МІНІСТЕРСТВО ОСВІТИ ТА НАУКИ УКРАЇНИ
НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ
КАФЕДРА КОНСТРУКЦІЇ ЛІТАЛЬНИХ АПАРАТІВ

ДОПУСТИТИ ДО ЗАХИСТУ
Завідувач кафедри, д.т.н., проф.
___________ Сергій ІГНАТОВИЧ
«____» ____________ 2021 р.

ДИПЛОМНА РОБОТА

ВИПУСКНИКА ОСВІТНЬОГО СТУПЕНЯ «МАГІСТР»
ЗІ СПЕЦІАЛЬНОСТІ:
«АВІАЦІЙНА ТА РАКЕТНО-КОСМІЧНА ТЕХНІКА»

Тема: «Особливості реконфігурації пасажирського літака у вантажний»

Виконавець: __________ **Валерія КРАВЧЕНКО**

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Київ 2021

MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE
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DEPARTMENT OF AIRCRAFT DESIGN

PERMISSION TO DEFEND
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MASTER DEGREE THESIS
ON SPECIALITY
«AVIATION AND AEROSPACE TECHNOLOGIES»

Topic: «Features of passenger into a cargo airplane reconfiguration»

Fulfilled by: ___________ **Valeriia KRAVCHENKO**

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Labor protection advisor:
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Kyiv 2021

НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ

Аерокосмічний факультет
Кафедра конструкції літальних апаратів
Освітній ступінь «Магістр»
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Освітньо-професійна програма «Обладнання повітряних суден»

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Завідувач кафедри, д.т.н, проф.
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«_____» _____________ 2021 р.

ЗАВДАННЯ

на виконання дипломної роботи студента

КРАВЧЕНКО ВАЛЕРІЇ ДЕНИСІНИ

1. Тема роботи: «Особливості реконфігурації пасажирського літака у вантажний», затверджена наказом ректора від 8 жовтня 2021 року № 2173/ст.
2. Термін виконання роботи: з 11 жовтня 2021 р. по 31 грудня 2021 р.
3. Вихідні дані до роботи: маса комерційного навантаження 68 120 кг, дальність польоту з максимальним комерційним навантаженням 7000 км, крейсерська швидкість польоту 850 км/год, висота польоту 12 км.
4. Зміст пояснювальної записки: аналіз авіаперевезень та вимоги до авіаперевезень, аналіз реконфігурації літака, розгляд питань документації, структурних змін, змін систем, авоніки, програмного забезпечення, а також зміни масових характеристик. Визначення вимог та сертифікації повітряного судна для льотної придатності. Розгляд теми охорона праці, охорона навколишнього середовища.
5. Перелік обов’язкового графічного (ілюстративного) матеріалу: креслення загального виду вантажного літака, креслення-схема змін систем літака при реконфігурації.

6. Календарний план-графік:

№	Завдання	Термін виконання	Відмітка про виконання
1	Огляд літератури за проблематикою роботи. Аналіз авіаперевезень та їх вимоги.	11.10.2021–13.10.2021	
2	Проведення досліджень структурних змін реконфігурованого літака.	14.10.2021–20.10.2021	
3	Дослідження проблеми зміни систем, авоніки, програмного забезпечення та питань документації.	21.10.2021–24.10.2021	
4	Розробка нової центровки літака при зміні масових характеристик.	25.10.2021–15.11.2021	
5	Виконання частин, присвячених охороні навколишнього середовища та охорони праці.	16.11.2021–21.11.2021	
6	Підготовка ілюстративного матеріалу, написання пояснювальної записки.	22.11.2021–29.11.2021	
7	Перевірка, редагування та виправлення пояснювальної записки.	30.11.2021–31.12.2021	

7. Консультанти з окремих розділів:

Розділ	Консультант	Дата, підпис	
		Завдання видав	Завдання прийняв
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Охорона навколишнього середовища	д.т.н, доцент Тамара ДУДАР		

8. Дата видачі завдання: 8 жовтня 2021 року

Керівник дипломної роботи ____________ Святослав ЮЦКЕВИЧ

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Head of Department,
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________ Sergiy IGNATOVYCH
«___» ________________ 2021

TASK

for the master degree thesis

VALERIIA KRAVCHENKO

1. Topic: «Features of passenger into a cargo airplane reconfiguration», approved by the Rector's order № 2173/ст from 8 October 2021.

2. Period of work: since 11 October 2021 till 31 December 2021.

3. Initial data: payload 68,120 tons, flight range with maximum capacity 7000 km, cruise speed 850 km/h, flight altitude 12 km.

4. Content: Analysis of air transportation and air transportation requirements, analysis of aircraft reconfiguration, review of documentation, structural changes, system changes, avionics, software, and changes in mass characteristics. Determination of aircraft requirements and certification for airworthiness. Review of health, safety, and environmental topics.

5. Required material: drawings of the general view of the cargo aircraft, drawing-scheme of changes in aircraft systems during reconfiguration.

6. Thesis schedule:

№	Task	Time limits	Done
1	Review of the literature on the subject of work. Analysis of air transportation and its requirements.	11.10.2021–13.10.2021	
2	Research on structural configurations of reconfigured aircraft.	14.10.2021–20.10.2021	
3	Research of the problem of changing systems, avonics, software and documentation.	21.10.2021–24.10.2021	
4	Development of a new centering of the aircraft with changes in mass characteristics.	25.10.2021–15.11.2021	
5	Execution of the parts, devoted to environmental and labor protection.	16.11.2021–21.11.2021	
6	Preparation of illustrative material, writing the report.	22.11.2021–29.11.2021	
7	Explanatory note checking, editing and correction.	30.11.2021–31.12.2021	

7. Special chapter advisers:

Chapter	Adviser	Date, signature	
		Task issued	Task received
Labor protection	PhD, associate professor Victoria KOVALENKO		
Environmental protection	PhD, associate doctor Tamara DUDAR		

8. Date of issue of the task: 8 October 2021 year

Supervisor: ____________ Sviatoslav YUTSKEVYCH

Student: ____________ Valeriia KRAVCHENKO

РЕФЕРАТ

Пояснювальна записка дипломної роботи магістра «Особливості реконфігурації пасажирського літака у вантажний»:

84 с., 20 рис., 7 табл., 51 джерел

Дана дипломна робота присвячена розгляду особливостей реконфігурації пасажирського літака у вантажний, що буде відповідати міжнародним стандартам польотів, нормам безпеки, економічності та надійності, а також розробці змін масових характеристик для збільшення навантаження комерційним грузом реконфігурованого літака.

В роботі було використано методи аналітичного розрахунку, компьютерного проєктування за допомогою CAD/CAM/CAE систем, ескізного проєктування нового реконфігурованого літака та показано зміни у системах та пристроях.

Практичне значення результату дипломної роботи магістра полягає в досягненні повної реконфігурації літака з пасажирського на вантажний, шляхом опису особливостей конструктивно-конструкторських рішень для отримання необхідної сертифікації відповідно до стандартів льотної придатності..

Матеріали дипломної роботи магістра можуть бути використані в навчальному процесі та в практичній діяльності конструкторів спеціалізованих проєктних установ.

Дипломна робота, компонування, центрування, реконфігурація, зміна систем, сертифікація

ABSTRACT

Master degree thesis «Features of passenger into a cargo airplane reconfiguration»

84 pages, 20 figures, 7 tables, 51 references

This thesis is dedicated to the features of reconfiguration of the passenger aircraft into a cargo aircraft, which will meet international flight standards, safety standards, economy and reliability, as well as the development of changes in mass characteristics to increase the loading of commercial cargo of the reconfigured aircraft.

The work has used methods of analytical design, computer design using CAD/CAM/CAE systems, practical design of new reconfigured aircraft and shows the changes in the systems and devices.

Practical value of the work is achieving a complete reconfiguration of the aircraft from passenger to cargo, by describing the features for structural and design solutions to receive the necessary certification in accordance with airworthiness standards.

The materials of the master's diploma can be used in the aviation industry and in the educational process of aviation specialties.

