

**МІНІСТЕРСТВО ОСВІТИ ТА НАУКИ УКРАЇНИ**  
**Національний авіаційний університет**  
**Кафедра конструкції літальних апаратів**

ДОПУСТИТИ ДО ЗАХИСТУ  
Завідувач кафедри, д.т.н., проф.  
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«\_\_» \_\_\_\_\_ 2023 р.

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**ЗДОБУВАЧА ОСВІТНЬОГО СТУПЕНЯ**  
**«БАКАЛАВР»**

**Тема: «Аванпроект пасажирського середньомагістрального літака  
пасажиромісткістю до 190 осіб»**

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**National Aviation University**  
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**PERMISSION TO DEFEND**

Head of the department,

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"\_\_" \_\_\_\_\_ 2023

**BACHELOR DEGREE THESIS**

**Topic: "Preliminary design of the medium range passenger aircraft with 190 passenger capacity"**

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Kyiv 2023

# НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ

Аерокосмічний факультет  
Кафедра конструкції літальних апаратів  
Освітній ступінь «Бакалавр»  
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## ЗАВДАННЯ

**на виконання кваліфікаційної роботи здобувача вищої освіти**

**ВОЛЯНЮКА ОЛЕГА ЮРІЙОВИЧА**

1. Тема роботи: «Аванпроект пасажирського середньомагістрального літака пасажиромісткістю до 190 осіб», затверджена наказом ректора від 1 травня 2023 року № 624/ст.
2. Термін виконання роботи: з 29 травня 2023 р. по 25 червня 2023 р.
3. Вихідні дані до роботи: маса комерційного навантаження 18374,4 кг, дальність польоту з максимальним комерційним навантаженням 6500 км, крейсерська швидкість польоту 842 км/год, висота польоту 10.5 км, габаритні розміри вантажної кабіни.
4. Зміст пояснювальної записки: вступ, основна частина, що включає аналіз літаків-прототипів і короткий опис проектного літака, обґрунтування вихідних даних для розрахунку, розрахунок основних льотно-технічних та геометричних параметрів літака, компоновання пасажирської кабіни, розрахунок центрування літака, спеціальна частина присвячена конвертації проектного літака в медичний, на основі ґрунтовного аналізу обрано медичне обладнання для конвертації та проведені розрахунки центрування літака в медичному варіанті.

5. Перелік обов'язкового графічного (ілюстративного) матеріалу: загальний вигляд літака (A1×1), компоувальне креслення фюзеляжу (A1×1), креслення переобладнаної версії медичного літака (A1×1).

6. Календарний план-графік:

№	Завдання	Термін виконання	Відмітка про виконання
1	Вибір вихідних даних, аналіз льотно-технічних характеристик літаків-прототипів.	29.05.2023 – 31.05.2023	
2	Вибір та розрахунок параметрів проєктованого літака.	01.06.2023 – 03.06.2023	
3	Виконання компоування літака та розрахунок його центрування.	04.06.2023 – 05.06.2023	
4	Розробка креслень по основній частині дипломної роботи.	06.06.2023 – 07.06.2023	
5	Огляд літератури за проблематикою роботи.	08.06.2023 – 09.06.2023	
6	Аналіз медичних модулів для конвертації літака.	10.06.2023 – 11.06.2023	
7	Оформлення пояснювальної записки та графічної частини роботи.	12.06.2023 – 14.06.2023	
8	Подача роботи для перевірки на плагіат.	15.06.2023 – 18.06.2023	
9	Попередній захист кваліфікаційної роботи.	19.06.2023	
10	Виправлення зауважень. Підготовка супровідних документів та презентації доповіді.	20.06.2023 – 22.06.2023	
11	Захист дипломної роботи.	23.06.2023 – 25.06.2023	

7. Дата видачі завдання: 29 травня 2023 року

Керівник кваліфікаційної роботи \_\_\_\_\_ Вадим ЗАКІЄВ

Завдання прийняв до виконання \_\_\_\_\_ Олег ВОЛЯНЮК

# NATIONAL AVIATION UNIVERSITY

Aerospace Faculty  
Department of Aircraft Design  
Educational Degree "Bachelor"  
Specialty 134 "Aviation and Aerospace Technologies"  
Educational Professional Program "Aircraft Equipment"

## APPROVED BY

Head of Department,  
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«\_\_\_» \_\_\_\_\_ 2023

## TASK

for the bachelor degree thesis

Oleh VOLIANIUK

1. Topic: "Transportation of oversized cargo by short range aircraft", approved by the Rector's order № 624/CT from 1 May 2023.
2. Period of work: since 29 May 2023 till 25 June 2023.
3. Initial data: payload 16 tons, flight range with maximum capacity 1300 km, cruise speed 800 km/h, flight altitude 11 km, cargo cabin dimensions.
4. Content (list of topics to be developed): introduction, main part: analysis of prototypes and brief description of designing aircraft, selection of initial data, wing geometry calculation and aircraft layout, landing gear design, engine selection, center of gravity calculation, special part dedicated to the conversion of the designed aircraft into a medical one, based on comprehensive analysis, selection of medical equipment for the conversion, and calculation of the aircraft's center of gravity in the medical variant.
5. Required material: general view of the airplane (A1×1), layout of the airplane (A1×1), drawings of a conversion version of the medical plane (A1×1).

6. Thesis schedule:

No	Task	Time limits	Done
1	Selection of initial data, analysis of flight technical characteristics of prototypes aircrafts.	29.05.2023 – 31.05.2023	
2	Selection and calculation of the aircraft designed parameters.	01.06.2023 – 03.06.2023	
3	Performing of aircraft layout and centering calculation.	04.06.2023 – 05.06.2023	
4	Development of drawings on the thesis main part.	06.06.2023 – 07.06.2023	
5	Literature review on the issue of work.	08.06.2023 – 09.06.2023	
6	The analysis of medical modules for aircraft conversion.	10.06.2023 – 11.06.2023	
7	Explanatory note checking, editing, preparation of the diploma work graphic part.	12.06.2023 – 14.06.2023	
8	Submission of the work to plagiarism check.	15.06.2023 – 18.06.2023	
9	Preliminary defense of the thesis.	19.06.2023	
10	Making corrections, preparation of documentation and presentation.	20.06.2023 – 22.06.2023	
11	Defense of the diploma work.	23.06.2023 – 25.06.2023	

7. Date of the task issue: 29 May 2023

Supervisor: \_\_\_\_\_

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Student: \_\_\_\_\_

Oleh VOLIANIUK

## РЕФЕРАТ

Кваліфікаційна робота «Аванпроект пасажирського середньомагістрального літака пасажиромісткістю до 190 осіб»:

74 с., 12 рис., 17 табл., 11 джерел

Подана кваліфікаційна робота присвячена проектуванню середньомагістрального літака пасажиромісткістю до 190 осіб з подальшою конвертацією повітряного судна в медичний варіант.

У роботі використано метод порівняльного аналізу літаків прототипів з метою вибору найбільш обґрунтованих параметрів для проєктованого літака. Також застосовано методи інженерних розрахунків для отримання основних геометричних та компоувальних переваг проєкту, а також для визначення ключових технічних рішень. В спеціальній частині проведено конвертацію розробленого літака в медичний варіант. На основі аналізу медичних модулів було обрано медичне обладнання необхідне для конвертації літака. Проведені розрахунки центру мас конвертованого літака.

Актуальність роботи полягає в конвертації повітряного судна з метою забезпечення комфортного перевезення тяжкохворих та поранених людей до місця надання медичної допомоги та стабілізації їхнього стану під час польоту.

Основне практичне значення дипломної роботи полягає в тому, що запропоновано конвертацію розробленого середньомагістрального літака для транспортування хворих пацієнтів у критичному стані.

Отримані результати даної роботи можуть бути використані як у авіаційній промисловості, так і у навчальному процесі авіаційних спеціальностей.

**Кваліфікаційна робота, аванпроект літака, компоування пасажирської кабіни, центрування літака, конвертація в медичний варіант**

## **ABSTRACT**

Bachelor degree thesis "Preliminary design of the medium range passenger aircraft with 190 passenger capacity"

74 pages, 12 figures, 17 tables, 11 references

The presented qualification work is dedicated to the design of a medium-range aircraft with a passenger capacity of up to 190 people, with subsequent conversion of the aircraft into a medical variant.

The work utilizes a method of comparative analysis of prototype aircraft to select the most justified parameters for the designed aircraft. Engineering calculation methods are also applied to obtain the main geometric and layout advantages of the project and to determine key technical solutions. In the special section, the conversion of the developed aircraft into a medical variant is conducted. Based on the analysis of medical modules, the necessary medical equipment for the aircraft conversion is selected. Calculations of the center of mass of the converted aircraft are performed.

The relevance of this work lies in the conversion of an aircraft to ensure comfortable transportation of critically ill and injured individuals to the place where medical assistance can be provided and their condition can be stabilized during the flight.

The main practical significance of the diploma work is in the proposed conversion of the developed medium-range aircraft for transporting critically ill patients.

Obtained results of this work can be utilized in the aviation industry as well as in the educational process of aviation specialties.

**Bachelor degree thesis, preliminary design of the aircraft, passenger cabin layout, center of gravity position, conversion into a medical variant**



<i>Format</i>	<i>Nº</i>	<i>Designation</i>	<i>Name</i>	<i>Quantity</i>	<i>Notes</i>
			<i>General documents</i>		
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## INTRODUCTION

Aviation plays a crucial role in global transportation and the modern world's economy. It is widely recognized as one of the safest and fastest modes of travel. The aviation industry continuously evolves and improves, learning from past experiences and addressing any identified shortcomings. Each new aircraft development incorporates cutting-edge technologies, innovative engineering solutions, and scientific advancements to enhance safety, reliability, and efficiency, irrespective of the operational conditions.

As part of this project, the goal is to completely modernize the aircraft based on the parameters obtained from the three prototypes. This modernization process will focus on identifying and implementing key factors that improve efficiency and safety, with the ultimate goal of preventing aviation disasters. The work will also encompass a comprehensive examination of the latest innovations and advancements in the aviation field. By considering these advancements, the project aims to design a modernized aircraft capable of accommodating up to 190 passengers, further contributing to the overall progress of aviation technology.

The project seeks to maximize the aircraft's potential by incorporating advanced medical technologies and equipment, enabling on-board medical personnel to provide immediate and specialized care during critical and time-sensitive situations. The full-scale invasion of 2022 had a devastating impact not only on people but also on many sectors: industrial, educational, food, and medical. As a result, the need for effective transportation and medical assistance in conflict zones became even more critical. This project aims to address these challenges by not only providing transportation for wounded soldiers but also ensuring the delivery of essential medication to people in need within the conflict zone. Through this initiative, the converted aircraft will contribute to saving lives and promoting the well-being of individuals affected by war.

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# 1. ANALYSIS OF PROTOTYPES AND SHORT DESCRIPTION OF DESIGNED AIRCRAFT

## 1.1 Choice of the projected data

The designed aircraft prototype (OL1) is a narrow-body twin-engine turbojet passenger aircraft. The cabin capacity of the liner is 189 people, depending on the modification. The maximum flight range with the maximum commercial load is 6,500 km.

The peculiarity of the liner is economy and environmental friendliness, due to the use of new turbojet engines. In the new aircraft, the fuselage has improved flow, due to the use of a uniform narrowing of the nose part. Due to the use of composite materials, it was possible to reduce the pressure in the cabin to more comfortable conditions, which correspond to those at an altitude of  $\approx 2400$  m. OL1 is made according to the scheme of an all-metal free-supporting four-engine narrow-fuselage low-plane with a wing-shaped wing and vertical tail. The design of the fuselage has been significantly changed to increase its reliability, ensure safety in the event of damage, reduce the rate of crack growth, ensure a given resource, reduce mass and improve the quality of the outer surface. Different layouts of the passenger cabin provide capacity from 90 to 189 people.

Pressurized cabin ventilation type. Reduced risk of aileron reversal, which is often experienced by wings with high sweep. Reduced landing distance (from 3.3 km to 2.2 km), which facilitates the landing of the aircraft on airfields whose runways correspond to A class. Using this information and data from prototype aircraft [4],[5] we will attempt to design an aircraft that can compete with the existing airplanes on the market. Statistical data from the prototypes are presented in the following Table 1.1.

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<i>Head of dep.</i>	Ignatovich S.R.				
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Table 1.1.

