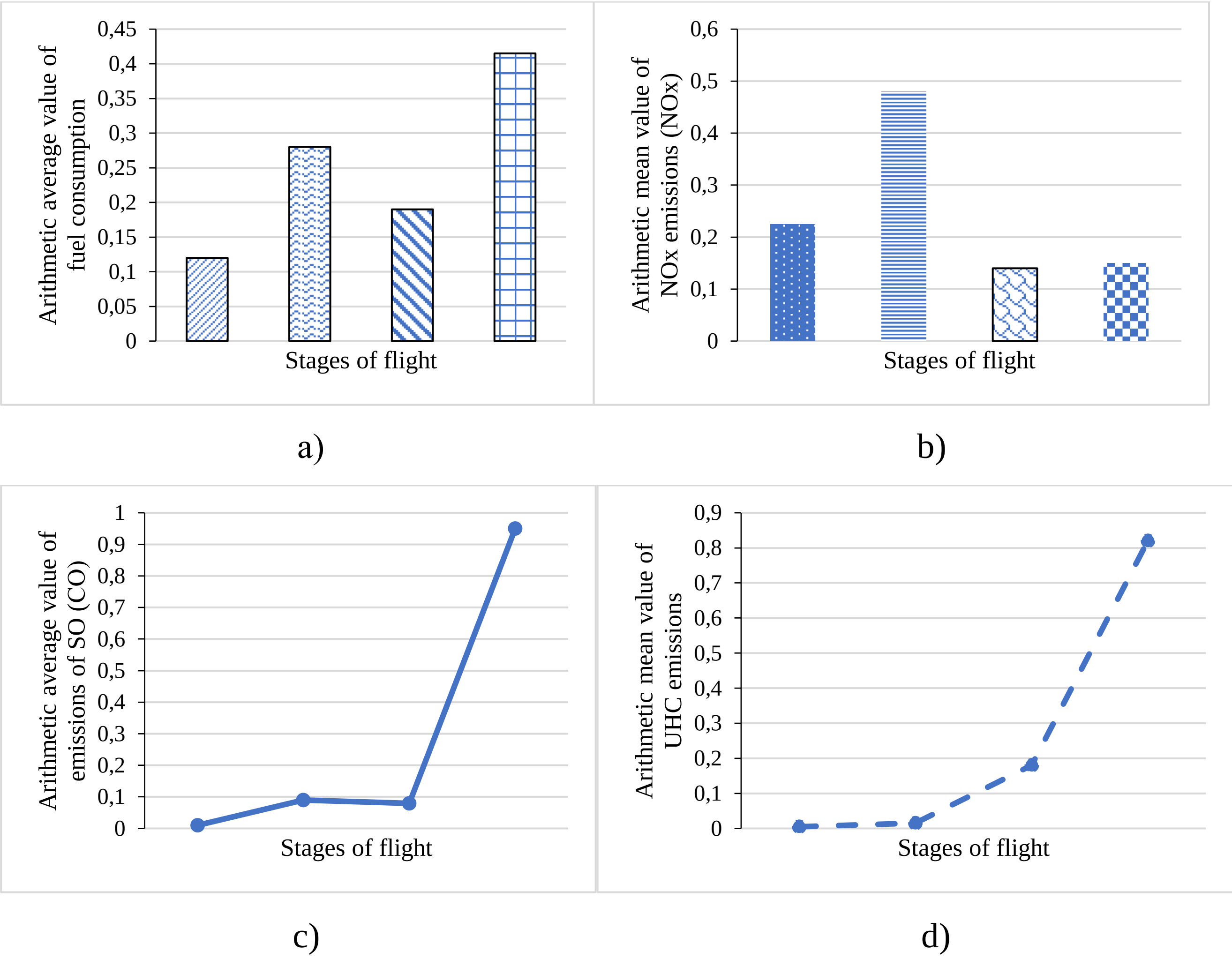
4.2. Research on increasing the efficiency of fuel use by passenger aircraft and ways to reduce greenhouse gas emissions

It is known that the main directions, results and programs of further studies of ISAO in the field of protection against emergency situations, which are implemented within the framework of the activities of the ISAO Committee on the protection of emergency situations from the effects of aviation (SAER), have recently been published in well-known documents [25-28], which indicate about significant achievements in the field of regulation and further reduction of emissions of carbon monoxide (CO2), nitrogen oxides (NOx) and unburned hydrocarbons (UHC) per unit of thrust in accordance with the requirements of SARP ICAO [28], as well as the parameters of the standard take-off and landing cycle, widely used for calculating air pollution at airports during aircraft flights at relatively low altitudes (up to 915 m). The structure of the characteristic flight modes implemented at the same time and the relative indicators of GHG emissions for a typical modern aircraft are shown in fig. 4.2.