Master thesis, cabin layout, center of gravity calculation, reconfiguration, system Change, certification

CONTENTS

ABBREVIATIONS

APU – Auxiliary Power Unit

CAAI – Civil Aviation Authority of Israel

CAEP – Committee on Aviation and Environmental Protection

CAN – Controller Area Network

CLS – Cargo Loading System

CS – Certification Specification

EASA – European Union Aviation Safety Agency

ECS – Environmental Control Systems

EU – European Union

EWIS – Electrical Wiring Interconnection System

FAA – Federal Aviation Administration

FAR – Federal Aviation Regulations

JAA – Joint Aviation Authorities

IAI – Israel Aerospace Industries

IATA – International Air Transport Association

ICAO – International Civil Aviation Organization

MAC – Mean Aerodynamic Chord

MDCD – Main Deck Cargo Door

MMEL – Master Minimum Equipment List

SARP – Standards and Recommended Practice

STC – Supplemental Type Certificate

TC – Type Certificate

ULD – Unit Load Device

INTRODUCTION

The COVID-19 pandemic has had a significant impact on the aviation industry due to travel restrictions and a slump in demand among travelers.

The dramatic drop in demand for passenger air transport (and freight, to a lesser extent) due to the COVID-19 pandemic and containment measures are threatening the viability of many firms in both the air transport sector and the rest of the aviation industry, with many jobs at stake.

The aviation of super-heavy aircraft is quite demanding on the airport infrastructure, moreover, large aircraft cannot pass the runway any easier and shorter. In the event of a decrease in demand for passenger air transportation, it has become more profitable for long-range aircraft to transport cargo.

As the world was locked down and COVID-19 struck aviation to an unprecedented extent, it opened the opportunity for passenger airlines to reconfigure passenger aircraft to the freighter one. Its boost capacity and serve the high demand to dispatch urgently needed personal protective equipment – and now the distribution of the much-awaited vaccines.

Air transportation plays a major role in the world economy. According to Boeing forecasts, over the next 20 years, the annual growth of air cargo was 4.7%, which means that air cargo in 2033 will increase almost 2 times [1].

The conversion of passenger aircraft into cargo aircraft is becoming one of the most interesting segments of the aircraft maintenance and repair market. Technically, this operation does not pose any big problems.

The statement of the problem diploma paper presented below comprises the features of the passenger into a cargo airplane reconfiguration.

The aircraft is a low-wing construction with a typical tail unit with two General Electric CF6-80C2 engines, mounted below the wing.

The requirements of national and international (FAR-25, CS-25) airworthiness laws, rules, recommendations, as well as current trends have been taken into account during the process of the aircraft design.

A special part of the work deals with the development of the special documentation and construction features of the passenger into a cargo airplane reconfiguration.

PART 1. ANALYSIS OF AIR CARGO TRANSPORTATION

1.1 The purpose of the air cargo transportation

One of the most valuable elements of the economic base of any country is the transport. Since ancient times, transport has been the engine of progress. Humans used any available means to transport both people and products. Transportation of products by air is the fastest and the most reliable way to deliver goods. The wide geography of flights, the ability to fly long distances in a short time make the use of air transportation very profitable and convenient.

Transportation by air – it is a method of transporting cargo and carrying passengers using an airplane. International and domestic air transport is controlled by a number of normative documents that can be conditionally divided into several groups:

1. The first group is the documents of the state regulation in the field of aviation, that include relevant laws, certification standards, and licensing rules.

2. The second group is federal aviation regulations.

3. The third category of normative documents are the internal Ukrainian rules for the transportation of passengers and transportation of goods using aircraft.

Separately, it is worth noting the Chicago Convention on International Civil Aviation of 1944 and the Warsaw Convention for the Unification of Air Carriage Rules of 1929 [2]. These documents have been ratified by most countries in the world and are binding. Also, the legal settlement was made under the Convention on the Contract for the International Carriage of Goods by Road (Geneva, May 19, 1956) [3].

The first cargo flight took place on November, 7, 1910, in the United States, between Dayton and Columbus, Ohio. Philip Orin Parmelee piloted a Wright Model B aircraft 65 miles (105 km) carrying a package of 200 pounds of silk for a store opening. Newspaper clippings quoted the Wright brothers as stating that he covered the distance in 66 minutes. But it was officially recorded that the flight lasted 57 minutes, a world speed record at the time. It was the first “cargo-only” flight solely to carry goods; the first customer-ordered flight, and the first example of multimodal air transport, as pieces of silk were delivered by car from Columbus airfield to the store [4].

Nowadays, airlines transport over 52 million metric tons of goods a year, representing more than 35% of global trade by value but less than 1% of world trade by volume. That is equivalent to $6.8 trillion worth of goods annually, or $18.6 billion worth of goods every day [5].

The air cargo industry is a highly profitable industry, so it is critical to serving markets that require speed and reliability in cargo transportation.

As the average cost per ton of goods sold rises, a larger percentage of trade will be transferred by air. Airfreight will remain the preferred solution for transporting more expensive goods that are time-sensitive and economically perishable.

1.2 The goal of the aircraft reconfiguration

Today's aircraft fleet is fueling an explosive growth in e-commerce as consumers turn to online shopping during the pandemic and most sellers have switched to shipping instead of offline sales. And while passenger flights are being reduced due to the pandemic, airlines are removing passenger seats to fill the cabin with payloads. The success story of the reconstruction by many airlines soon became a trend, and later a good example for reconfiguring a passenger plane fully into a freighter.

Thus, logistics giants are using the airline industry's downturn to grow their fleets by acquiring aging passenger aircraft, by giving them a second life like moving cargo.

When an aircraft is almost "reaching its age" and has completed its useful operational service as a passenger jetliner, it can either be scrapped or recreated again in a different segment. Converting passenger aircraft into a freighter is a way to extend the economic life of an aircraft. Quite a number of cargo airlines choose to operate a first-hand quality converted freighter. The converted freighters meet the high dispatch reliability required, they are more economical for the company, and they can gain the same amount of revenue without using an expensive production freighter. But converting a passenger plane into a cargo carrier isn't as easy as just taking out the seats. Converting aircraft is a complex engineering task. The aircraft also needs to be extensively retrofitted to handle the payload. This requires highly skilled technicians and a large number of parts that must be precisely timed to ensure a smooth workflow and timely completion to bring the aircraft back to commercial service.

What are the main advantages of aircraft conversion? Why don't airlines just buy new planes?

The boxes don't care if they fly in the new Boeing 747 or the 30-year-old Boeing 747, but let's look at how this affects the customer's budget.

Conversion of the Boing 747, according to the Israeli company IAI can cost from $25 to $30 million [6]. This is a little less than what a used 20-year-old Boeing 747 could cost in "excellent" condition. And, of course, there are maintenance issues associated with purchasing an older aircraft.

But even if a company spends a total of $70 million on the acquisition, conversion, and maintenance costs, it's still cheaper than paying the current list cost price of $380 million for a new Boeing 747-8F [7].

1.3 Procedural aspects of aircraft reconfiguration

The development and reconfiguration of cargo aircraft almost always followed several years after the creation and certification of the preceding types of passenger transport category aircraft. As a consequence, the certification basis of cargo aircraft, as derivatives of passenger aircraft ("derivative"), was based on the certification basis of their passenger prototypes.

The FAA, having analyzed the accumulated experience of operating cargo aircraft converted from passenger aircraft and identified a number of shortcomings in their design, testing and certification, issued in 1994 a special Advice Circular AC 25-18 "Aircraft of the Transport Category Modified for Cargo Transportation". The circular provides guidance for demonstrating compliance with FAR-25 requirements that apply to converted passenger aircraft for operation in all-cargo or combined cargo-passenger (combi) configurations. The AC highlights the relationship of these requirements to FAR Part 121 and Part 135 and the procedural issues of certification of converted cargo aircraft, their applicability to type design and operational requirements [8].