### Operational-technical data of prototypes

Statistic data of prototypes	B720B	B737	OL1
Max commercial payload, kg	19600	12000	18374,4
Crew, number of pilot	3+4	3+4	2+4
Passengers (max)	114	185	189
Wing loading, [kN/m <sup>2</sup> ]	3,5	6,3	6,26
Mean cruising lift-to-drag ratio	12	15	17,78
Flight range with max payload [km]	6690	5765	6500
Cruise Altitudes, [km]	11,7	12,5	10.5
$V_{kp\ max}/H$ , km/h/km	983	852	842
Thrust/weight ratio [kN/kg]	2,5	3	3,3
Power of all engines/MTOW	0.0016	0.0015	
Number of engines and their type	4	2	2
Take off thrust, [kN]	62	133	133
Take off power, [kN]	40	80	80
Cruising thrust, [kN]	39	39	37,2953
Spec. fuel cons., take off, [kg/kN]	62	61	59,2781
Spec. fuel cons., cruising, [kg/kN]	30	28	28
Pressure ratio	4,5	5	5
Aerodrome code letter	B	A	A
Approach speed, [km/h]	258,39		260,61
Landing speed, [km/h]	243,39		249,29
Speed of take off, [km/h]	291,22		290,88
Take off run distance, [m]	1448	2241	1606
Landing run distance, [m]	801	1630	906
Take off distance, [m]	1920		2015
Landing distance, [m]	1322		1300

## 1.2 General information

Layout refers to the process of connecting various components of an aircraft, such as wings, engines, tailplanes, and landing gear, and arranging passenger and onboard equipment within the fuselage. The main goals of layout in aircraft design include proper component positioning, achieving desired load distribution, and integrating structural and strength schemes for aircraft components. Established technical solutions from previous aircraft designs are often utilized, with minor modifications to meet specific requirements. This approach optimizes weight and maximizes internal volume for accommodating desired loads. Specific considerations are given to crew placement, fuel arrangement, and flexible positioning of components and cargo to maintain balance and performance.

The primary objectives of the aircraft layout, which must be addressed during the design project, encompass various aspects such as component positioning, achieving the desired aircraft load, and maintaining appropriate centering ranges. Additionally, the development and integration of structural and strength schemes for aircraft components (e.g., fuselage, wings, tail, landing gear) are crucial considerations.

Requirements for the aircraft layout often present conflicting demands. For instance, ensuring ease of maintenance necessitates numerous cutouts and access points in the airframe structure. However, these areas require additional reinforcement to maintain the required structural strength, resulting in increased weight, production complexities, and higher costs. Therefore, compromises must be made to reconcile these conflicting requirements.

In aircraft design, well-established technical solutions successfully applied to other aircraft are employed whenever feasible. Minor modifications are made to component designs (e.g., wings, landing gear, fuselage) to meet specific technical, economic, and other requirements. The principle of combining multiple functions within the same structural element or unit is also utilized. For example, hatches are designed to serve both technological and operational functions, and the same structural frames in the tail section of the fuselage are employed for attaching the vertical tail and

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engines. This approach not only reduces weight but also provides increased internal volumes for accommodating desired loads.

When developing the aircraft's design and power scheme, the following approaches should be implemented:

- Concentrated loads on structural elements should be transmitted along the shortest possible path.

- Bending moments should ideally be transmitted along the tallest available structure height, while torques should follow a closed circuit over the largest possible area.

It is essential to consider specific placement requirements or flexible positioning needs for all components and cargo within the aircraft. For example, crew members and piloting/navigation equipment should be located in the nose section of the fuselage, while fuel must be arranged to minimize changes in the aircraft's center of gravity due to consumption.

During the aircraft layout process, priority is given to placing fuel and variable-weight cargo (passengers, baggage, cargo). Specific cargoes that require designated locations are then accommodated, followed by other cargoes that can be placed more flexibly while optimizing the utilization of fuselage volume and other areas of the airframe to ensure operational convenience, among other factors. Typically, the layout and centering process involves iterative steps, gradually achieving the desired operational and technical indicators of the designed aircraft through successive approximations.

**1.3 Aerodynamic layout**

The aerodynamic layout is carried out to achieve the lowest possible energy consumption. The necessary flight data of the aircraft can be provided due to the optimal choice of fuselage parameters, tailings, type of mechanization of the wing, its elongation, sweep, narrowing, relative thickness of the profile. At the same time, the location of the focus relative to the center of mass of the aircraft in different flight modes is important, which is ensured by the selection of the appropriate profile. The



result of the aerodynamic layout of the aircraft is the previous one variant of the overall drawing in three projections, which is subject to clarification after performing the volume-mass and structural-strength layout.

### 1.4 Volume-mass

The purpose of volume-mass layout is the optimal placement of commercial and service loads, household equipment, chassis, functional systems in a certain volume of the fuselage and other aircraft units. When choosing the shape and dimensions of the cross-section of the fuselage, it is necessary to be guided by the requirements for aerodynamics and ensuring the comfort of passengers. At this stage of the development of the layout, it is necessary to make a decision on the number, type and placement of doors, hatches and emergency exits. In the process of volume and mass layout, calculations of the center of the aircraft are performed for the most typical cases of operation, including when parking on the ground.

#### 1.4.1 Passenger equipment

Passenger equipment includes seats, shelves for hand luggage, emergency rescue and household equipment. The layout of the passenger cabin must meet the requirements for ensuring the specific volume of the cabin per passenger. This parameter is important in view of the requirements to ensure the necessary level of comfort for both passengers and crew members. The values of these values must be at least those indicated in the Table 1.2.

Table 1.2

**Minimum values of the specific volume of passenger cabins, m<sup>3</sup>/person.**

The diameter of the fuselage	Flight duration, hours					
	to 1	1...2	2...4	4...6	6...8	8 ...
Less 4 m	0,84	0,85	0,92	0,98	1,2	1,2
4 m and more	0,96	0,98	1,06	1,13	1,27	1,36

The dimensions of the passenger cabin are determined by the number of passengers with standard seating options. Currently, three classes of passenger cabins (cabins) are used in air transportation: first (usually on long-haul aircraft), business class (on planes where there is no first class) and economy. These classes differ in passenger comfort and service conditions. Often, airlines practice their own classes of passenger service, which can combine the properties of neighboring classes. For example, economy-comfort or economy-premium classes, which are between business class and economy class, are often practiced. Economy class seats can have backs that do not recline or recline up to 360 degrees.

### **1.4.2 Crew cabin**

The crew cabin should, on the one hand, occupy the smallest volume, and on the other hand, provide satisfactory conditions for the pilots' work and rest. It is necessary that the layout of the crew cabin, the location of the main and emergency controls allow the crew members to pilot the aircraft without excessive effort and fatigue. The general ergonomic requirements are as follows: levers and handles, which are most often used by pilots, should be located in the visibility zone, in the most optimal working zone, and others - in the reach zone and, if possible, in the visibility zone. The crew of modern passenger aircraft consists of two or three people: two pilots or two pilots and a flight engineer (on long-haul airplanes). In connection with the recent widespread use of displays on dashboards, the work places of flight engineers are most often placed between pilots. Sometimes in the cabins of the crew there are places for an inspector (instructor, trainee).

### **1.4.3 Cargo compartments**

Cargo compartments can be located on the floor of the passenger cabin or under it in the sealed part of the fuselage. In the first case, cargo compartments tend to be located in front and behind the passenger cabin. This approach makes it possible to ensure the necessary centering of the plane depending on the number of passengers by adjusting the weight of the cargo. The locations of the cargo bays are determined when

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estimating the length of the fuselage, and it is recommended to use data from prototype aircraft. Having decided on the types and sizes of containers at the stage of forming the fuselage section, and knowing that, you can calculate the total length of the cargo compartments and the number of containers.

#### **1.4.4 Galleys and buffets**

To provide food for passengers during flights on intercontinental and long-haul routes, depending on the number of passengers, 1...2 kitchens are provided. If the plane has passenger cabins of different classes, then it must have two kitchens. When the flight duration is less than three hours, hot meals are not provided to passengers, so the plane can only be equipped with a buffet for cold drinks, tea, coffee and light snacks. Buffets may not be installed on aircraft with a take-off weight of up to 10 tons. Buffet kitchen equipment must be located near the door. Kitchens and buffets cannot be placed near toilets or combined with wardrobes. On wide-body aircraft, buffet and kitchen equipment can be located under the floor, and service carts with food are delivered to the cabins by an elevator.

#### **1.4.5 Wardrobes**

Wardrobes for outerwear of passengers are located near the entrance and exit doors, close to the passenger cabin. The wardrobe for the crew is usually made separately. Clothes in wardrobes are placed on shoulders that are hung on fixed pipes. The width of one row is 500...600 mm, the step of the shoulders is 70...80 mm.

#### **1.4.6 Lavatory**

To ensure normal living conditions for passengers and crew members, water supply and waste separation systems are used on passenger planes. According to the principle of operation, the latter systems are of two types: water-vacuum (for example, on the A-320 aircraft) [13] and recirculation (Boeing 737 aircraft) [4]. The number of toilets depends on the number of passengers and the duration of the flight (Table 2.1).

### 1.4.7 Normal, emergency exits, and emergency evacuation devices

The layout of the passenger cabin of the aircraft is greatly influenced by the placement of emergency and rescue equipment. One of the main factors is the number and parameters of normal and emergency exits, provision of passages to them. According to the requirements of the Aviation Rules (AR-25) [1] with up to 50% of both normal and emergency exits on both sides of the fuselage open, the evacuation of passengers and crew members must be carried out in a time not exceeding 90 seconds. To fulfill these requirements, the following types of emergency exits are used on airplanes (Table 1.3).

Table 1.3

#### Types and parameters of emergency exits

Type	Width x height, mm (not less)	Rounding radii of the corners from the width	Location
I	610x 1220	1/3	At floor level
II	510x1120	1/3	For high-rises - at floor level. When located above the wing, there may be a threshold: inside the aircraft, the height is not more than 250 mm; from the outside - no more than 430 mm
III	510x915	1/3	When located above the wing, there may be a threshold: inside the aircraft, the height is not more than 510 mm; from the outside - no more than 685 mm
IV	485x660	1/3	When located above the wing, there may be a threshold: inside the aircraft, the height is not more than 735 mm; from the outside - no more than 915 mm
A	1070x1830	1/6	At floor level

With the number of passenger seats more than 299, each emergency exit on board the fuselage must be an exit of type A or I. It is allowed to have 110 passenger seats for each pair of exits of type A, and 45 seats for each pair of exits of type I. In the event of

an emergency landing, emergency exits must be provided in accordance with the following requirements:

- on airplanes with the number of passenger seats 9 or less - one exit on each side of the airplane above the waterline, corresponding to the size of, at least, a type IV exit;
- on airplanes with the number of passenger seats of 10 or more - one exit on each side of the aircraft above the waterline, corresponding to the dimensions of at least one type III exit for each block or part of a block of 35 passengers - at least two such exits in the passenger cabin, that is, one on each side of the plane.

*Table 1.4*

**Additional emergency exits when the number of passengers is more than 189**

Additional emergency exits (on each side of the fuselage)	An increase in the number of passenger seats is permissible
Type A	110
Type I	45
Type II	40
Type III	35

On airplanes with a passenger capacity of more than 20 people, emergency exits for crew members must be located in the crew accommodation area - one per on each side of the fuselage or an upper hatch must be provided. Exits should be rectangular in size, at least 485x510 mm.

The distribution of emergency exits along the fuselage should be as even as possible, taking into account the features of passenger accommodation, but it is not required that the dimensions and location of emergency exits along the sides of the cabin be symmetrical. If more than one such exit is required on each side of the fuselage, then they must be located at the ends of the cabin. In case the aircraft has one longitudinal passage in the passenger compartment, then the emergency exits must be located in such a way that passengers have the opportunity to reach them both from the front and from the rear. If there are two or more longitudinal aisles for unobstructed

access of passengers to emergency exits, transverse aisles to them between longitudinal aisles should be at least 510 mm wide. The passage from one passenger cabin to another for access to the emergency exit must be unobstructed, but the cabins can be separated from each other by curtains.

### 1.5 Structural and strength layout

One of the tasks of structural and power layout is also the installation of operational and technological (production) connectors of aircraft parts. Simultaneously with the process of structural and power layout, possible technologies for manufacturing parts of the aircraft and its assembly are considered, since the technological processes that are chosen can determine the features of the power scheme of the structure.

The structural drawing together with the general view of the aircraft (in three projections) serves as the basis for theoretical drawings of the fuselage and its connection with other parts of the aircraft.

The general appearance of the aircraft allows you to associate its main overall dimensions with external forms. It is necessary, for example, for making drawings of a model intended for aerodynamic research (blowing in a wind tunnel). Making a drawing of the general appearance is inextricably linked with layout and centering, aerodynamic calculation, calculation of stability and controllability, etc. According to their results, the necessary changes and additions are made to the drawings of the general appearance of the aircraft.