However, at the same time, the thrust and duration of engine operation are indicated in table 5.1

Tables 4.1 - Engine operating modes

	Rise	Height set	Landing	Steering
Engine thrust:	100 %	85 %	30 %	7 %
Duration of work, min:	0,7	2,2	4,0	26,0



a) – fuel consumption; b) – PP NOx; c) - ZR SO; d) – 3P UHC

Figure 4.2 – Characteristic relative values of fuel consumption and gaseous emissions for the main elements of the ISAO standard take-off and landing cycle on the example of aircraft equipped with CFM 56 engines of different series

However, in the real operating conditions of civil aircraft, including when flying at significant (cruising) flight altitudes, they largely affect the composition and amount of characteristic emissions of harmful substances and have a much wider impact on the global climate. This is evidenced by the data presented in the work [29], which shows the characteristic quantitative indicators of emissions of hazardous waste regulated by the Kyoto Protocol for a typical fleet of existing civil aircraft or an outdated fleet of operated domestically produced aircraft. and foreign airlines of foreign airlines in accordance with the recommendations of the EMEP/CORINAIR international methodology, which is widely used in the countries of the European Central Asian Conference (ECAC).

The results of numerous experiments show that the mass of greenhouse gas emissions in Central Asia is proportional to the amount of aviation fuel burned in industry (for example, when 1 kg of kerosene is used, 3.15 kg of CO is released into the atmosphere). According to the ISAO assessment, which was presented in the report at the CAER/10 meeting [26], the total mass of fuel consumed by the world CA and the corresponding CO emissions by year, taking into account forecasts for the period until 2025, are presented in Fig. 4.3.

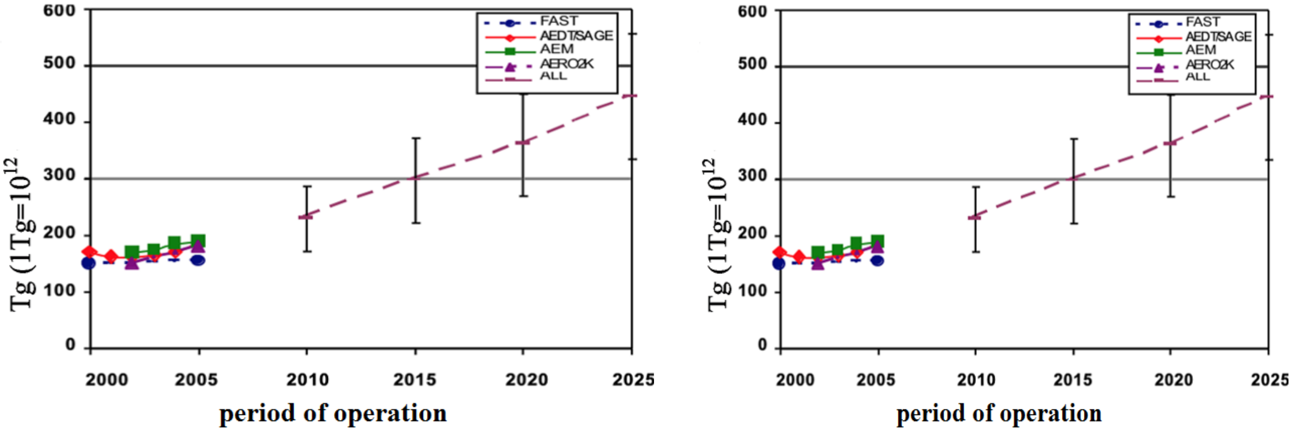


Figure 4.3 – ISAO updated data on the estimation of the total amount of aviation fuel burned in the world CA

a) and corresponding emissions of greenhouse gases in the form of CO2 carbon dioxide

b) in the period up to 2025 using various calculation models

It is obvious that emissions of hazardous waste, as well as the scale of aviation's impact on the environment, are related to the fuel efficiency indicators of the fleet of aircraft and engines of Central Asia achieved today. The results of the generalized global trends of changes in similar indicators performed by the International Air Transport Association (IATA) are shown in fig. 4.4.

In the table 4.2 suggested where and what values of the specified indicators.

Table 4.2 – Suggested indicator values

Parameters	Fuel consumption (l/100 tkm)	CO2 emissions (kg CO2/tkm)
Base value for 1990	56,1	1,42
Target norm of 2012 according to the Kyoto Protocol	41,6	1,05

Forecasts of a number of international programs to improve the fuel efficiency of existing and new generations of aircraft, carried out in the USA and Europe..