First and foremost, the circular states that the certification of a modified cargo aircraft must determine that the cargo compartment floor and any force structure designed to support or support the compartment and its contents meet the applicable requirements of the original type certification baseline or the current requirements of Part 25 of the Aviation Regulations for structural strength. This requires, in addition to performing strength reserve calculations of modified or newly installed structures under the most critical loading conditions (§ 25.305) [9], also performing both damage tolerance and fatigue strength assessments of these structures as required by § 25.571 of the Aviation Regulations [10]. Changes to the basic structure that must be evaluated include load path deviations, additional openings, changes in loading options for existing openings, cut-outs, etc. Particular attention must be paid to preventing the possibility of catastrophic consequences of decompression of a pressurized airplane. Floor load limits must be established and must be shown both in the Aircraft Loading and Center of Gravity Manual as well as on clearly visible stencils on the floor and side panels of the cargo cabin. Limitations on cargo aircraft weight, alignment and weight distribution should also be established as operational limits in the Aircraft Flight Manual.

The means of arranging and fixing (securing) individual packages and each cargo individually (i.e. nets, straps, chains, lashing points, mooring devices, etc.) must, first of all, have sufficient static strength to safely secure the cargo and to prevent possible injury to flight crew members and additional crew. However, it must be ensured that any cargo or its package will not move and block rescue equipment or restrict access to emergency exits and any other equipment necessary for emergency evacuation and rescue (§ 25.561(c)(1)) [11] during an emergency landing of the aircraft. It is also unacceptable for loads to puncture fuel tanks and piping or to move loads that could cause a fire or explosion by destroying nearby systems. Additional calculations of the strength of the barrier net and the rigid baffle and their attachment points, simulation of the extension (elongation) of the barrier net under load and determination of the available free space in the cabin compartment when the net is moved are required to prove that the intended means of protection for flight and additional crew are appropriate. For both designs of these means, it is necessary to provide and prove the acceptability of load distribution from all cargo ripped off and held by the net or baffle to the adjacent fuselage support structures and to give them, if possible, adequate energy absorption characteristics.

Normally, modifying a passenger airplane to operate as a cargo version may not result in a significant change in the airplane's mass distribution. However, if there is a significant change in the mass distribution, the effects of that change must be investigated both by analytical methods and by flight tests to evaluate the structural strength, flutter characteristics and controllability of the aircraft to demonstrate compliance with the applicable requirements of Section B of the Aviation Regulations.

The second most significant problem addressed in AC 25-18 at the time of its publication related to the fire safety of cargo aircraft. A separate section of this circular was devoted to a detailed explanation of the unambiguity and clarity of establishing the classification of cargo compartments, since this determined the scope of modification of the passenger cabin into a cargo cabin and the list of required additional equipment and fire protection systems.

When certifying cargo compartments, the probability of a fire occurring in them is assumed to be 1.0, and therefore in this case it is of primary importance to ensure that it can be detected in a timely manner. According to § 25.857(c) and (e), Class C and Class E cargo compartments must have a separate approved smoke or fire detection sensor system that signals a fire to the pilot or flight engineer's workstation [12]. The system must detect a fire at a temperature much lower than the temperature at which the structural strength of the airplane is significantly reduced. In doing so, tests must demonstrate that the smoke or fire detection sensors in any compartment cannot be falsely activated by a fire in any other compartment as prescribed in § 25.855(h)(3)(i) [13]. This requirement applies to cargo aircraft on which the lower cargo compartments are retained in the passenger aircraft configuration, i.e., Class C. In order to establish the operability of the fire detection system in Class C and Class E cargo compartments, a means of monitoring the operation of each sensor circuit by the crew in flight must be provided. Of particular importance was the introduction of the requirement in § 25.858(a) that the fire detection system must provide a visual signal to the flight crew within 1 minute of the onset of fire [14]. This is due to the fact that previously there was no clear limit on fire detection time in the Aviation Regulations, and in the advisory circulars it was limited to 5 minutes. The particular importance of the alarm system in ensuring the fire safety of cargo aircraft necessitates a demonstration of its effectiveness in all approved operating configurations and flight conditions (§ 25.858(d)) [14].

The most commonly used smoke detectors for detecting fires in the cargo hold are photoelectric type (Type II) smoke detectors developed in accordance with the FAA TSO-C1d (Technical Standard Order), which are based on the US Aviation Standard AS 8036 (Society of Automotive Engineers - SAE). Compliance of smoke detectors with TSO-C1d requirements does not constitute grounds for approval of an aircraft fire detection system. For this purpose, according to AC-29A Recommendation Circular "Tests to Evaluate Smoke Detection, Intrusion and Removal and Related Emergency Procedures of the Aircraft Flight Manual," certification flight tests must be performed. These tests must be performed while flying at cruise speed with normal pressure difference between the cockpit and the environment at maximum normal airflow distribution. The aircraft shall perform flights with different configurations of ventilation air distribution and pressure drop based on departure conditions (one air conditioning subsystem operating, two air conditioning subsystems operating, cockpit unsealed, etc.) in flight at cruise speed. The effect of the degree of loading and distribution of cargo packages within the compartment must be taken into account. In the tests, the combustible material in the smoke generators must be similar to that which is likely to burn in the areas being evaluated [15].

Usually, when converting a passenger aircraft to a cargo version, the design and equipment of the lower baggage and cargo compartments, which in this case are used only for cargo transportation, are retained. The fire-extinguishing system in these compartments, according to § 25.851(b) of the Aviation Regulations [16], is usually supplied with a fire-extinguishing agent - chladone - in an amount sufficient to suppress any possible type of fire which may occur in the compartment, taking into account the volume and the intensity of air exchange in the compartment. At the same time, the capacity of the fire-extinguishing system is calculated for two turns of operation. The first stage should provide achievement and maintenance of fire-extinguishing agent concentration in the cargo compartment of not less than 5 % within 5 minutes for intensive suppression of the ignition source. The second stage is designed to maintain a fire-extinguishing agent concentration of at least 3% for a time determined in accordance with ETOPS ("Extended-range Twin Engine Operational Performance Standards") flight rules to prevent reignition and flame propagation. According to § 25.855(f), measures must be taken to ensure that cargo or baggage does not affect the performance of the extinguishing equipment, and the distribution of the extinguishing agent in the compartments must be determined by flight test results (§ 25.855(h)(3)) [13].

The cargo cabin and some lower cargo compartments which have been converted to Class E compartments of the examined cargo aircraft types are not equipped with any fire extinguishing system and therefore, the only method of fire suppression is complete forced depressurization of the aircraft by shutting off the cabin and compartment ventilation lines and opening the bleeder valves. In this case, according to § 25.857(e)(3), means must be provided for shutting off the flow of ventilation air into or within the compartment, and the controls for these means must be placed in the cockpit in places easily accessible to flight crew members [12]. By reaching the maximum permissible flight altitude, the concentration of oxygen in the cockpit and compartments decreases significantly, and the flame of fire is deprived of a feed. In this case, according to the Aircraft Flight Manual, an emergency landing of the aircraft at the nearest airfield should be performed according to the flight task worked out in advance.

In accordance with the provisions of § 25.857(c)(2) and (e)(4), when a fire occurs and is suppressed in the cargo cabin or cargo compartments, dangerous amounts of smoke, toxic gases, and flammable vapor must be prevented from entering the compartments occupied by crew and additional crew members [12]. On examined cargo aircraft, this requirement is met by the installation of a smoke screen or a rigid partition separating the habitable compartments from the cargo cabin. The effectiveness of these safeguards under § 25.857(h)(2) must be evaluated in flight tests, and the acceptability of the developed safeguard procedures to remove smoke entering the cockpit must also be verified [12].

However, AC Advisory Circular 25-18 emphasizes the need to follow the provisions of AC Advisory Circular 25-9a, which prescribes guidelines for smoke detection, intrusion and evacuation tests, and the development of related emergency procedures for the Aircraft Flight Manual. It is noted that the adequacy of the smoke detection system, the means of preventing smoke intrusion into occupied compartments, and the smoke evacuation procedures must be proven by flight test results, not analytically. When developing fire suppression procedures and demonstrating compliance with fire control and containment requirements, the requirements for safe subsequent flight continuation and landing set forth in § 25.831 ("Ventilation") and § 25.1309 ("Equipment, Systems, and Facilities") must also be considered [17, 18]. Under § 25.1439(a) ("Protective Breathing Equipment") of the Aviation Regulations, portable protective breathing equipment (PBE) must be provided for aircrew members of cargo aircraft [19]. This equipment must be designed to provide protection to aircrew members from exposure to smoke, carbon dioxide, and other noxious gases while performing their duties in flight and during firefighting.