The drawing of the general view of the aircraft must be drawn up in accordance with requirements of “ESKD” and “DSTU” [2],[3] and is related to the composition and textual part of the layout, in which the necessary calculations and justification of the decisions taken should be given.

### 1.6 Selection of the main parameters of the wing

Among the main parameters of the wing are the profile and relative thickness  $\bar{C}_a$  or  $\bar{C}_{cep}$ , sweepback;  $\chi$  0.25 chords each, aspect ratio  $\lambda$ , taper ratio  $\eta$ , the angle of the

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transverse V of the wing and the specific load on the wing, the shape of the wing in plan. Combinations of parameters, which are given in the Table 1.5, are typical for modern airplanes.

Table 1.5

**Characteristic combinations of parameters**

Aircraft wing parameters	Take-off weight of the aircraft			
	to 15t	from 20t to 40t	From 50t to 100t	over 150 t
$l_0$	8...12	7...9	6,5...8	6,5...9,0
$\chi^\circ$	6°...8°	20°...25°	30°...32°	32°...35°
$\bar{C}_A$	0,12...0,14	0,11...0,12	0,10...0,12	0,12...0,14
Ro(kPa)	2,0...3,0	3,5...4,0	4,5...5,5	8,5...6,0

The aerodynamic characteristics of the wing are largely determined by the shape of the wing in plan. Profile parameters ( $\bar{X}_C, f$ ) and relative wing thickness ( $\bar{C}_A$ ), as the practice of aircraft construction shows, depend on the Mach number M of the cruise flight-Mk (see in Table 1.6).

Table 1.6

**Dependence of profile parameters on Mach number**

$M_c$	$\chi^\circ$	$\lambda$	$\eta$	$\bar{C}_A, \%$	$\bar{X}_C$	$f, \%$
0,85...0,9	35°...40°	6,5...8,5	3,5...4,5	9...12	35...45	0...2,5
0,6...0,8	0°...25°	7...12	2,5...3,5	12...18	30...40	1...3,5

The appropriate range of application of different types of profiles:

High-bearing type NACA - at  $V > 400$  km/h.

Laminated type NACA-at  $400 \text{ km/h} < V < 650 \text{ km/h}$ .

Laminated high-speed at  $600 \text{ km/h} < V < 750 \text{ km/h}$

Critical (peak) - at  $750 \text{ km/h} < V < 850 \text{ km/h}$

Supercritical - at  $V > 800 \text{ km/h}$ .

For the wings of modern airplanes, the speed of which is close to sonic, close to symmetric and asymmetric profiles with a sharper front edge and with a relatively rear position of maximum thickness are used  $\bar{X}_C = 35 \dots 45 \%$ . They are characterized by a smoother pressure distribution along the chords of the wing, which reduces the value of the local air speed over the upper surface of the wing and contributes to an increase in the critical flight number  $M_{\text{critical}}$ . In recent years, so-called supercritical profiles (double curvature profiles) are also being used for the wings of passenger planes, the speed of which is close to sonic, which, compared to ordinary profiles of the same relative thickness, have higher (by  $0.08 \dots 0.1$ ) values  $M_{\text{critical}}$ . It should be taken into account that all the measures mentioned above, aimed at increasing the  $M_{\text{critical}}$  flight, adversely affect the stiffness properties and weight characteristics of the wing, and also lead to a noticeable decrease in the maximum values of the lift force coefficients  $P_{\text{in mach}}$ .

The sweepback shape of the wing is a means of increasing the critical Mach number of the flight. Increasing the sweep of the wing not only moves the beginning of the wave crisis to high flight speeds, but also softens its flow, reduces the increase in resistance, improves the stability and controllability characteristics of the aircraft, the speed of which is close to sonic. In addition, the arrow shape of the wing increases the critical speed of flutter and divergence. However, with increasing the angle of arrow-likeness, they decrease  $P_{\text{in mach}}$  and  $C_{\text{mach}}$  wing the effectiveness of take-off and landing mechanization decreases. Due to the lateral flow of the boundary layer to the ends of the swept wing, it has a tendency to the final disruption of the flow at large angles of attack, the consequence of which may be the loss of transverse controllability and longitudinal instability of the aircraft during landing. The arrow shape complicates the production and increases the weight of the wing.

Transport aircraft, the speed of which is close to sound, have wings with zero and small sweep. The extension of such wings lies in a fairly wide range  $\lambda = 8 \dots 12$ , and large values of elongation belong, as a rule, to large-sized aircraft with a long-

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calculated flight range. Increased values of wing elongation are sometimes chosen for aircraft with a short flight range in connection with the desire to improve their take-off and landing characteristics. A formula can be used to approximate the elongation of the wing of the aircraft being designed  $\lambda=10,5\cos^2\chi$ . The obtained elongation value is corrected based on the data on the parameters of the wing of similar aircraft.

The narrowing of the wing  $\eta$  has contradictory effects on the aerodynamics, weight and stiffness of the wing. The main trend among them wings with a large narrowing to the final disruption of the flow with a simultaneous decrease in the efficiency of the ailerons. In connection with the specified circumstances, the narrowing of the straight wings of airplanes, the speed of which is close to the sound speed, is usually small and amounts to, which provides close to the minimum inductive resistance of the wing and high values  $\eta=2...2,5$  which provides close to the minimum inductive resistance of the wing and high values  $C_{in\ mach\ const}$ . The angle of the transverse V wing, as is known, serves as a means of ensuring the degree of transverse stability of the aircraft. For straight wings of airplanes, the speed of which is close to sound, the value of the transverse V angle is in the range of  $5^\circ...7^\circ$  - for the low-plane scheme, up to  $-1^\circ...-2^\circ$  - for the high-plane. The sweep increases the lateral stability of the wing, so a negative transverse V should be added to swept wings. However, structural and other requirements (for example, landing with a roll) may cause a positive V of a swept wing. This will cause the installation of automatic yaw dampers in the control system and will require some increase in the area of the vertical tail.

Select the following parameters:  $\lambda = 10,2$ ;  $\eta = 3,7$ ;  $\bar{C} = 0,1$ ;  $\chi_{0.25} = 25^\circ$ .

### 1.7. Selection of main fuselage parameters

Aerodynamic and weight characteristics of the fuselage significantly depend on its shape and dimensions, which are determined by such geometric parameters as the shape of the cross section, elongation  $\lambda_F$  and fuselage diameter  $D_F$ . It should be noted that the elongation and length of the fuselage are specified during the layout of the aircraft in terms of providing the necessary volumes for the accommodation of the crew, passengers and cargo, as well as acceptable shoulders  $L_{ve}$  i  $L_{ho}$  horizontal and

vertical wing of the aircraft. Lengthening of the fuselage and its parts (nose  $l_n$  and tail  $l_t$ ) are chosen from the understanding of aerodynamics and the weight of the fuselage. When choosing  $l_F$  designed aircraft can be guided by such statistical data of modern aircraft. At  $M_k \leq 0,7$ :  $l_F = 7 \dots 8$  - passenger planes SRP and LRP;  $l_F = 8 \dots 9$  - mid range aircraft. At  $M_k \leq 0,9$ :  $l_F = 9 \dots 10$  - airplanes with a large passenger capacity;  $l_F = 10 \dots 13$  - long-distance highways. It should be taken into account that the value of  $l$  increases slightly if the aircraft engines are located on the tail part of the fuselage. The extensions of the nose and tail parts of the fuselage lie within: At  $M_k \leq 0,7$ ;  $l_n = 1,2 \dots 1,5$ ;  $l_t = 2,0 \dots 2,5$ ; At  $M_k \leq 0,9$ ;  $l_n = 1,7 \dots 2,0$ ;  $l_t = 3,0 \dots 3,2$ ;

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## Conclusions to the part 1

In this analytical section, we have chosen prototype aircraft, namely the Boeing 720B and Boeing 737-Max [4], and given a concise description of each. The selection of these aircraft allows us to gather valuable insights and learn from their design principles and performance characteristics. This will help to take into account not only the advantages of these prototype aircraft, but also we will eliminate previous failures.

To facilitate the development of our aircraft, we have included tables containing important data for emergency exit selection and other important parameters. These values play a crucial role in ensuring the safety and functionality of the aircraft and by updating these tables and their values we can make more accurate calculations.

The proposed aircraft design incorporates a low-wing monoplane structure, which offers advantages in terms of stability and aerodynamic efficiency. The use of two turbojet engines provides the necessary thrust for efficient flight operations.

Furthermore, we have provided a comprehensive overview of the goals and features associated with key components such as the wing, fuselage, flight control system, landing gear, tail unit, and passenger compartment. Understanding the specific design considerations and functionality of these components is vital for creating a well-rounded and efficient aircraft.

Considering all of the aforementioned factors, we can now proceed to the next stage.

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## 2. PRELIMINARY DESIGN OF MID-RANGE PASSENGER AIRCRAFT

### 2.1 Determination of geometric parameters of the wing

The geometric characteristics of the wing are determined based on the take-off mass  $m_0$  and the specific load on the wing  $P_0$ . First, the area of the wing is found:

$$S_{wing} = \frac{m_0 \cdot g}{P_0} = 149.21 m^2,$$

where  $S_{wing}$  – wing area,  $m^2$ ;  $g$  – acceleration due to gravity  $m/s^2$ ;  $P_0$  – wing loading at cruise regime of flight;  $m_0$  – take off mass of the aircraft.

The wing span is calculated according to the formula:

$$l = \sqrt{S_{wing} \cdot \lambda_w} = 38.02 m,$$

where  $l$  – wing span, m;  $\lambda_w$  – aspect ratio.

A tip chord:

$$b_t = \frac{c_{root}}{\eta_w} = 1.59 m,$$

where  $b_t$  – tip chord, m.

Maximum wing thickness is determined in forehead i-section and is:

$$c_i = c_w \cdot b_t = 0.0795 m,$$

where  $c_w$  – related wing thickness

Board chord for trapezoidal shaped wing is:

$$b_b = b_o \cdot \left( 1 - \frac{(\eta_w - 1) \cdot D_f}{\eta_w \cdot l_w} \right) = 5.45 m$$

where  $b_o$  – root chord, m;  $\eta_w$  – wing taper ratio;  $b_b$  – wing board chord, m;  $D_f$  – fuselage diameter, m.

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When choosing the power scheme of the wings, the number of spars and their position, as well as the places where the wings are joined, are determined. Modern airplanes use a caisson wing and two or three spars; one spar wing is used on light sports, sanitary and other aircraft.

In the wing with two spars:

$$\bar{X}_1 = 0,2; \bar{X}_2 = 0,6.$$

In the wing with three spars:

$$\bar{X}_1 = 0,15; \bar{X}_2 = 0,4; \bar{X}_3 = 0,65$$

The formula provided allows us to calculate the Mean Aerodynamic Chord (MAC):

$$b_{MAC} = \frac{2b_o^2 + b_o b_t + b_t^2}{3(b_o + b_t)} = 4,279m$$

After determining the geometric characteristics of the wings, they proceed to the assessment of the geometry of the ailerons and the mechanization of the wing. When selecting a wing propulsion system, we assess the necessary number and placement of spars. To calculate the average aerodynamic chord, a geometric method is employed (refer to Fig.2.1; Fig.2.6).

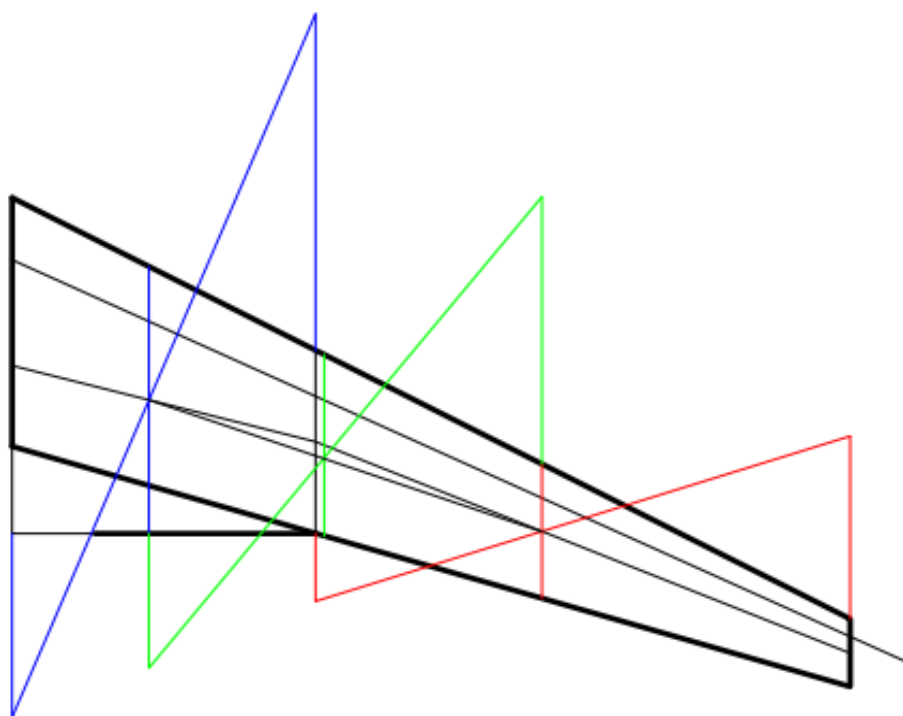


Fig. 2.1. Determination of mean aerodynamic chord.