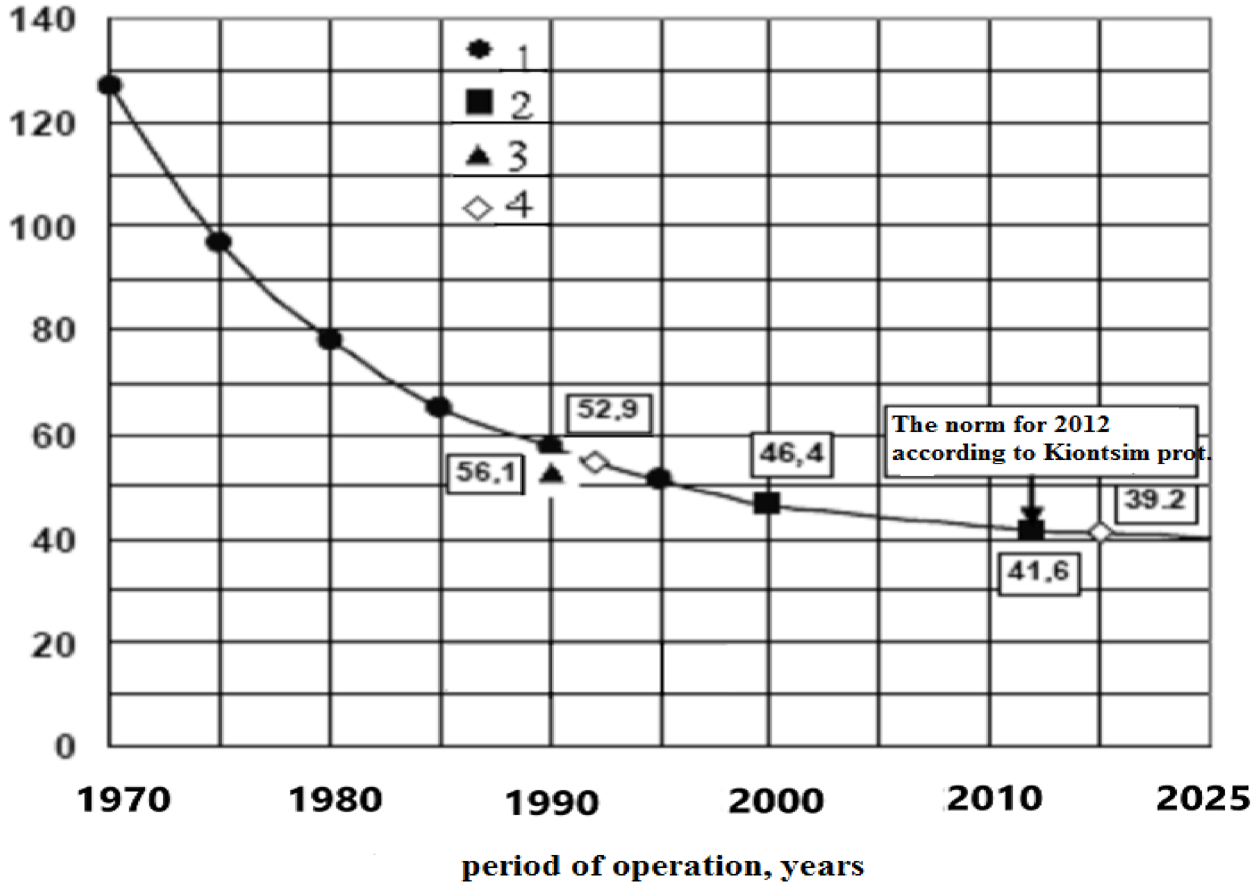


Figure 4.4 – Characteristic dependence of the change in fuel efficiency by year in the period from 1970 to 2020 for the aircraft fleet of the IATA member states (according to the data of the IATA Environment Review 2000)

1 – IATA forecast for 2000-2012; 2 – the actual value for the aircraft of the IATA fleet for the years 1970-1995; 3 – IATA base value for 1990; 4 is the base value of NASA for 1992 and 2015

Table 5.3 – Target standards of the US national plan (2007) for research and development of air transport in the period until 2020 in the area of reducing the influence of CA on natural disasters (according to Flight Int., 2008, v. 173, No. 1521)

<table>
<tr><th>Generations and years of commissioning of new aircraft</th><th>Increasing fuel efficiency and reducing CO2 emissions</th><th>Reduction of NOx relative to norms CAER/2</th><th>Noise reduction relative to norms of chapter 4 (sum of equations in 3 k/points)</th><th>Goals of the European ASARE program for 2020</th></tr>
<tr><td>N+1 in the period up to 2015</td><td>33 %</td><td>-</td><td>-</td><td rowspan="3">• CO2 50 %
• NOx 80 %
• Lower. AS on 20 EPNdB (relative to 2000)</td></tr>
<tr><td>N+2, 2020-25 гг.</td><td>40 %</td><td>-</td><td>42 EPNдБ</td></tr>
<tr><td>N+3, 2030-35 гг.</td><td>70 %</td><td>80 %</td><td>62 PNдБ</td></tr>
</table>

4.4. Conclusions to the section

According to the research results of this section, we note the main points:

- during the analysis of the Air Code of Ukraine, the peculiarities of the requirements for environmental protection were determined compared to the previous code, i.e. the new version covers a wider range of existing problems in this direction;

- based on the results of research in the field of increasing the fuel efficiency of the aircraft fleet and reducing greenhouse gas emissions from monitoring scientific publications, CAER/10 requirements, data on the forecast of emission limits (emissions of harmful substances) by aircraft engines and their acoustic characteristics, determined and provided with the aim of reducing aviation noise and increasing fuel efficiency.