A characteristic feature of cargo aircraft is the presence of large cargo doors in the cargo cabin, which are equipped with a complex control system with a large number of locking and locking elements compared with the cargo doors of the lower cargo compartments. On most of the analyzed cargo planes the design of cargo cabin doors was made taking into account the requirements of § 25.783(g) of the Aviation Regulations, according to which they have to be secured against opening in flight as a result of mechanical failure or failure of one of the structural elements. This must include devices for direct visual inspection of the door locking mechanism (§ 25.783(e)) and visual alarm devices to alert flight crew members concerned that the door is not fully closed, locked and latched (§ 25.783(f)) [20].

However, in a number of cases in operation on some cargo planes, accidental and spontaneous opening of cargo doors in flight occurred due to, for example, failure to follow the sequence of door closing steps (locking the locks before the door was not fully closed, issuing a false locking signal without locking them, etc.). A large number of wiring parts and massive control units created large loads in the control system, as a result of which unbalanced wiring, mechanisms, the presence of residual loads in the system and violations of the control system adjustment caused the control wiring to move under the influence of vibrations, overloads in flight. In particular, insufficient consideration of these loads and incorrect choice of materials in the control system of the upper cargo door of the 747 resulted in destruction of the less strong (aluminum) and, therefore, worn stoppers, subsequent movement of control wiring and, eventually, opening of the (steel) door locks with catastrophic consequences not only for the airplane crew, but also for the people living in the area of the accident.

A series of similar adverse incidents involving cargo doors led the FAA and JAR in the Aviation Rulemaking Advisory Committee (ARAC) to modify almost entirely FAR and JAR §25.783 (CS) in 2004. (Amendment No. 6 also makes this change to § 25.783 of AR-25.) The new version of the requirements retains the principal approach to the formation of any door control system, but the requirements are stated in clearer and more elaborate language that eliminates ambiguity and defines the execution and interaction of the individual elements of the door control system. This paragraph also includes new additional requirements, many of which are of direct relation to cargo doors. In particular, all power sources that can initiate the unlocking or unlocking of any door must be automatically isolated from the door locking and locking systems prior to flight, and it must be impossible to reapply power to the door systems during flight. On most of the examined cargo airplanes with electrically actuated cargo cabin door controls, its complete closure (i.e. locking of the locks and closing of the vent panels) is followed by deactivation of the power supply, after which it is additionally blocked by a sensor signal when the landing gear is retracted.

The locks and their operating mechanism must be designed so that, under all conditions of aircraft loading in flight and on the ground when the door is locked, there are no forces or moments tending to open the locks. The locking system must contain means for securing the locks in the locked position, which must be independent of the locking system, and no failure in the locking system must take the locks out of the position in which they secure the locked locks. Blocking means shall guarantee sufficient locking to prevent the door from being opened even in the event of a single locking mechanism failure. It must be prevented from moving the stopper into the locking position if the lock and the locking mechanism are not in the locked position. It is also necessary to provide an unambiguous and rapid signal to pilots of incompletely closed and locked doors in the form of an audio signal alerting pilots before or at beginning of the takeoff that the cargo doors are incompletely closed, locked and latched.

As already noted, the long distances and lengths of nonstop flights of many cargo planes and the restriction of flight crew duty hours (FAR § 121.481) [21], have necessitated the fitting of high-capacity cargo planes with rest areas for pilots. In addition, special types of transportation and unusual cargo (e.g., mail couriers, animal transports, etc.) required that, in addition to flight crew members, other people, often supernumeraries, be on board such planes. The requirements of FAR § 121.583(a)(1) through (8) list the positions (specialties) of people who may be allowed to board an airplane without proof of compliance with all requirements relating to the carriage of passengers. These people usually include crew members of various airlines, inspectors, couriers, military specialists, airline employees, cargo escorts, etc. Technical justifications and proof of compliance are developed for their admission aboard each type of cargo aircraft and serve as the basis for FAA approval of exceptions to the applicable requirements of FAR Part 25. These exceptions clearly define the conditions that must be met on status and level of training of additional "crew members," equivalent equipment to be installed to replace some of the equipment required for regular passengers, etc.

In essence, these exemptions are in fact not exemptions, but procedural documents that establish an adequate level of safety for additional "crew members." Specifically, the original FAA Exemption No. 4808 for the 757-200PF (06/09/87) sets forth a specific number of people - no more than 5, other than flight crew members - who may be allowed aboard a cargo aircraft, provided they are of adequate physical condition and have adequate levels of training and preparation, etc. Although the entry door on the port side is modified from Type I to Type II and has a threshold unacceptable for non-wing emergency exits, it is considered an acceptable emergency exit, given the level of training of additional "crew members". Exceptions to the requirements of FAR §§ 25.783(g), 25.807(c)(1), 25.809(f), 25.813(b) are allowed. The subsequent FAA Exception No.

4808A approves the removal of the emergency ramp from the left service door, the Type I emergency exit, and the use of emergency ropes or emergency brake winches to lower additional "crew members" to the ground. (The right service door is plugged, and other emergency exits in the form of sliding cockpit shutters are provided instead on the starboard and port side. At the same time, it must be possible to open the right window from outside the aircraft). And the final Exception No. 4808B clarifies that as a refresher course of training and instruction for additional "crew members", their pre-flight briefing before each flight may be used.

Regardless of these exceptions, compliance with applicable requirements of Part 25 of the Aviation Regulations (§§ 25.785 - 25.815, 25.851, 25.1411, 25.1415) must be confirmed to ensure acceptable conditions for the life of additional "crew members" in normal conditions and in an emergency situation in flight, their emergency evacuation during an emergency landing of a cargo aircraft and rescue after landing. Given the possibility of a fire and the need to suppress it by depressurizing the aircraft, adequate oxygen supply must be provided for additional "crew members" according to the applicable requirements of §§ 25.1441, 1441A, as well as acceptable air exchange and temperature regimes at their accommodations according to § 25.831(a),(g*) of the Aviation Regulations.

CONCLUSION TO PART 1

This chapter analyzes the goals, missions, and main benefits of air transportation, considering the history, perspectives, and rapid development of air transportation in our time. The advantage of using air transportation during a pandemic was also noted.

After reviewing literature sources such as scientific publications, certifications, airworthiness standards, etc., the main goals of aircraft reconfigurations nowadays were considered.

Based on this analysis, the main procedural aspects of aircraft reconfiguration were identified as well as their compliance with FAR-25 requirements.

PART 2. AIRCRAFT RECONFIGURATION

2.1 Documentation issues

There are many steps to be taken to meet the certification of aircraft cargo conversion.

First, the customer sends aircraft information, including serial numbers and information about onboard systems, to the company where the new design will be created.

Then the engineers started working on the aircraft structure and systems modification. Once all the modifications are complete, the aircraft is cleaned and washed while paperwork is completed behind the scenes.

The newly-converted aircraft then takes flight to test its airworthiness in the new configuration, followed by delivery to the customer. The conversion process takes, on average, around 100 days. But if a customer chooses to have the firm handling extra work like maintenance and painting, it can take as long as 120 days.

According to the certification of the passenger to freighter conversion, the requirements for IATA, EASA must be fulfilled [22]. Prior to a newly developed airplane model entering service, it must receive a type certificate (TC) from the responsible aviation regulatory authority. Starting from 2003, EASA has been responsible for the certification of airplanes in the European Union (EU) and some non-EU European countries. This certificate demonstrates that the aircraft type meets the safety requirements established by the EU.

A supplemental type certificate (STC) is a TC issued when an applicant has received FAA approval to modify an aeronautical product from its original design. The STC, which incorporates by reference the related TC, approves not only the modification but also how that modification affects the original design.

In our case, let’s consider the following:

Airworthiness Category: Large Transport Airplanes

Certifying Authority, STC: State Aviation Administration of Ukraine. Kyiv, 14 Peremogy Avenue, 01135, Ukraine.

TC Holder**:** The Boeing Company. P.O. Box 3707, Seattle, WA 98124-2207, United States of America.

STC Holder: Antonov State Enterprise. Kyiv, 1 Akademika Tupoleva St., 03062, Ukraine.