The geometric parameters of the aileron are determined using a systematic approach:

- Aileron span:

$$l_{ail} = (0.3 - 0.4) l_w / 2 = 2.58m;$$

- Aileron area:

$$S_{el} = (0,05 \dots 0,08) \cdot \frac{S_w}{2} = 1.84m^2$$

## 2.2 Determination of geometric characteristics of the fuselage

When choosing the shape and dimensions of the cross-section of the fuselage, it is necessary to proceed from the requirements of aerodynamics (streamlining and cross-sectional area).

With regard to passenger and transport aircraft, the speed of which is less than the speed of sound ( $V < 800$  km/h), the wave resistance is almost not affected. Therefore, the form should be chosen under the conditions of ensuring the smallest values corresponding frictional resistance  $C_{xf}$  and profile resistance  $C_{xp}$ ,

In supersonic flights on the value of wave resistance  $C_{xf}$  the shape of the nose of the fuselage floats. The use of a chewing shape of the nose part of the fuselage significantly reduces its wave resistance.

For supersonic aircraft, the nose part of the fuselage must fold:

$$l_{nl} = (2 \dots 3) \cdot D_f$$

where  $D_f$  - diameter of fuselage.

In addition to taking into account the requirements of aerodynamics, when choosing the shape of the section, it is necessary to take into account the conditions of layout and strength requirements.

To ensure the minimum weight, the most appropriate form of the cross-section of the fuselage should be recognized as a round section. In this case, the thickness of the fuselage skin is obtained the smallest. As a type of such an intersection, you can use the combination of two or more neighborhoods both vertically and horizontally. For transport aircraft, when choosing the shape of the cross-section of the fuselage, the issues of aerodynamics do not become paramount, and the cross-section can be made

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rectangular or close to it.

We define the following parameters of the fuselage:

Length of the aircraft fuselage:

$$L_{fus} = FR \cdot D_f = 39.48\text{m}$$

where  $F_R$  – fineness ratio,  $D_f$  – diameter of fuselage.

Length of aircraft fuselage forward part:

$$L_{fwd} = FR_{fwd} \cdot D_f = 6.58 \text{ m,}$$

where  $F_R$  – fineness ratio of forward part.

-Length of the fuselage tail part:

$$L_{tail} = FR_{tail} \cdot D_f = 10.528\text{m}$$

where  $F_R$  – fineness ratio of tail part.

It should be taken into account that finding the required width of the passenger compartment does not yet allow finding the optimal dimensions of the cross-section of the fuselage. From a constructive point of view, it is rational to have a round cross-section of the fuselage, because in this case it will be the strongest and lightest. However, this form may not always be optimal for accommodating passengers and cargo. It is more appropriate to form the cross-section of the fuselage in the form of an oval or the intersection of two circles. It must be remembered that the oval shape is inconvenient in production, and the upper and lower panels will bend under excessive pressure and will require the introduction of zygomatic beams and other reinforcements in the structure.

The pitch of normal frames in fuselage structures is between 360 and 500 mm, depending on the size of the fuselage and the class of layout of passenger cabins. According to layout understanding, with fuselage diameters less than 2800 mm, they often deviate from this form and use the intersection formed by two intersecting circles. In this case, the floor of the passenger cabin is made in the plane of closing the arcs.

The windows of the passenger cabin are located in one light line (on the rich deck by the number of decks). The shape of the windows is round with a diameter of

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300...400 mm or rectangular with rounded corners. The step of the windows corresponds to the step of the frames 500...510 mm.

It is also necessary to perform a check on the volume per person. The length of the passenger cabin  $L_{cab}$  for the placement of chairs of the same type, which are located in  $N$  transverse rows with a constant step  $L_{cs}$ , can be calculated using the formula:

$$L_{cab} = L_1 + (N - 1)L_{cs} + L_2$$

where  $L_1$  - distance from the plane of the front partition to the first row of seats, mm  
 $L_2$  - distance from the plane of the rear partition to the back of the chair, mm. 1-st. class pas-  $V_{cab/n} = 1,5...1,8m^3$ ; Business- $V_{cab} = 1,2...1,3m^3$ ; Economy class  $V_{cab} = 0,9...1,0m^3$ ;

The width of the passenger cabin can be calculated according this formula:

$$B_{cab} = n_3 b_3 + n_{aisle} b_{aisle} + 2\delta + 2\delta_{wall} = 3390\text{mm}$$

where  $n_3$  – number of blocks of seats;  $b_3$  – width of block of seats, mm;  $n_{aisle}$  – number of aisles;  $b_{aisle}$  - aisle width, mm;  $\delta$  - distance between external armrests to the decorative panels, mm;  $\delta_{wall} = 80 - 120$  – width of the wall, mm.

### 2.3 Crew cabin calculation

The length of the cabin depends on the number and relative location of the crew's workplaces. On average, the length of the cockpit is 2300...3300 mm. The crew cabin is separated from other areas of the fuselage by a strong partition equipped with a door with a lock.

When designing the cockpit, it is also necessary to remember that during visual flight, the pilot must be able to clearly see such a part of the airspace that allows controlling the flight path and preventing collisions with other aircraft or obstacles. Practically, this is ensured by minimum viewing angles during cruising flight, start-up, run and taxiing. To determine the viewing angles, the starting point is the point of the calculated position of the pilot's eyes. For example, the forward view in cruise flight mode from the calculated position of the pilot's eyes should be 170 down and 200 up. Therefore, in order to ensure the necessary inspection, zones are defined in which objects must be absent, for example, the lamp posts of the crew cabin, which limit the field of vision, as well as zones in which the sizes of these objects must be limited. For

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the same purpose, the windows of the crew cabin lantern are made according to a special form. Each passenger aircraft must have the following number of flight attendants:

1) Airplanes with a passenger capacity of more than 9, but less than 51 passengers - 1 flight attendant;

2) Airplanes with a passenger capacity of more than 50 but less than 101 passengers - 2 flight attendants;

3) In airplanes with a passenger capacity of more than 100 passengers - 2 flight attendants and one additional flight attendant for each compartment (or part of a compartment) containing 50 seats in excess of the specified 100.

During take-off and landing, flight attendants must be as close as possible (as practicable) to the necessary exits at floor level and be evenly distributed throughout the aircraft to ensure the most efficient exit of passengers in emergency evacuation conditions. This determines the location of flight attendants' workplaces.

## 2.4 Galley and buffets calculation

On wide-body aircraft, buffet and kitchen equipment can be located under the floor, and service carts with food are delivered to the cabins by an elevator. The total volume of galley  $V_g$  in m<sup>3</sup> and its area  $S_g$  in m<sup>2</sup> can be determined as:

$$V_g = (0,1 \dots 0,12) N_{pas} = 19,36 \text{ m}^3$$

$$S_g = \frac{V_g}{H_g} = 8,42 \text{ m}^2$$

where  $H_g=2,3$ - galley height;  $N_{pas}$  - maximum number of passengers.

An example of the layout of the buffet is shown in (Fig. 2.2)

### 2.4.1 Wardrobes calculation

Wardrobe area  $S_w$  in m<sup>2</sup> can be defined as:

$$S_w = (0,035 \dots 0,04) N_{pas} = 8,8 \text{ m}^2;$$

where  $N_{pas}$  – number of passengers

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For long-haul aircraft, wardrobes have a larger area

$$S_w = (0,035 \dots 0,04) N_{pas} ;$$

An example of the wardrobe of a long-haul aircraft is shown in (Fig. 2.3).

Hand luggage and headgear are stored on shelves located along the sides of the passenger compartment above the seats. Shelves are equipped with doors. The height of the shelves from the cabin floor depends on the class of the aircraft and is, as a rule, 1500...1800 mm.

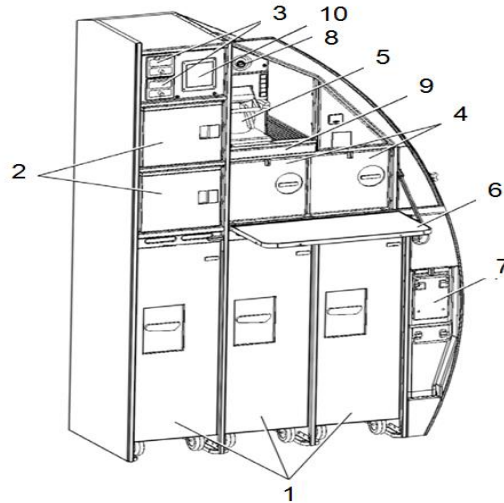


Fig. 2.2. Location of buffet elements

1 - service carts; 2 - convection ovens; 3 - stove control panels; 4 - flight attendant's containers; 5 - coffee maker; 6 - table; 7 - garbage container; 8 - nozzles of individual ventilation; 9 - tray for water; 10 - a mirror.

#### 2.4.2 Toilet facilities calculation

The number of toilets depends on the number of passengers and the duration of the flight (Table 2.1). If the duration of the flight is less than one hour and the number of passengers is up to 15 people, you cannot use the toilet in the plane. However, comfort within the cabins should not be overlooked, so it is proposed to arrange the toilet and other equipment according to the following scheme (Fig.2.4.).

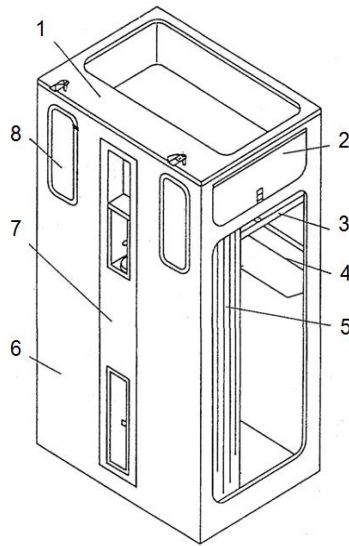


Fig. 2.3. Wardrobe

1 – upper panel; 2 – cabinet for removable equipment; 3 - pipe; 4 - box; 5 - curtain; 6 front panel; 7 - drinking column; 8 - lampshade lighting.

Table 2.1

**Number of toilets**

Flight duration, hours.	Less than 2	2...4	more than 4
Number of passengers per toilet	60	50	40

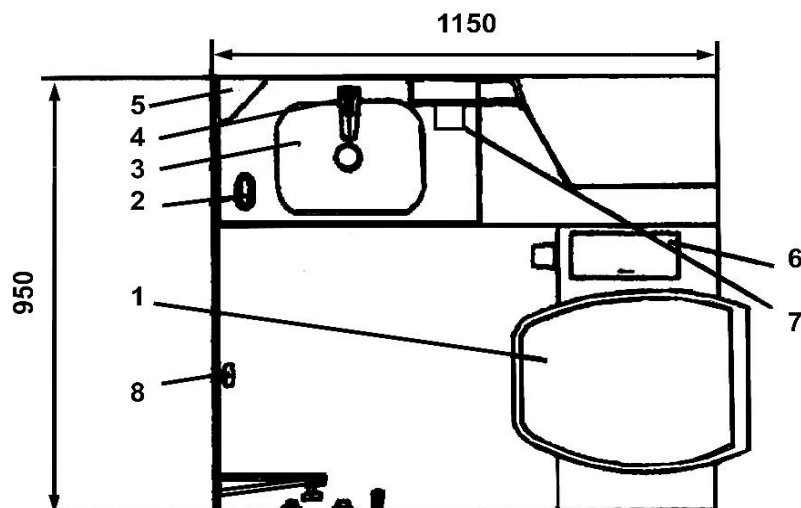


Fig. 2.4. View of the toilet in the plan:

1 – toilet; 2 – wash basin; 3 – dressing table; 4 – ceiling; 5 – shelf for small things; 6 – tank for used toilet paper; 7 – soap dish; 8 – door handle.