GENERAL CONCLUSIONS

Today's problem, faced by engineers developing new systems and mechanics who maintain these systems, is the trouble-free operation of these systems during the operation of the aircraft. On the basis of these problems, there is a need to ensure reliability in operation in the face of the great contradiction of the complexity of systems and components of aviation devices, which depends on the further complexity of service and the skills of service personnel.

The paper discussed the topic of methodological maintenance of the operational reliability of the fuel system of a long-range passenger aircraft with two turbojet engines.

In the first section of the work, the fuel system of the aircraft was considered and analyzed:

The main requirements for the fuel system of a passenger plane;

The influence of factors on the operation of the fuel system of a passenger aircraft;

Overview of schemes and methods of supplying fuel to the engine of a passenger aircraft;

Overview of the main structural elements of the fuel system of a passenger aircraft;

Technical requirements related to fuel systems of passenger aircraft;

Peculiarities of passenger aircraft fuel system maintenance;

In the second chapter, methods of determining reliability and ways of increasing the reliability of the fuel system are considered, as well as an example of increasing the reliability of a generalized fuel system, in which the following solutions were proposed:

The proposed improvements through the application of redundancy of fuel system elements will significantly increase the reliability of the passenger aircraft fuel system, which will withstand up to 2 failures without serious consequences for the flight and will be similar to AFS, SS and EHS in terms of reliability and failsafe, however, these improvement measures will lead to an increase in the total mass of the fuel system for approximately 80-100 kg. It should be noted that the use of triple redundancy of SS and EHS ensures high reliability and failure, meets the requirements of AP25 standards, but this requires an increase in the mass of these systems (SS and EHS) by hundreds of kg. However, this does not stop the designers and currently 3 or more channel SS and EHS are widely used, which ensure high reliability and safety of the flight.

Proposed improvements to the fuel system

- install a second pump on the engine in parallel with the first one, which will work if the first one fails for some reason. The second pump can be driven, like the first, from the box of aircraft units (CSA) or from an additional electric motor and turn on after the failure of the first;

- Make the fire hydrant with 2-chain control (that is, it works only when both contacts are closed), also add the same fire hydrant in parallel and the same again in series, but with a two-motor and two-chain fire hydrant, also put a single-motor double-chain faucet in parallel with it;

-Increase the safety margins of pipelines and units of the fuel system by pressure up to three, as provided for in the AHS

Also, as part of the thesis, attention was paid to the issues of labor protection during technical maintenance of the fuel system and environmental protection, the conclusions of which are given below.

The obtained value of the resistance of the rectangular contour grounding device made of rods with a welded connecting strip is r_kz=3.9 Ohms, this resistance is less than the normative r_H= 4 Ohms, it can be concluded that this circuit meets the standards and can be used for grounding. There are n = 18 grounding devices in this grounding circuit.

Thus, the entire development minimizes the possible impact of the harmful and dangerous factor of electric shock and the occurrence of a static current arc that can lead to the ignition of fuel vapors.

It should also be noted that noise and chemically aggressive factors have a significant impact on the technical personnel who serve the AT, chemicals have a special impact on the skin, eyes and oral cavity.

To ensure the safety of personnel during technical work on the aircraft, it is necessary not only to establish labor protection standards, but also to apply new methods of automating maintenance.

The procedure for conducting attestation of workplaces according to working conditions is determined in accordance with the resolution of the Cabinet of Ministers of Ukraine "On the procedure for conducting attestation of workplaces according to working conditions" and "Methodical recommendations for conducting attestation of workplaces according to working conditions".

According to the results of the study of the section on environmental protection:

- during the analysis of the Air Code of Ukraine, the peculiarities of the requirements for environmental protection compared to the previous code were determined, that is, the new version covers a wider range of existing problems in this direction;

- based on the results of research in the field of increasing the fuel efficiency of the aircraft fleet and reducing greenhouse gas emissions from monitoring scientific publications, CAER/10 requirements, data on the forecast of emission limits (emissions of harmful substances) by aircraft engines and their acoustic characteristics, determined and provided with the aim of reducing aviation noise and increase fuel efficiency.

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