These are the steps of the type-certification process that need to be considered during the passenger to freighter conversion [22]:

- Technical Familiarization and Certification Basis. The manufacturer of the aircraft submits a project to EASA when it is determined that it has achieved a sufficient degree of maturity. The EASA certification group and the set of rules are established which will be applied for the certification of that particular airplane type (Certification Basis).

- Establishment of the Certification Programme. EASA and the manufacturer should determine and agree on how to demonstrate the conformity of the aircraft type to each requirement of the Certification Framework. This goes along with determining the "level of involvement" of EASA in the certification process.

- Compliance demonstration. The manufacturer of the aircraft must demonstrate the conformity of its product to the regulatory requirements: the engines, design, control, electrical systems and flight performance are analyzed on the basis of the certification baseline. Demonstration of compliance is accomplished by analysis through ground tests (fatigue tests, bird strikes and simulator tests) as well as through in-flight tests. EASA inspectors conduct a detailed review of this demonstration of conformity by reviewing documents at their offices in Cologne and attending some of these conformity demonstrations (test certification). This is the longest phase of the type certification procedure. In the case of large aircraft, the deadline for completing the conformity demonstration is set at five years and can be extended if necessary.

- Technical Completion and Issuance of Approval. If the manufacturer is technically satisfied with the demonstration of compliance, EASA completes the investigation and issues a certificate.

Environmental requirements are not affected by changes in aircraft configuration because there are no changes to the engine, design weights of the aircraft, performance, noise, and emissions requirements.

EASA Validation Basis: In accordance with Regulation (EC) 1702/2003 [23].

The following items need to be recertified based on proposed changes:

- Joint Type
- Main Deck Cargo Compartment
- Rigid Cargo Barrier Wall, Emergency Landing Conditions
- New, Modified or Reused Equipment Qualification Standard
- Complex Digital Devices
- Decompression - Small Compartments
- Emergency Exit Arrangement
- Emergency Exit Dimensions
- Controller Area Network Bus
- Software
- Cargo Door

The STC implementations are based on a combination of the following certification bases:

1. CS-25 Amendment 8 [24]
2. CS-25 Amendment 12 [25]
3. CS-25 Amendment 16 [26]
4. CS-25 Amendment 17 [27]
5. CS-FCD Flight Crew Data [28]
6. CS-Master Minimum Equipment List (MMEL) [29].

Also, for reconfiguration of the aircraft, different Service Bulletins must be provided to cover changes in the installation of a new configuration.

The changes specified in these service bulletins comply with the applicable regulations, and are FAA approved, as well as EASA/Joint Aviation Authorities (JAA) approved for 747-400 airplane EASA/JAA. These service bulletins and its approval were based on the airplane in its original Boeing delivery configuration or as modified by other approved Boeing changes.

2.2 Construction issues

In the design process, the aircraft must be given a set of certain properties that will allow it to most effectively fulfill the task set by the front-line and meet all the necessary standards and requirements set forth in the relevant regulatory documentation.

The aircraft must have the specified flight performance characteristics corresponding to its class, the reliability of all systems and structural elements (the concept of reliability includes durability, reliability and maintainability), manufacturability during production and technical operation, comfort, efficiency, etc.

Requirements for aircraft in the design process are divided into two groups:

1. General technical requirements are the minimum state requirements aimed at ensuring flight safety. They are developed on the basis of deep theoretical and experimental research and are contained in regulatory documents.

2. Operational and technical requirements are the required properties of an aircraft. Operational and technical requirements are developed by the customer and contain the following groups of requirements:

- to flight technical data, payload, equipped, crew (aircraft designation and options for its use; conditions and features of use; number and composition of payload; required crew composition; flight performance):
- to comfort and manufacturability (physiological, hygienic and living conditions; use of progressive technological processes; provision of free access to components and assemblies; high maintainability, etc.);
- specific, due to the peculiarities of operation.

Passenger to freighter conversion involves:

- Changing the aircraft mission and configuration to adapt it to a new market.
- Major structural modifications as required for the new configuration.

- Installation of specific systems as required for the new missions.

A typical task for conversion involves the following:

• Removing everything from the passenger airplane that is no longer needed, such as internal equipment and furnishings (toilets for passengers, galley, seats, stowage bins, side and ceiling panels, carpet flooring, oxygen and overhead consoles, entertainment system act.).

• Removing and deactivating the passenger doors.

• Reinforcement of main deck cargo compartment floor beams to meet the cargo load requirements.

• Installation of the Main Deck Cargo Door (MDCD) with safety vent doors and replacing or reinforcing the surround structure. The MDCD is mounted on the left side of the fuselage after the wing.

• Installation of electric MDCD operation system.

• Installation of portable oxygen equipment for use during accessing MDCC in-flight.

• Installation of 9g rigid barrier / net.

• Installation and modification of area behind the cockpit for the supernumerary seat.

• Modification of the cargo area (cargo lining, ceiling, and lighting, floor, drainage system, etc.)

• Conversion of the main deck into the cargo compartment "Class E" with in-flight access.

• Installation of a one-minute smoke detection system.

• Installation of powered Cargo Loading System (CLS), to allow loading of different unit load devices (ULD) within the main deck.

• Modification of cockpit and avionics equipment as required.

• Installation of lightweight window plugs.

2.3 Structural changes

Continuing the construction topic, let's examine the structural changes: the interior of the cabin is being completely emptied. Seats, overhead compartments, galleys, and toilets for passengers are taken out, as well as a huge amount of cables. This is done so that engineers can rebuild with a clean slate.

Then the cabin floor is removed in all zones and replaced with a reinforced structure that allows the airplane to handle the weight of the cargo pallets. It is also fitted with a carpet of rollerballs in zones AE, FE, D, K2, CA, CF, WB, K1, and B that allows easier loading and removal of pallets as rollers help guide and move the pallets.