When calculating the mass and options for centering the aircraft, it is necessary to take into account the mass of water reserves and, depending on the type of waste disposal system, chemical reagents. During the execution of the layout, you can be guided by the data in the Table2.1, and the total supply of water and chemical reagents is defined as:

$$\sum m_p = q_p N_{pas}$$

The calculation of the total supply of water and chemical reagents per passenger is in the Table2.2.

Table 2.2

**Water and chemical reagent reserves per person.**

Flight duration, hours	Quantity per person $q_p$ , kg
less 2	0,7
2...4	1,0
more 4	2,0

**2.4.3 Cargo compartments calculation**

Cargo compartments can be located on the floor of the passenger cabin or under it in the sealed part of the fuselage. In the first case, cargo compartments tend to be located in front and behind the passenger cabin. This approach makes it possible to ensure the necessary centering of the plane depending on the number of passengers by adjusting the weight of the cargo. The locations of the cargo bays are determined when estimating the length of the fuselage, and it is recommended to use data from prototype aircraft. Approximate volume of cargo compartments in  $m^3$ , that are located on the floor of the passenger cabin can be estimated by the formula

$$V_{cargo} = v * n_{pass} = 37.8 m^3,$$

where  $n_{pass}$  – number of passengers.

Means the sum of the weight of the commercial load (passengers with luggage, mail, cargo, including the weight of pallets) and the weight of fuel.

When placing cargo compartments under the floor of the passenger cabin, their volume is determined based on the weight of cargo and mail and the method of transportation (in containers or on pallets).

The area of the cargo compartment is determined by formula:

$$S_{cargo} = \frac{M_{bag}}{0.4K} + \frac{M_{cargomail}}{0.6K} = 23.625m^2$$

Where  $M_{bag}$  – mass of baggage’s of all passengers,  $M_{cargomail}$  – mass of additional cargo and mails on the board of aircraft, near 15 kilograms for each passenger.

### 2.5 Calculation of the main parameters and layout of the chassis

At the initial stage of design, when the centering has not yet been completed and there are no drawings of the general appearance of the aircraft, only a part of the chassis parameters is determined:

$$e = (0,15 \dots 0,20)b_A;$$

If it is too large, it becomes difficult to separate the front support during take-off, and if it is too small, it is possible to overturn the aircraft on its tail, when the rear cabins and trunks are loaded first. In addition, the load on the front support will be too small and the aircraft will be wobbly when moving on a slippery runway and crosswind.

The chassis base is found from the expression:

$$B = (0,3 \dots 0,4)L_f = (6 \dots 10)e = 13,52m.$$

Large values belong to aircraft with engines on the wing (EoW). The last equality means that the front support accounts for 6...10% of the weight of the aircraft. The removal of the front support will be equal to:

$$d = B - e = (0,94 \dots 0,9)B = 12,67m.$$

The track of chassis is calculated according to the formula:

$$T = (0,7 \dots 1,2) \cdot B \leq 12m.$$

$T=6,09m$ . Under the condition of preventing lateral hooding  $T > 2H$ . Here  $H$  is the distance from the runway to the center of mass (CM) of the aircraft. The positions of I and M can be taken by height. For low-flying aircraft, the CM is located below

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the building horizontal of the fuselage. The wheels of the landing gear are selected based on the take-off weight of the aircraft according to the load on the parking lot; dynamic loads are taken into account when choosing the wheels of the front support. The type of pneumatics (balloon, half-balloon, arc) and the pressure in them are determined by the surface of the runway for which the aircraft is intended to be operated. Brake wheels are installed on the main, and sometimes on the front support.

Wheel loads are determined by:

- main support wheel:

$$P_{main} = \frac{9,81(B - e)m_0}{B \cdot n \cdot z} = 109367,11 (N);$$

- front support wheel:

$$P_{front} = \frac{9.81 \cdot C_{d-e} \cdot m_0}{B \cdot n \cdot z} = 44334,37 (N);$$

where n and z are the number of supports and wheels on one support, respectively;

CD = 1,5...2,0 – dynamic coefficient.

According to the calculated value of the load on the wheels  $P_{main}$  and  $P_{front}$  and the amount of take-off  $V_{tu}$  and landing  $V_1$  speeds are selected from the catalog of pneumatics. We choose the following wheel parameters Table 2.3.

*Table 2.3.*

### Wheel parameters

Main supports (brake): (mm)	1100x330B
Front support: (mm)	950x350A

## 2.6 Layout and calculation of the main parameters of the tail unit

One of the most important tasks of the aerodynamic layout is the choice of the location of the horizontal tail. To ensure the longitudinal static stability of the aircraft in relation to overloading, its center of gravity must be located in front of the focus of the aircraft, and the distance between these points, related to the value of the average aerodynamic chord (MAC) of the wing, determines the degree of longitudinal stability.

Determination of geometric parameters of tail feathers:

$$S_{HTU} = (0.18 \dots 0.25)S = 29.8 \text{ m}^2,$$

$$S_{VTU} = (0.12 \dots 0.20)S = 22.3 \text{ m}^2,$$

Where  $S$  – area of wing.

Determination of the area and direction of the elevator:

$$S_{el} = (0.3 \dots 0.4) S_{HTU} = 8.94 \text{ m}^2,$$

$$S_{rudder} = (0.2 \dots 0.22) S_{VTU} = 4.46 \text{ m}^2.$$

Elevator trimmer area:

$$S_{te} = (0.08 \dots 0.12) S_{el} = 0.894 \text{ m}^2.$$

The area of the steering wheel trimmer:

$$S_{tr} = (0.04 \dots 0.06) S_r = 0.233 \text{ m}^2.$$

The range of horizontal tail assembly is determined by the following ratio:

$$l_{HT} = (0.32 \dots 0.5)l_w = 11.41 \text{ m}.$$

Determination of the chords of horizontal tail assembly (HT):  $b_{fin}$ ,  $b_{MAC}$ ,  $b_{root}$

are performed according to the formulas:

$$b_{fin} = \frac{2S_h}{(\eta_w + 1) \cdot l_h} = 1,32 \text{ m}$$

$$b_{MAC} = 0,66 \cdot \frac{\eta_h^2 + \eta_h + 1}{\eta_h + 1} b_h = 2,83 \text{ m};$$

$$b_{root} = b_{fin} \cdot \eta_h = 3,96 \text{ m};$$

VT tail assembly chords:

$$b_{fin} = \frac{2 \cdot S_v}{(\eta_v + 1) \cdot l_v} = 1,68 \text{ m};$$

$$b_{MAC} = 0,66 \cdot \frac{\eta_v^2 + \eta_v + 1}{\eta_v + 1} b_v = 3,72 \text{ m};$$

$$b_{root} = b_{fin} \cdot \eta_h = 5,22 \text{ m};$$

## 2.7 Aircraft center of mass determination

The power scheme of the unit is understood as the articulation of structural elements that ensure the perception of loads and their transfer to the balancing points in

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the form of transverse force, bending and torque moments. The main elements of the power scheme are spars, wing and tail panels, reinforced ribs, reinforced frames. In the process of layout, it is necessary to perform the linking of power schemes, which consists in the fact that:

- wall elements of the wing (spars and beams) and tails must be connected to reinforced frames of the fuselage;

- a place must be provided for the passage of the centerplane caisson through the fuselage;

- chassis niches should not cross the power set of the wing;

- chassis rack mounting units must rest on reinforced elements (ribs, frames, chassis niche walls);

- the power elements of the tail should rest on the reinforced frames of the fuselage;

- steering wheel mounting brackets are made as a continuation of reinforced ribs.

The binding of the power scheme is reflected in the drawing of the general view, where the axes of the spars, reinforced ribs and frames are drawn with dashed-dotted lines with two dots.

## 2.8 Aircraft center of mass determination

When performing volume-mass layout, calculations of the centering of the aircraft are performed, i.e., finding such a position of the center of mass (CM) of the aircraft relative to the mean aerodynamic chord of the wing (MAC), in which:

- in the case of the variant with the rearmost position of the CM, the minimum permissible margin of static stability of the aircraft is ensured;

- in the case of the variant with the most forward position of the CM, conditions are provided for the sufficiency of the pitch rudder or stabilizer deflection for longitudinal balancing of the aircraft in all flight modes.

The more efficient the longitudinal control and balancing of the aircraft, the greater the maximum allowable front centering and, accordingly, the wider the permissible operating range of centers.

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During the operation of the aircraft, the position of its CM changes both as a measure of fuel production in flight and as a result of various options for loading and flight masses. Therefore, it is necessary to calculate the ranges of the centering of the aircraft for the most typical cases of its operation:

- take-off weight with the landing gear released;
- take-off weight with the landing gear removed;
- landing mass with released landing gear;
- overdrive option (without commercial load with the maximum amount of fuel) with the chassis removed;
- parking option (without commercial load, fuel, crew) with released chassis.

Calculating the centering of the aircraft is usually an iterative process, which is carried out by the method of successive approximation to the desired result, or by changing the layout, or by permuting groups of masses, or by using both options at the same time.

When performing layout, the centering point is determined along the x-axis, along the fuselage (Fig.2.6). The initial data for the calculation of center points are the known masses, the theoretical drawing and the preliminary layout of the fuselage, wings, wings, chassis. The drawing must be made according to one of the scales in accordance with the current standards:

Before directly determining the center of gravity, the mass of the aircraft is calculated. It includes the masses  $m_i$  of the main parts and assemblies of the aircraft, including fuel and cargo. It should be remembered that on modern subsonic aircraft fuel is placed in the wing caissons, sometimes, on long-haul aircraft, additional tanks are placed in the vertical or horizontal wings.

The management of masses is drawn up in the form of a table - centering information, which includes the coordinates of the centers of mass of all components of the take-off mass of the aircraft relative to the nose of the fuselage  $x_i$ , as well as static mass moments  $m_i x_i$  (table 3.1, 3.2.). To determine the coordinates  $x_i$  a schematic drawing of the previous variant of the layout of the aircraft should be used.

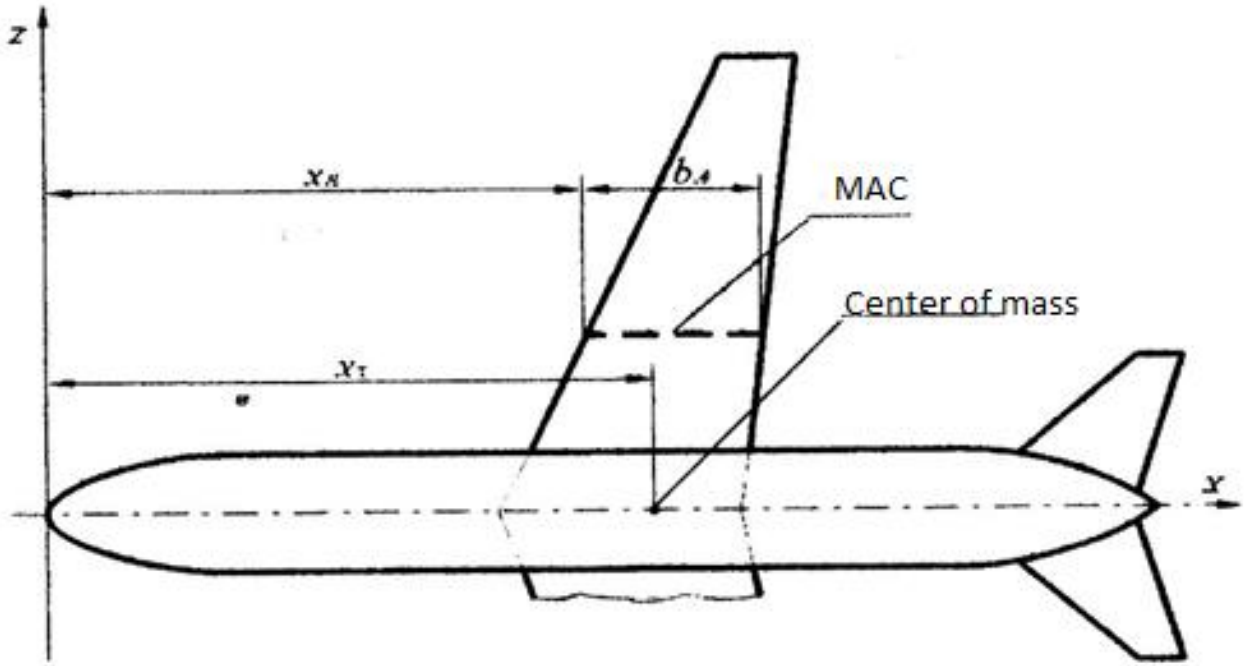


Fig. 2.6. To determine the position of the center of mass of the aircraft relative to the “MAC” In order to reduce time when calculating the centering of the aircraft and the arrangement of units, the following technique is proposed.

### 2.8.1 Determination of the center of mass of the equipped wing

The mass of the equipped wing includes the mass of its structure, part of the mass of the equipment (located in the wing), the landing gear and the mass of fuel. Regardless of where the main supports of the chassis are located (on the wing or on the fuselage), they, together with the front support, are included in the centering information of the masses of the equipped wing (Table 2.5.). The beginning of the indicated coordinates of the centers of gravity of the masses is chosen in the projection of the starting point of MAC onto the XOY plane. The name of the object, their relative and absolute masses and the coordinates of the centers of mass are included in the centering information. The coordinates of the centers of mass of the fuel in each tank (group of tanks) are located (see the appendix).

$$x'_w = \frac{\sum m'_i x'_i}{\sum m'_i} = 1.44 \text{ m},$$

where  $\sum m'_i x'_i$  - total moment of mass of wing,  $\sum m'_i$  - total mass.

Table 2.5

### Centering information of the masses of the equipped wing

N	Name of the object	Mass		C.G coordinates Xi, m	Mass moment, Xi * mi
		units	total mass, kg		
1	wing (structure)	0,1269	12082,66	1,93	23263,04
2	fuel system	0,0059436	565,91	1,93	1089,57
3	Flight control system, 30%	0,00317	162,82	2,57	417,96
4	electrical equipment, 10%	0,00317	301,83	0,43	129,14
5	anti-ice system, 40%	0,010584	1007,74	0,43	431,16
6	hydraulic systems,70%	0,0112	1066,40	2,99	3193,81
7	power plant	0,04391	4180,85	-1,00	-4180,85
8	equipped wing without landing gear and fuel		22963,73	0,92	21235,50
9	nose landing gear	0,030696	2922,69	3,00	8768,07
10	fuel	0,29718	28295,70	1,71	48425,26
	total	0.5327536	54182,12	1,45	78428,82

#### 2.8.2 Determination of the center of mass of the equipped fuselage

The origin of the coordinates is chosen in the projection of the nose part of the fuselage on the horizontal axis (see appendices). The construction axis of the fuselage is taken as the x-axis. An approximate list of objects of mass and recommendations for determining the coordinates of their centers of mass is given in the Table2.6.

The coordinate of the center of mass of the equipped fuselage is determined by the formula:

$$x'_w = \frac{\sum m'_i x'_i}{\sum m'_i} = 17.85 \text{ m},$$

where  $\sum m'_i x'_i$  - total moment of mass of fuselage,  $\sum m'_i$  - total mass.

Table 2.6

### Centering information of the mass of the equipped fuselage

№	Objects names	Mass		C.G coordinates Xi, m	mass moment
		units	total mass		
1	Fuselage	0,08382	7980,84	17,77	141787,56
2	Horizontal tail	0,00879	836,93	38,08	31871,59
3	Vertical tail	0,00868	826,46	36,52	30183,72
4	Radar	0,0045	428,46	1,97	845,79
5	Radio equipment	0,0023	218,99	1,97	432,29
6	Instrument panel	0,0053	504,63	1,58	796,92
7	Aero-navigation equipment	0,0045	428,46	1,97	845,79
10	Flight control system 70%	0,00399	379,90	19,74	7499,30
11	Hydraulic system 30%	0,0048	457,03	17,77	8119,55
12	Electrical equipment 90%	0,02853	2716,46	15,79	42898,26
13	Auxiliary power plant	0,0061474	585,32	38,30	22415,12
Equipped fuselage without payload			19516,34	18,61	363279,83
Equipment					
14	Crew		190,00	1,97	375,06
15	Attendance		300,00	19,74	5922,00
16	Documentation and tool	0,0047	447,51	2,76	1236,73
17	Water		364,00	18,95	6897,95
18	Additional equipment	0,0074	704,58	15,79	11126,78
Equipped fuselage			21522,43	18,07	388838,35
19	Nose landing gear	0,007674	730,67	6,20	4533,53
<b>Total</b>			22253,10	17,68	393371,88
Commercial payload					
20	Passenger		13200,00	17,77	234511,20
21	Baggage		5174,40	18,56	96014,10
22	Food /meal		728,00	19,74	14370,72
<b>Total</b>			41355,50	17,85	738267,90

This formula allows you to determine the MAC position of the leading edge of the wing in relation to the nose of the fuselage. This is achieved by calculating the  $X_{MAC}$  value using the following equation:

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$$X_{MAC} = \frac{m_f x_f + m_w x_w - m_0 C}{m_0 - m_w}$$

For low wing position:

$$C = (0.22-0.25)b_{MAC} = 1.004$$

$$X_{MAC} = \frac{41355.5 \cdot 17.85 + 54182.12 \cdot 1.44 - 95537.62 \cdot 1.004}{95537.62 - 54182.12} = 17.41$$

where  $m_0$  – aircraft takeoff mass, kg;  $m_f$  – mass of equipped fuselage, kg;  $x_f$  – coordination of fully equipped fuselage,  $m_w$  – mass of equipped wing, kg;  $x_w$  – coordination of equipped wing;  $C$  – distance from MAC leading edge to the C.G. point.

$$x_T = X_{MAC} + C;$$

$$x_T = 17.42 + 1.004 = 18.41;$$

$$x_T = \frac{C}{b_{MAC}} 100\%;$$

$$x_T = \frac{1.004}{4.182} \cdot 100\% = 24\%$$

As a result of the calculations, the values of the centers of the aircraft, which are given in the Table 2.7, should be obtained.

Table 2.7

**The value of aircraft centers according to statistics**

Straight wing		Arrow-shaped wing	
low-wing	high-wing	low-wing	high-wing
13...32	15...33	18...38	20...42

If these values cannot be obtained, it is recommended to use the following means of centering correction:

-change the location of the heaviest loads in the fuselage;

-move the wing along the fuselage (at the same time, not only the center of mass of the aircraft will move, but also the MAC of the wing). In order to facilitate the calculation of centering options, it is recommended to summarize the masses and the corresponding coordinates of the masses in the Table2.8. Mandatory variants of aircraft centering calculations for the most typical cases of aircraft operation are summarized

in the Table 2.9. For the landing variant, the mass of fuel can be roughly accepted 15%...20% (depending on the type of aircraft) of the mass of fuel at take-off, and for refueling - the mass of fuel as much as possible (due to the lack of commercial load) and is determined by the capacity of the aircraft's fuel tanks.

For the landing variant, the mass of fuel can be roughly accepted 15%...20% (depending on the type of aircraft) of the mass of fuel at take-off, and for refueling - the mass of fuel as much as possible (due to the lack of commercial load) and is determined by the capacity of the aircraft's fuel tanks. The centering process is considered complete only after the centering values for the most typical aircraft operation options fall within the recommended ranges.

Table 2.8

**Consolidated centering list**

Name of the object	mass $m_i$ in kg	coordinate $X_i$ , m	mass moment kg, m
equipped wing	22963,73	0,92	21235,50
Nose landing gear (extended)	730,67	6,20	4533,53
main landing gear (extended)	2922,69	3,00	8768,07
fuel reserve	28295,70	1,71	48425,26
fuel for flight	21522,43	18,07	388838,35
equipped fuselage (without payload)	13200,00	17,77	234511,20
Passengers (economy)	5174,40	18,56	96014,10
Passengers (business)	728,00	19,74	14370,72
on board meal	730,67	5,70	4168,19
baggage	2922,69	3,00	8768,07
cargo, mail	22963,73	0,92	21235,50
flight attend	730,67	6,20	4533,53
crew	2922,69	3,00	8768,07
Nose landing gear (retracted)	28295,70	1,71	48425,26
Main landing gear (retracted)	21522,43	18,07	388838,35

Table 2.9

## Consolidated centering list

No	Name of the object	Mass $m_i$ kg	mass moment $m_i X_i$	center of mass $X_{CM}$	Centre of gravity position
1	Take off mass (L.G. extended)	95537,61597	816696,72	18,20	30,24
2	Take off mass (L.G. retracted)	95537,61597	816331,38	18,19	30,15
3	Landing weight (LG extended)	69225,3	772219,72	18,04	26,58
4	Ferry version (without payload, max fuel, LG retracted)	76435,2	471435,37	18,15	29,15
5	Parking version (without payload, without fuel for flight, LG extended)	46133,4	397816,9295	18,11	28,17

## Conclusion to the part 2

As part of this project, extensive calculations were conducted for a one-class passenger aircraft with a seating capacity of 189 passengers. The aircraft, weighing 95214 kg during take-off, is powered by two CFM International LEAP-1B turbofan engines. Thorough calculations were performed to determine the specific parameters of the wing, fuselage, tail, and landing gear. Also taken, meticulous attention was given to the integration of cutting-edge technology and advanced systems within the aircraft design. This includes state-of-the-art avionics, communication systems, and passenger amenities to enhance the overall passenger experience.

The project also involved rigorous testing and simulation to ensure the aircraft's performance meets stringent safety standards and regulatory requirements.

Moreover, considerations were made for environmental sustainability, with a focus on minimizing fuel consumption and reducing emissions. Efficient aerodynamic design, lightweight materials, and advanced engine technology were incorporated to optimize fuel efficiency and reduce the aircraft's ecological footprint.

In addition to the structural calculations, careful consideration was given to the interior layout of the aircraft. The required number and dimensions of essential amenities such as kitchens, toilets, and wardrobes were meticulously determined to ensure optimal functionality and passenger comfort.

Moreover, the center of gravity of the aircraft was meticulously calculated, taking into account the distribution of weight across various components. This crucial information contributes to the overall stability and performance of the aircraft during flight.

To create a comprehensive design, detailed drawings of the aircraft were meticulously prepared, incorporating all calculated parameters and specifications. With the aforementioned aspects in place, the aircraft will provide fast, comfortable, and safe transportation for passengers.

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### 3. CONVERSION OF THE MEDIUM RANGE PASSENGER AIRCRAFT INTO MEDICAL VARIANT

#### 3.1 History and importance of medical aircraft.

Over the past two decades, there have been significant advancements in aeromedical evacuation (AE), which involves long-distance air transportation of patients. As a result, AE has become a crucial component of contingency medical care worldwide. In situations like the 2022 war in Ukraine, converting passenger aircraft into specialized medical transports plays a vital role in providing medical assistance and evacuating casualties.

The conversion process entails transforming a passenger aircraft into a dedicated medical transport capable of delivering urgent medical care and efficiently transporting wounded individuals. One of the primary benefits of such conversions is the ability to quickly respond to emergencies and provide medical assistance on-site. In conflict scenarios where access to medical facilities may be limited or impossible, medical aircraft allow for the deployment of medical personnel, equipment, and medications directly to the scene, ensuring swift assistance and reducing the risk of fatalities due to inadequate treatment access.

Furthermore, converting aircraft into medical transports facilitates the evacuation of injured individuals to medical facilities where necessary procedures and surgeries can be performed. Medical aircraft provide a means for rapid transportation of injured individuals to larger medical centers equipped with the resources needed for qualified medical care.

Additionally, medical aircraft can serve as mobile hospitals, delivering medical assistance on-site. This is particularly crucial in war conditions when quick access to medical facilities may be limited. These aircraft can be equipped with essential medical equipment, ventilators, medications, and other necessary resources for providing required assistance.

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It enables prompt response to emergencies, provision of urgent medical assistance on-site, evacuation of casualties to medical facilities, and provision of mobile medical care. This contributes to saving lives and improving treatment outcomes for those affected by military actions. One of the earliest examples of such conversion dates back to 1918 when Major Nelson E. Driver and Captain William C. Ocker modified a Curtiss JN-4 Jenny biplane into an airplane ambulance (Fig.3.1) This pioneering effort allowed the US Army to transport patients by airplane for the first time. In 1922 the US Army converted the Fokker F-IV, the largest single-engine airplane at the time, into an air ambulance designated as the A-2.



Fig. 3.1. The Curtiss JN-4 Jenny was converted to an air ambulance.

In the same year, Colonel Albert E. Truby, a physician in the US Army, outlined the various potential uses of airplane ambulances. These included transporting medical officers to aircraft crash sites and evacuating casualties from the crash to hospitals, transferring patients from isolated stations to larger hospitals for more comprehensive care, transporting seriously wounded individuals from the front lines to rear hospitals during times of war, and delivering medical supplies in emergency situations. The transportation of patients by air gained operational significance as well.



helicopter, needs to be relatively close to the expected concentration of casualties to ensure a rapid response.