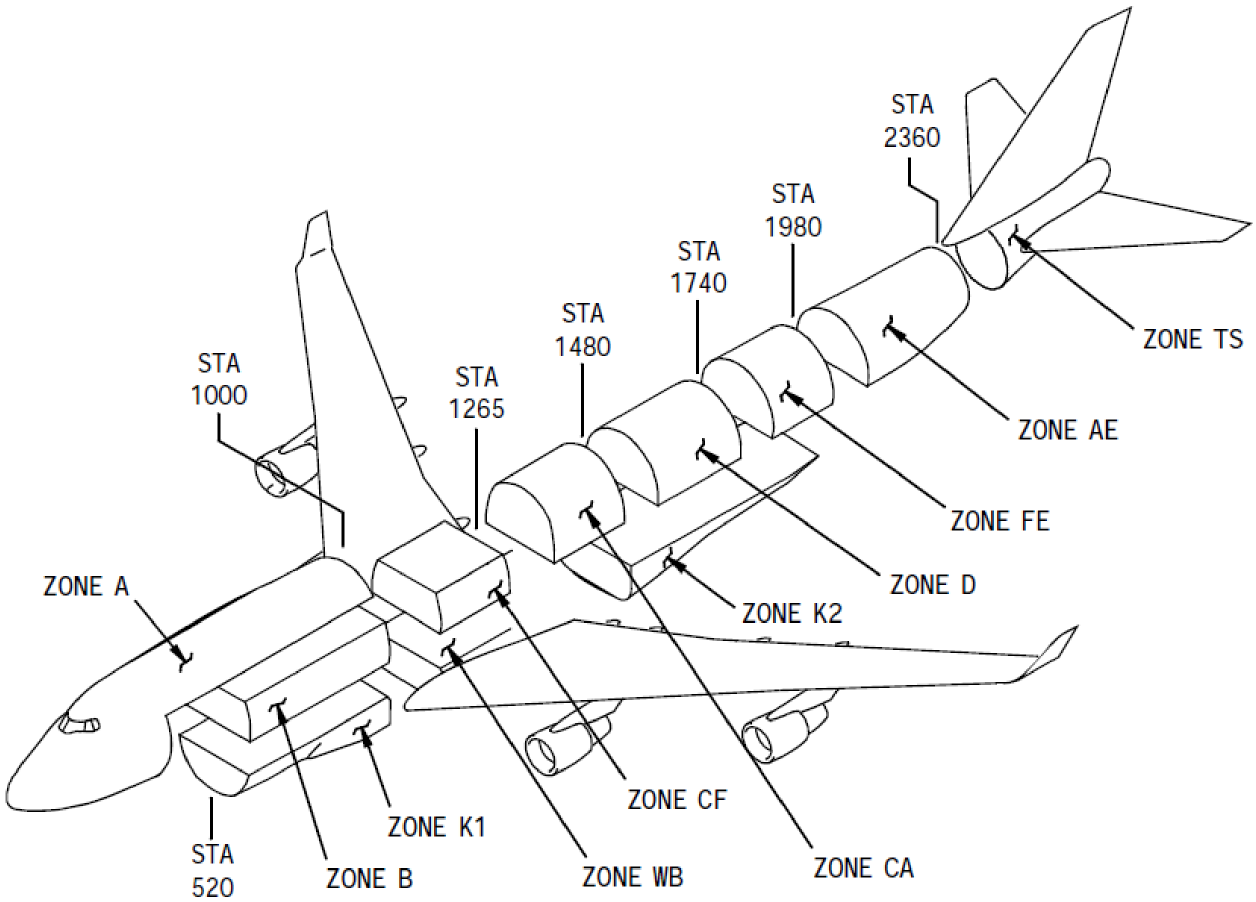

Figure 2.1 Structural changes

Also, the stairway for the passenger configuration is removed and it is substituted by the crew ladder near the first main entry door (1L). A new stairway will give access between the main cargo deck and the upper deck compartment. Also, the door for the stairway has a blowout latch if decompression occurs.

As cargo planes do not need emergency exits, they are deactivated and sealed. Therefore, it turns out that the exits: main entry doors 1L and 5L are active, and the rest of the other entry doors are deactivated.

The further important change is the cargo door, located on the side of the fuselage. Engineers started by cutting out a section of the fuselage. Then a "plug" is installed in its place. And the cargo door is installed. At the same time, passenger windows become covered because they are not needed. The view of these changes you can see in the figure below.

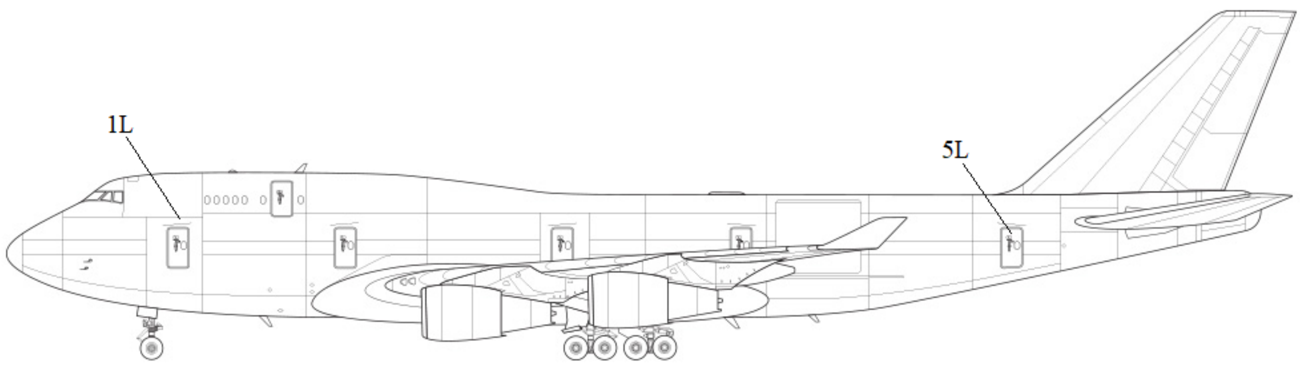

Figure 2.2 Doors and windows reconfiguration

In the event of a fire in the cargo compartment, pilots should be able to continue flying without worrying about smoke and fumes. This means installing a sealed metal bulkhead with a door between the cockpit and cargo compartment. This bulkhead also protects the cockpit from cargo in the rear.

But in addition to the bulkhead, there must be a structure to prevent the load from falling forward in the cabin, effectively blocking the door. This is usually done by installing another bulkhead or by using a cargo-restraining net. In either case, it needs to be able to withstand forces of up to 9g.

2.3.1 System changes

The cockpit needs to be modified, and systems for ventilation, fire detection/suppression (according to compartment classification), and temperature control are adapted to suit the new mission of the aircraft. According to aircraft systems, these systems are affected by structural changes in the design of the aircraft (new wires, ducts, units installation):

1. ECS

Since the ECS has to be fully modified to meet the purpose of the new aircraft the general scheme of the ECS will be changed such way:

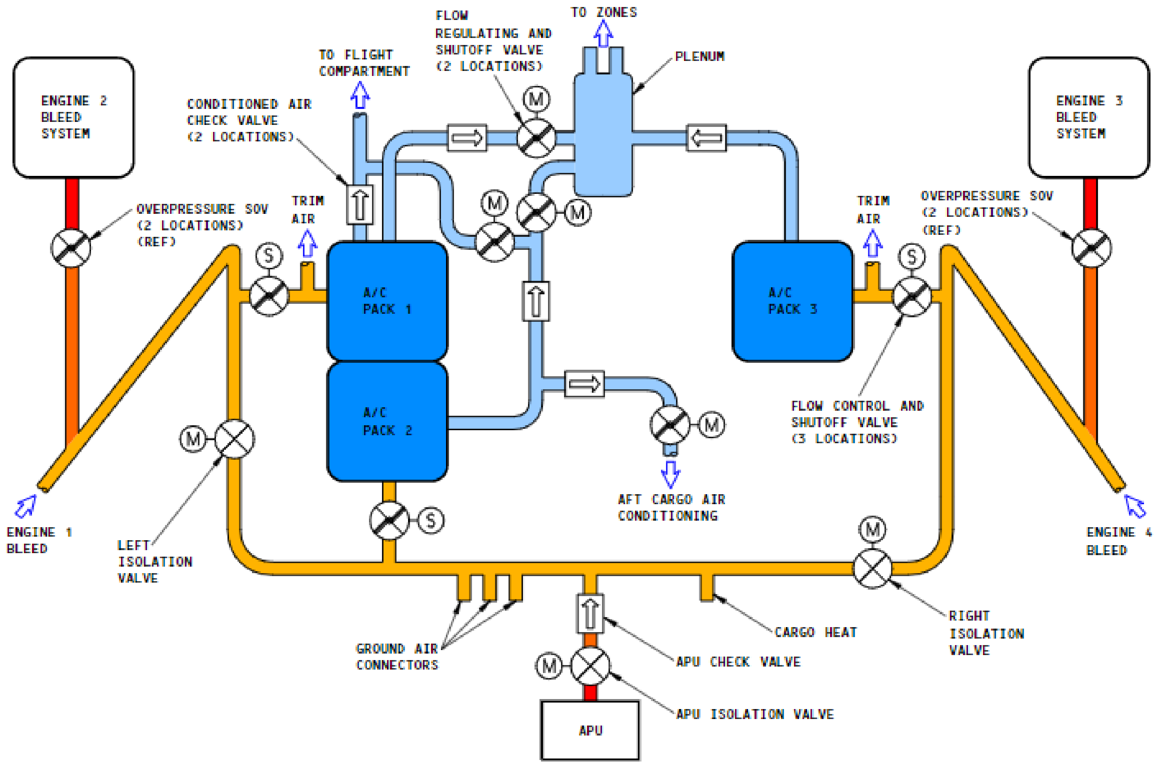

Figure 2.3 ECS scheme for passenger configuration

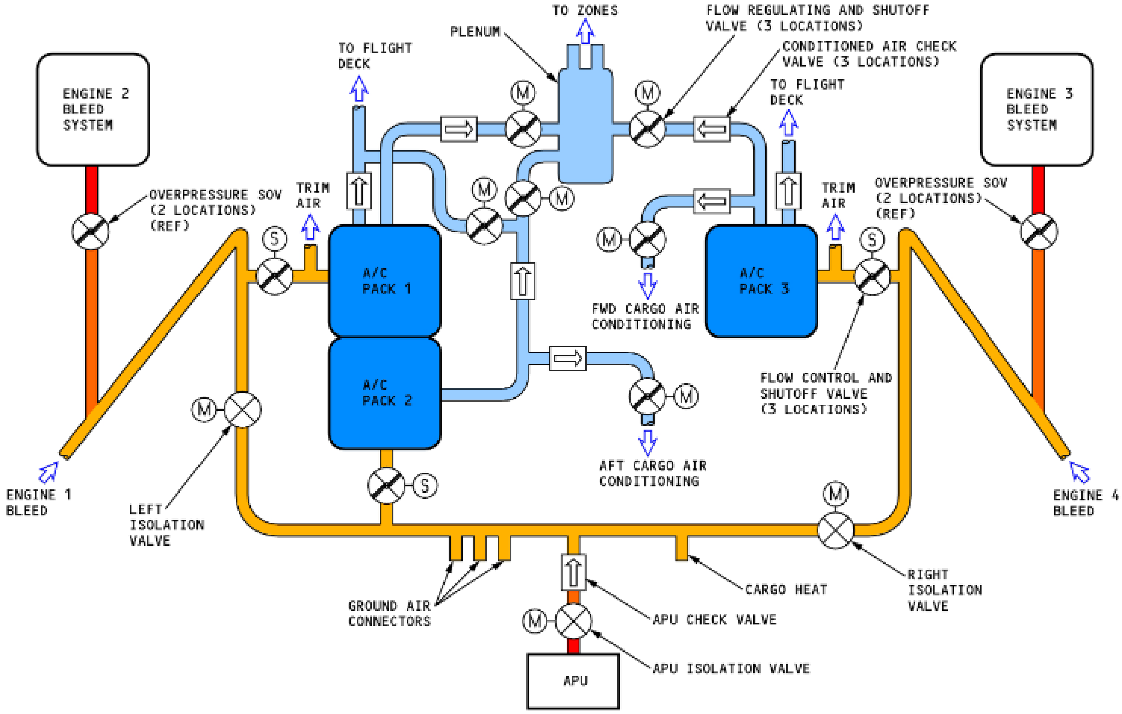

Figure 2.4 ECS scheme for converted configuration

As a result, all components need to be removed, salvaged or replaced in these zones: A, B, CF, CA, FE, AE, K1, K2, Left and Right Side A/C Pack, Left and Right Side Wheel Well Bay, Overwing Trim Air System.

After all units, ducts, packs, etc. are removed, we need to install new substitutions for them.

a) Install the duct module for the pneumatic section at Auxiliary Power Unit (APU).

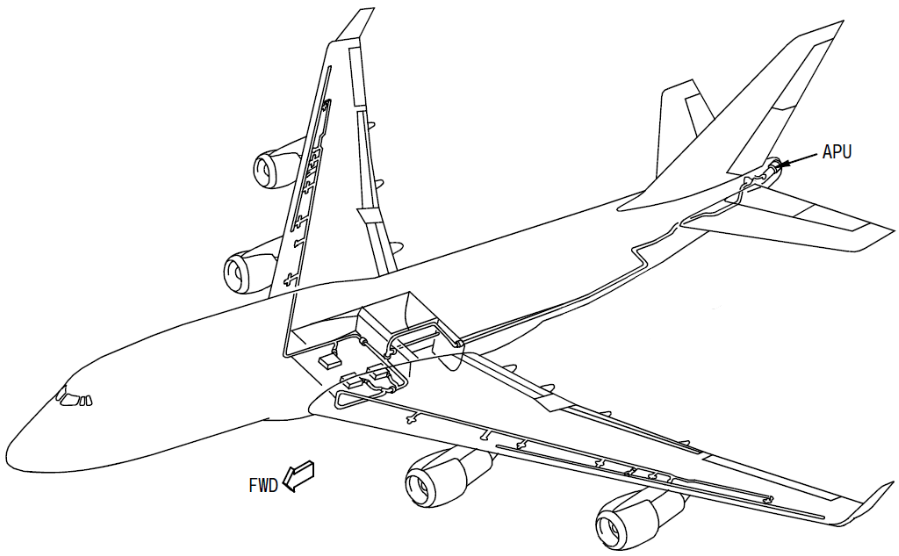

Figure 2.5 Duct module installation

b) Install the ducts for the packs and trim air system duct.

The heat loss in flight from different sections of the cargo cabin, known as "zones", is different. For this reason, each zone requires conditioned air at a different temperature. The air-conditioning packs are designed to supply air at the lowest temperature required for any of the zones. Since this air would be too cold for the other zones, the trim air valves add some hot air to these zones to maintain the selected (desired) temperature.

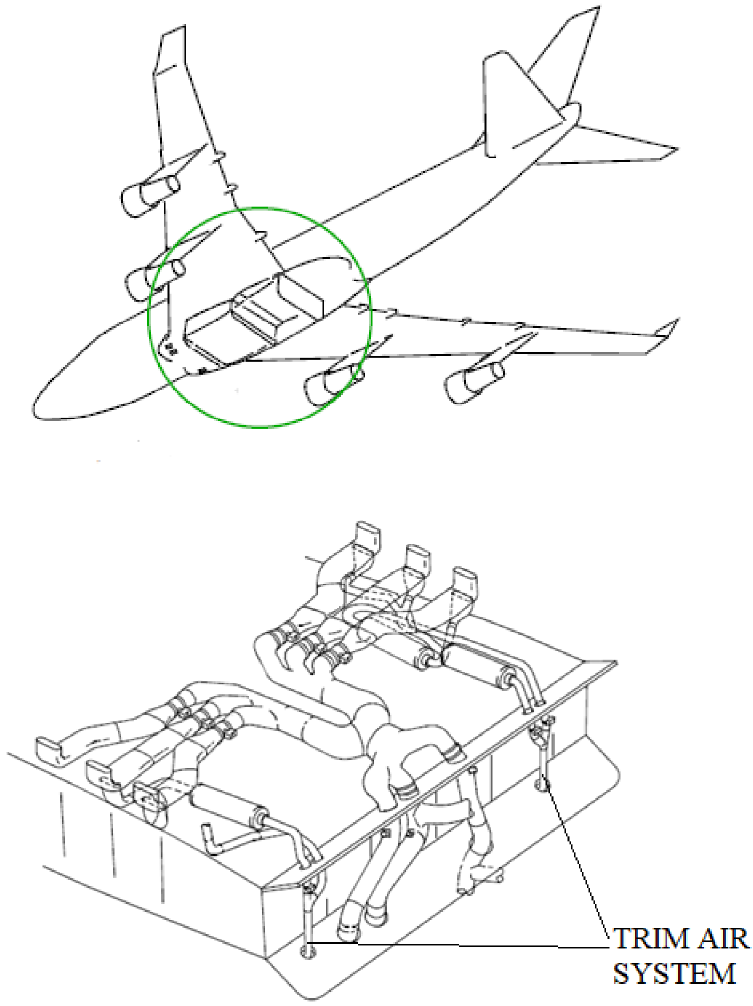

Figure 2.6 Duct module and trim air system installation

c) Install the air conditioning pack, pack dump valve (SMACCS) and water separator drain at the air conditioning bay.

The pack's dump valve controls airflow to the packs, but this valve is related to a fire protection system for main deck cargo. The purpose of the dump valve is to override the control of the outflow valves and move them to the fully open position, therefore depressurizing the aircraft and dump pack air overboard. This became necessary for cargo aircraft because when a main deck smoke warning appeared, the air supply to the main deck needed to be cut off and a dump valve opened to divert some air to the lower cargo bays to avoid overpressure in the air ducts.