The principle of "Medical Care" pertains to the care provided to patients during transport. This aspect of medical care distinguishes MEDEVAC from mere casualty transportation. The principle of "appropriateness" relates to using the most suitable mode of evacuation, be it ground or air, and directing casualties to the most suitable medical facility, which is typically the closest one. However, there may be exceptions to this rule. The principle of "precedence" involves categorizing patients based on their need for evacuation. Together, appropriateness and precedence support the concept of triage, where casualties are sorted, and resources are conserved to maximize the benefit. During mass casualty situations, medical providers often face the challenge of matching patient needs with available evacuation resources and must make difficult triage decisions to ensure the most effective utilization of limited resources. Applying the principles of appropriateness and precedence will help deal with this mismatch. As a prototype for this task, we have chosen the Boeing 737 MAX [4], a medium-haul aircraft, because it can access most airports, has sufficient range, and provides enough space to accommodate equipment and medical personnel for patient transportation.

**3.2 Aircraft conversion principles**

In recent cases of infectious diseases caused by highly pathogenic agents (for example, Ebola fever virus, Lassa fever virus, SARS-CoV, MERS-CoV [7], pandemic influenza virus), which have the potential to spread over several continents within a few days, international health protection authorities took measures – which are, in part, of high economic relevance – to limit the consequences of a possible spread. In the event of an emergency, air transport presents several advantages over land transport by ambulance or helicopter. Among the advantages is the saving of transport time as up to dozens of the sick or wounded can fit on board such a rebuilt aircraft. Aeromedical evacuation (AE) is a challenging process, further complicated when a patient has a highly hazardous communicable disease. Here are several reasons why the conversion of an airplane into a medical aircraft is important:

1)Rapid medical assistance: A medical aircraft can deliver qualified medical personnel and necessary equipment to places where proper medical facilities are lacking or where it is impossible to provide immediate medical assistance. This is particularly useful in countries with limited resources or remote areas.

2)Transporting the sick or injured: A medical aircraft enables the transportation of sick or injured individuals over long distances where it would be impossible or highly time-consuming to use other means of transport. Rapid access to medical care can significantly increase the chances of survival and improve the condition of patients.

3)Emergency situations and deployment: Medical aircraft can be used for swift response to emergency situations such as natural disasters, epidemics, or mass casualties. They can be rapidly deployed to any part of the world to provide assistance to those in need.

4)Equipment and personnel: Converting an aircraft into a medical aircraft allows equipping it with specialized medical equipment and ensuring the presence of qualified medical personnel. A medical aircraft can be equipped with X-ray machines, ECG machines, defibrillators, ventilators, infusion systems, and other life-saving medical devices. Additionally, it can carry doctors, nurses, anesthesiologists, and other medical staff experienced in providing emergency medical care.

5)Life-saving: Medical aircraft enable the transportation of individuals with critical conditions for whom every minute matters. The quick response and availability of effective medical equipment onboard the aircraft can help save patients' lives.

6)Specialized medical care: Medical aircraft can be equipped with specialized intensive care units, surgical blocks, resuscitation equipment, and more. This allows for the provision of high-tech medical care to patients even during transportation.

7)Mass emergency evacuations: In the case of mass disasters, epidemics, or military conflicts, medical aircraft can be used for the rapid evacuation of a large number of affected individuals from the danger zone to safe medical facilities.

8)Delivery of medical resources: In addition to patient transportation, medical aircraft can be used to deliver medical equipment, medication, blood, organs for

transplantation, and other necessary medical resources to remote or crisis-stricken areas.

9)Coordination of medical services: Medical aircraft play a vital role in coordinating and organizing medical services during emergencies. They can function as command centers for managing the actions of medical rescue services and mobile medical teams.

10)Transportation of patients with special needs: Medical aircraft can be suitable for transporting patients with limited mobility or complex medical conditions that require special attention and care during transport. These aspects underscore the importance and necessity of converting an aircraft into a medical aircraft. They allow for immediate medical assistance, transportation of the sick and injured, coordination of medical services, and the provision of medical care in emergency situations.

A medical aircraft facilitates communication among different medical centers, medical transport crews, and medical teams at the scene. It can provide communication, transmit information about patients' conditions, assist in making decisions regarding urgent medical care, and resource allocation.

Furthermore, a medical aircraft can coordinate evacuation routes, direct rescue services to disaster or emergency locations, and provide logistical support for delivering medical assistance. It is an integral part of crisis management systems, helping to ensure efficient and organized medical care in extraordinary circumstances.

**3.3 Conversion of designed aircraft**

Before proceeding with the conversion of a passenger aircraft into a medical aircraft, comprehensive preparations and assessments must be conducted to identify all the requirements and needs related to medical equipment and functionality. This thorough planning is crucial to ensure the efficient and safe provision of in-flight medical care for patients. To initiate the conversion process, it is necessary to first remove the existing passenger seats from the chosen prototype. This step is essential to create sufficient space for medical equipment, patient transport, and healthcare professionals to perform their duties effectively. Next, we present a comprehensive

plan outlining the necessary steps and considerations for converting a OL1 into a medevac aircraft:( Patient Categories; Medical Equipment Requirements; Staffing and Expertise; Medical Protocols and Guidelines).

This assessment serves as a foundation for tailoring the aircraft's configuration, medical equipment selection, and staffing to meet the specific medical needs of the patients being transported. Assessment of needs:

It is crucial to conduct a comprehensive assessment of medical needs, specifically focusing on the types of patients to be transported in the converted medical aircraft. This assessment should include an evaluation of the medical conditions, acuity levels, and specific requirements of the patients who are likely to be transported.

Key considerations for the assessment of medical needs may include:

- 1) Space design: At the initial stage, it is necessary to remove all passenger seats that were designed in the prototype as on the Boing 737 Max (Fig. 3.2.).
- Determine the necessary areas inside the plane: medical area, operating room, isolators like on C-130 (Fig. 3.3.);[11]
- Develop plans for partitions and creation of separate rooms or compartments.
- Take care of ventilation, lighting and storage of medicines.



Fig. 3.2 Boing 737 without sits.

2) Medical equipment:

- Select the necessary medical equipment based on the medical needs.
- Install the equipment, ensuring correct placement and fastening.
- Consider power supplies for equipment, such as connecting to the aircraft's electrical system or using dedicated power supplies.

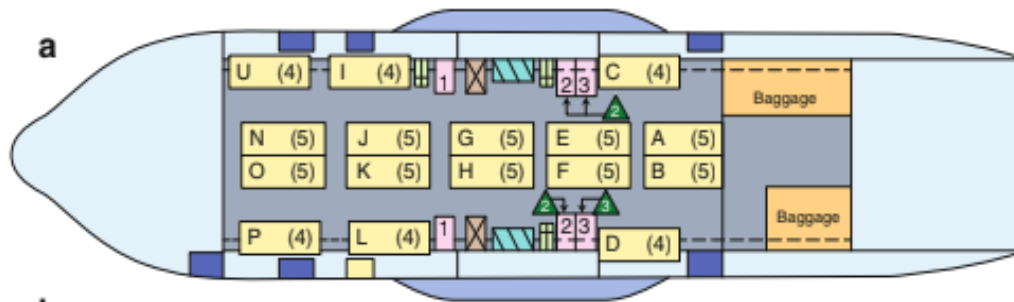


Fig. 3.3. Schematic of C-130 Hercules configured for (a) maximum litter patients.

3) Power supply and life support systems: Verify that the aircraft has an adequate and reliable power source to support the operation of the medical equipment throughout the flight. This includes assessing the electrical systems and considering the installation of backup power systems, such as auxiliary generators or additional batteries, to ensure uninterrupted power supply. Develop and implement life support systems to meet the needs of patients who require additional oxygen or respiratory support. This may involve installing oxygen delivery systems, such as onboard oxygen concentrators or portable oxygen cylinders, and ensuring proper ventilation and airflow within the aircraft cabin to maintain a safe and comfortable environment for patients with respiratory conditions. By addressing power supply requirements and implementing appropriate life support systems, the converted medical aircraft can effectively meet the energy demands of medical equipment and ensure the provision of necessary life-saving support for patients during the flight.

4) Communication systems:

-Establish a reliable communication system for medical personnel to speak with each other and the outside world during flight (Fig.3.4). It will also help reduce the number of attendants on board the aircraft.





Fig. 3.4. Communication of doctors on board a medical aircraft.

5) Security and isolation: Implement stringent safety protocols to ensure the well-being of patients and medical personnel throughout the flight. This includes measures such as securing medical equipment, providing restraints and harnesses for patients during turbulence, and adhering to infection control practices. Install effective isolation systems, such as negative pressure rooms or partitions, to minimize the risk of airborne transmission of infections and create a safe environment within the aircraft. Taking into account all the points mentioned above, it is crucial to conduct thorough economic calculations for the conversion of the aircraft. This includes assessing the costs associated with removing passenger seats, installing medical modules, integrating medical equipment and communication systems, and ensuring compliance with regulatory standards. Additionally, it is important to consider the expenses related to sourcing and procuring new medical equipment, supplies, and medications.

### 3.4. Equipment used for conversion

To convert an aircraft into a medivac, certain medical equipment will be needed to ensure the safety of patients and provide the necessary medical care during transport.

For this, many different types of life support and emergency surgery equipment can be used to stabilize the patient during the flight.



Fig. 3.5. Special quarantine boxes (EpiShuttles).

There a little part of equipment that can be used for converting an aircraft into a medevac:

1) Medical monitors: They play a crucial role in measuring and continuously monitoring vital signs of the patient throughout the medical transport process. These monitors provide real-time information on important physiological parameters, including pulse rate, blood pressure, oxygen saturation levels, electrocardiogram (ECG) readings, and more. By closely monitoring these vital signs, healthcare professionals can promptly identify any changes or abnormalities in the patient's condition, allowing for early intervention and appropriate adjustments to the medical care being provided. (Fig3.6)

2) Ventilators: They are critical devices that offer respiratory support to patients who require artificial ventilation. These life-saving machines deliver controlled and synchronized breaths to patients who may have compromised or insufficient respiratory function. Ventilators can be programmed with various modes of breathing, such as assist-control, pressure support, or synchronized intermittent mandatory

ventilation, allowing healthcare professionals to tailor the ventilation settings to meet the specific needs of each patient.

3) Defibrillators: They are indispensable medical devices used to restore a normal heart rhythm in patients experiencing arrhythmias or cardiac arrests. These life-saving devices deliver controlled electrical shocks to the heart, interrupting abnormal rhythms and allowing the heart to resume its natural, coordinated beating pattern. Defibrillators are equipped with sophisticated algorithms and sensors that analyze the patient's heart rhythm and determine the appropriate energy level for defibrillation. They can be operated manually by trained healthcare professionals or automated, known as automated external defibrillators (AEDs), which provide voice prompts and instructions for use by bystanders or first responders.



Fig. 3.6. Medical monitors with respiratory system.

4) Infusion pumps: They are essential devices used for precise and controlled administration of fluids and medications into the patient's bloodstream. These pumps ensure accurate dosing and infusion rates, minimizing the risk of medication errors and optimizing patient safety during medical transportation.

5) Portable X-ray machines: They provide the capability to obtain X-ray images in the aircraft, enabling healthcare professionals to perform real-time diagnosis and monitor the patient's condition. This portable imaging technology allows for quick and accurate identification of fractures, injuries, or other medical conditions, facilitating

timely interventions and appropriate treatment decisions. By having access to on-board X-ray imaging, medical teams can assess the severity of injuries, track progress, and adjust treatment plans accordingly, all within the confines of the medical aircraft.

6) Medical stretchers and immobilizers: They play a crucial role in ensuring the safe and comfortable transport of patients during medical evacuation (medevac) missions. These specialized equipment provide a secure and stable platform for patients, minimizing movement and reducing the risk of further injury or discomfort during transit. Medical stretchers are designed to accommodate patients of varying sizes and conditions, offering adjustable features and padding for optimal support.

7) Laboratory equipment: It may include portable laboratory devices that enable healthcare professionals to perform essential diagnostic tests and analyses while in the medical aircraft. These portable devices are designed to measure critical blood parameters, electrolyte levels, and other biochemical markers that aid in assessing a patient's overall health status and guiding medical interventions. By having access to such laboratory equipment on board, medical teams can quickly obtain important diagnostic information, monitor the patient's condition, and make informed decisions regarding appropriate treatments or adjustments to the medical care being provided.

8) Medical modules of the opened and quarantined type: They are specifically designed to ensure the comfortable and safe transportation of patients during the flight. These specialized modules offer a controlled environment that is isolated and equipped with appropriate ventilation systems, ensuring the containment of infectious diseases and preventing the spread of contaminants within the aircraft. The modules are designed with patient comfort in mind, providing adequate space, adjustable beds, and necessary medical equipment within reach of healthcare professionals. The isolation capabilities of these modules allow for the secure transport of patients with contagious illnesses, ensuring the safety of both the patient and the medical team. By utilizing medical modules of this nature, healthcare providers can maintain a high standard of infection control, minimize the risk of cross-contamination, and provide a conducive environment for the ongoing medical care and well-being of the patients during their journey. (Fig.3.5; Fig.3.7) [8];[9].



Fig. 3.7 Opened module STC 2800 SERIES.

All this equipment can be used during conversion and almost would be useful both for doctors and for patients. Medical equipment, such as advanced life support systems, portable diagnostic tools, surgical instruments, and medication delivery systems, enables healthcare professionals to provide immediate and comprehensive care to patients in need. These equipment aids in stabilizing patients, managing their conditions, and addressing critical medical emergencies during transport.

Additionally, the integration of advanced communication systems, patient monitoring devices, and telemedicine capabilities within the medical aircraft facilitates real-time collaboration between medical teams on board and medical experts on the ground. This seamless communication and data exchange ensure accurate and informed decision-making, enhancing the overall quality of care delivered to patients during the transportation process. Moreover, the availability of specialized medical equipment within the medical aircraft significantly contributes to improving outcomes

for patients, especially in remote or hard-to-reach areas where access to medical facilities may be limited. By bringing critical medical resources directly to the patient's location, the medical aircraft plays a vital role in bridging the gap in healthcare delivery and reducing response times, ultimately saving lives and minimizing the long-term impact of medical emergencies.

### 3.5. Recalculation of center of gravity positioning options

At this stage of conversion, we recalculate the aircraft's center of gravity by considering the weight of the modules and additional equipment used by the personnel post-conversion. This calculation is crucial in determining whether the aircraft conversion will affect its center of gravity. It involves determining the coordinates of the center of mass for the modules, medical personnel, and food, which collectively contribute to the overall distribution of weight within the aircraft. This evaluation ensures that the converted aircraft maintains proper balance and stability during operation. Here attaching the Tables (2.8; 2.9; 3.1; 3.2) with calculations.

*Table 3.1*

**Calculation of mass of modules and personnel**

No	Module name	2800 series	EpiShuttle	
1	Number of modules, units.	54	12	
2	Module weight	16500,00		
3	Maximum module weight, kg	150	150	
4	Additional equipment for the module, kg	100	100	
5	Accompanying doctors, individuals	10		
6	Nurses, individuals	15		
7	Personnel weight, kg	2000		
8	Food weight, kg	400		
9	Chair weight, kg	200		
	Verification	19100,00		19102,40

Table 3.2

**Calculation of the center of mass for modules and personnel**

Moment load	344896,02		Length of the placement zone.
Coordinate of the center of mass of modules:	15,346	253209	30,692
Coordinate of the center of mass of medical personnel:	34,586	76089,2	7,788
Coordinate of the center of mass of food:	38,98	15592	1
Verification	344890,2		

After analyzing the weight and balance tables, we have found that the transition to the medical variant has a minimal impact on the center of gravity. This significantly simplifies the aircraft retrofitting process and its subsequent operation. Additionally, it means that substantial structural modifications to the aircraft are not required, and the centering of medical equipment can be achieved with high precision. Taking into account the aforementioned aspects, it can be added that from an economic standpoint, such conversion is advantageous. This approach streamlines the retrofitting process and ensures efficient utilization of the aircraft for medical missions without unnecessary complications.

Furthermore, this seamless integration of medical equipment allows for swift and effective response in critical situations, saving valuable time and potentially saving lives. The ability to convert the aircraft into a medical variant without significant alterations not only reduces costs but also ensures the availability of a versatile platform for various emergency medical missions. By optimizing the use of existing resources, such as the aircraft's structural capacity and systems, the medical conversion maximizes operational efficiency while maintaining the highest standards of patient care.

### Conclusion to part 3

In conclusion, the strategic implementation and integration of cutting-edge medical equipment within medical aircraft play a pivotal role in revolutionizing the provision of efficient and life-saving healthcare services in critical and emergency situations. By leveraging advanced technology and state-of-the-art medical tools, medical teams can deliver timely and effective medical care, significantly improving the outcomes and survival rates of patients in need. The utilization of medical aircraft as mobile healthcare units enables rapid response and transportation to inaccessible areas, ensuring that critical care reaches those who need it most, even in challenging circumstances.

The integration of advanced technologies within medical aircraft introduces a multitude of benefits that directly impact the delivery of medical care. With access to advanced imaging systems, diagnostic tools, and monitoring equipment, medical teams can swiftly assess and address patient needs, ensuring prompt and efficient medical interventions that can be life-saving.

Furthermore, the incorporation of advanced communication systems within medical aircraft significantly enhances collaboration and facilitates seamless coordination among medical personnel.

In essence, the integration of advanced medical equipment within medical aircraft represents a significant advancement in the field of emergency medical transportation. By embracing technological innovations and harnessing the power of modern communication systems, medical teams can rise to the challenges presented by critical situations, delivering optimal care to patients in a timely and efficient manner. Through this integration, medical aircraft become not just a means of transportation, but a fully equipped and mobile medical unit capable of providing essential care and making a tangible difference in the lives of patients in their most vulnerable moments.

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## GENERAL CONCLUSIONS

In summary, this diploma work encompasses several key areas related to aircraft design and medical aviation. It begins by discussing the selection of prototype aircraft, providing a concise overview of each model. It then delves into the calculations and considerations involved in designing a one-class passenger aircraft, including its weight, engine specifications, and the determination of essential facilities such as kitchens, toilets, and wardrobes.

The subsequent focus shifts to the crucial role of cutting-edge medical equipment within medical aircraft. The integration of advanced technologies, such as imaging systems and diagnostic tools, empowers medical teams to promptly assess and address patient needs, resulting in efficient and potentially life-saving interventions. Moreover, the incorporation of advanced communication systems facilitates seamless collaboration and coordination among medical personnel, enhancing the overall quality of emergency medical care.

The significance of equipping medical aircraft with state-of-the-art medical equipment becomes evident when considering its impact on patients in critical need of emergency medical transportation. By embracing technological advancements and harnessing modern communication systems, medical teams can deliver optimal care, making a tangible difference in the lives of vulnerable patients. This project aims to leverage these advancements to create a reliable and efficient medical transport system that can save lives and provide crucial medical assistance in the most challenging environments.

Ultimately, this comprehensive analysis highlights the importance of thoughtful aircraft design and subsequent conversion into a medical variant. Based on the calculations made, there will be no problems when converting the aircraft, because they don't change parameter of the center of mass.

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# Appendix

**Appendix A**  
**INITIAL DATA AND SELECTED PARAMETERS**

Passenger Number 189  
Flight Crew Number 2  
Flight Attendant or Load Master Number 4  
Mass of Operational Items 1725.18 kg  
Payload Mass 18374.4 kg

Cruising Speed 842 km/hr  
Cruising Mach Number 0.7849  
Design Altitude 10.5 km.  
Flight Range with Maximum Payload 6500 km.  
Runway Length for the Base Aerodrome 3.3 km.

Engine Number 2  
Thrust-to-weight Ratio in N/kg 3.3000  
Pressure Ratio 28.00  
Assumed Bypass Ratio 5.50  
Optimal Bypass Ratio 5.50  
Fuel-to-weight Ratio 0.2500

Aspect Ratio 10.20  
Taper Ratio 3.70  
Mean Thickness Ratio 0.1  
Wing Sweepback at Quarter Chord 25.0 degree  
High-lift Device Coefficient 1.1  
Relative Area of Wing Extensions 0.05  
Wing Airfoil Type -Supercritical airfoil  
Winglets - do not apply  
Spoilers - installed

Fuselage Diameter 3.76 m.  
Fineness Ratio 10.50 m  
Horizontal Tail Sweep Angle 30.0 degree  
Vertical Tail Sweep Angle 35.0 degree

**CALCULATION RESULTS**

Optimal Lift Coefficient in the Design Cruising Flight Point 0.49855

Induce Drag Coefficient 0.00892

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ESTIMATION OF THE COEFFICIENT  $D_m = M_{critical} - M_{cruise}$   
Cruising Mach Number 0.78492  
Wave Drag Mach Number 0.79904

Calculated Parameter  $D_m$  0.01412

Wing Loading in kPa (for Gross Wing Area):

At Takeoff 6.26

At Middle of Cruising Flight 5.289

At the Beginning of Cruising Flight 6.033

Drag Coefficient of the Fuselage and Nacelles 0.0094

Drag Coefficient of the Wing and Tail Unit 0.00893

Drag Coefficient of the Airplane:

At the Beginning of Cruising Flight 0.02928

At Middle of Cruising Flight 0.02803

Mean Lift Coefficient for the Ceiling Flight 0.49855

Mean Lift-to-drag Ratio 17.7863

Landing Lift Coefficient 1.707

Landing Lift Coefficient (at Stall Speed) 2.56

Takeoff Lift Coefficient (at Stall Speed) 2.1

Lift-off Lift Coefficient 1.533

Thrust-to-weight Ratio at the Beginning of Cruising Flight 0.515

Start Thrust-to-weight Ratio for Cruising Flight 2.042

Start Thrust-to-weight Ratio for Safe Takeoff 2.69

Design Thrust-to-weight Ratio 2.798

Ratio  $D_r = R_{cruise} / R_{takeoff}$  0.759108

SPECIFIC FUEL CONSUMPTIONS (in kg/kN\*h):

Takeoff 37.2953

Cruising Flight 59.2781

Mean cruising for Given Range 63.8488

FUEL WEIGHT FRACTIONS:

Fuel Reserve 0.02423

Block Fuel 0.27295

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**WEIGHT FRACTIONS FOR PRINCIPAL ITEMS:**

- Wing 0.1269
- Horizontal Tail 0.00879
- Vertical Tail 0.00868
- Landing Gear 0.03837
- Power Plant 0.08782
- Fuselage 0.08382
- Equipment and Flight Control 0.1253
- Additional Equipment 0.01208
- Operational Items 0.01812
- Fuel 0.29718
- Payload 0.19298

Airplane Takeoff Weight 95214 kg  
 Takeoff Thrust Required of the Engine 133.2 kN

- Air Conditioning and Anti-icing Equipment Weight Fraction 0.0216
- Passenger Equipment Weight Fraction  
 (or Cargo Cabin Equipment) 0.0126
- Interior Panels and Thermal/Acoustic Blanketing Weight Fraction 0.0063
- Furnishing Equipment Weight Fraction 0.0152
- Flight Control Weight Fraction 0.0057
- Hydraulic System Weight Fraction 0.016
- Electrical Equipment Weight Fraction 0.0317
- Radar Weight Fraction 0.003
- Navigation Equipment Weight Fraction 0.0045
- Radio Communication Equipment Weight Fraction 0.0023
- Instrument Equipment Weight Fraction 0.0053
- Fuel System Weight Fraction 0.0088

**Additional Equipment:**

- Equipment for Container Loading 0.0074
- No typical Equipment Weight Fraction  
 (Build-in Test Equipment for Fault Diagnosis,  
 Additional Equipment of Passenger Cabin) 0.0047

**TAKEOFF DISTANCE PARAMETERS**

- Airplane Lift-off Speed 290.88 km/hr
- Acceleration during Takeoff Run 2.03 m/s<sup>2</sup>
- Airplane Takeoff Run Distance 1606. m.
- Airborne Takeoff Distance 409. m.
- Takeoff Distance 2015. m.

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**CONTINUED TAKEOFF DISTANCE PARAMETERS**

Decision Speed 276.33 km/hr

Mean Acceleration for Continued Takeoff on Wet Runway 0.11 m/s\*s

Takeoff Run Distance for Continued Takeoff on Wet Runway 4371.85 m.

Continued Takeoff Distance 4780.83 m

Runway Length Required for Rejected Takeoff 4986.86 m

**LANDING DISTANCE PARAMETERS**

Airplane Maximum Landing Weight 73594. kg

Time for Descent from Flight Level till Aerodrome Traffic Circuit Flight 21.3  
min

Descent Distance 49.81 km

Approach Speed 260.61 km/hr

Mean Vertical Speed 2.08 m/s

Airborne Landing Distance 393. m

Landing Speed 249.29 km/hr.

Landing run distance 906 m.

Landing Distance 1300 m.

Runway Length Required for Regular Aerodrome 2170. m.

Runway Length Required for Alternate Aerodrome 1846. m.

**ECONOMICAL EFFICIENCY**

**THESE PARAMETERS ARE NOT USED IN THE PROJECT**

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**Appendix B**  
Center of gravity of the wing

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# Appendix C

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# Appendix D

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