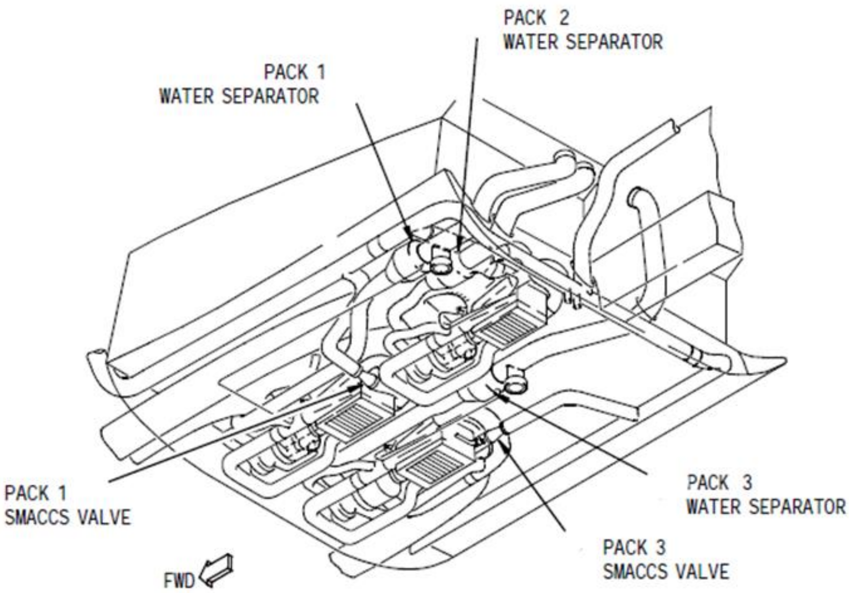

Figure 2.7 Pack module installation

d) Install air conditioning system duct at the flight deck.

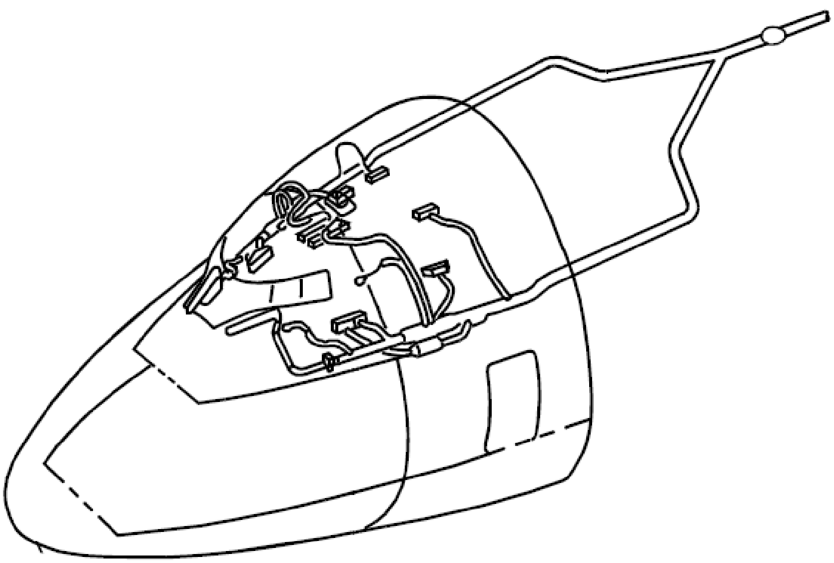

Figure 2.8 Flight deck ducts installation

e) Install the air distribution ducts, riser ducts in the upper and main deck, which also includes branch ducts for plenums, conditioning, and ventilation.

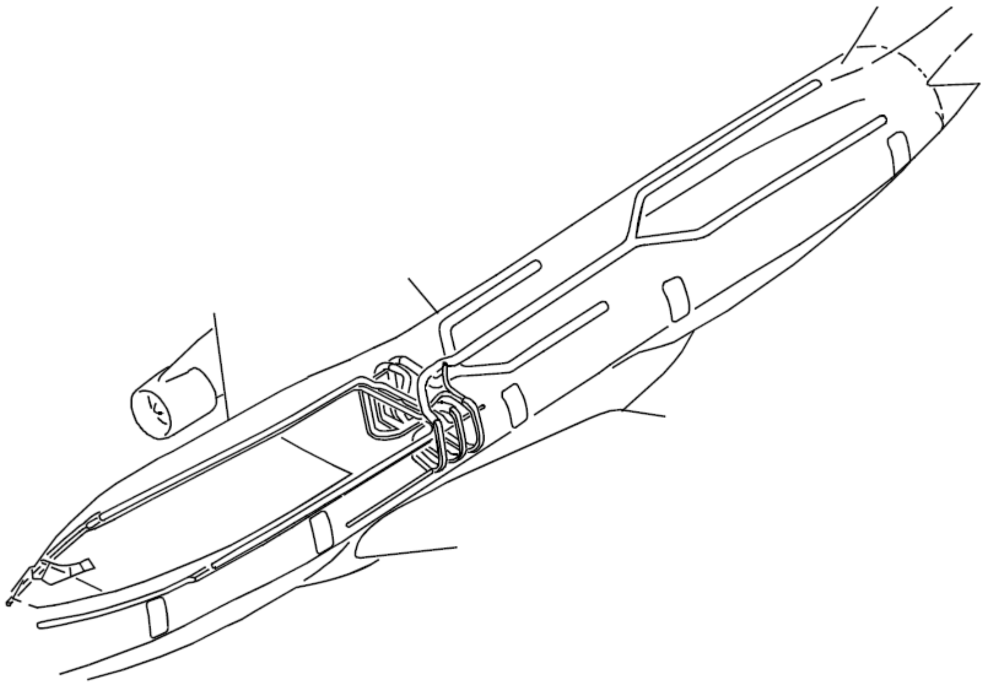

Figure 2.9 Upper and main deck ducts installation

f) Install air supply ducts in the FWD and AFT cargo compartments.

It includes conditioning air exhaust and supply system. In the aft bulk cargo compartments it is also necessary to install flapper valves. The flapper valve is located behind the right sidewall aft of the bulk cargo compartment door. When the flapper valve for the aft/bulk cargo compartment is open, it gives an outlet for air to flow to the outflow valves. It closes to isolate the aft cargo compartment when the fire suppression system for the compartment is discharged.

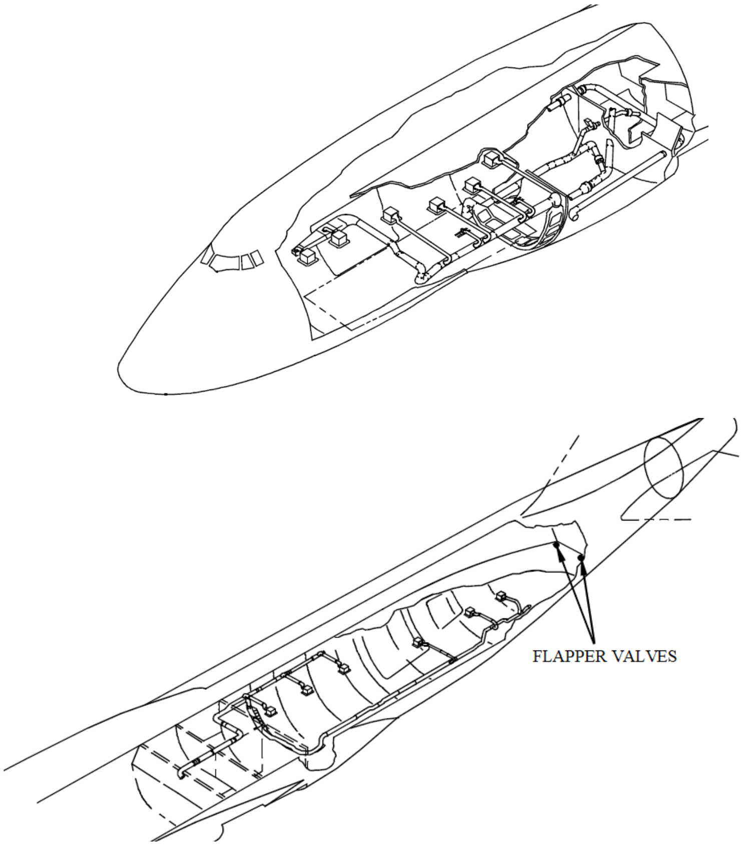

Figure 2.10 FWD and AFT supply ducts installation

g) Install air supply ducts at equipment racks, panels, and instruments.

It is needed to keep the temperature in the equipment racks within the limit, for this reason E/E cooling, heating, and exhaust system were installed. The supply module also includes restrictor for instrument panels, AFT E/E equipment ventilation fans and screen. One fan operates to pull air out of the duct and supply it to the outflow valves. The air exits the airplane at the outflow valves. A backup fan will operate if the primary fan fails. An inlet screen prevents foreign object damage to the fans.

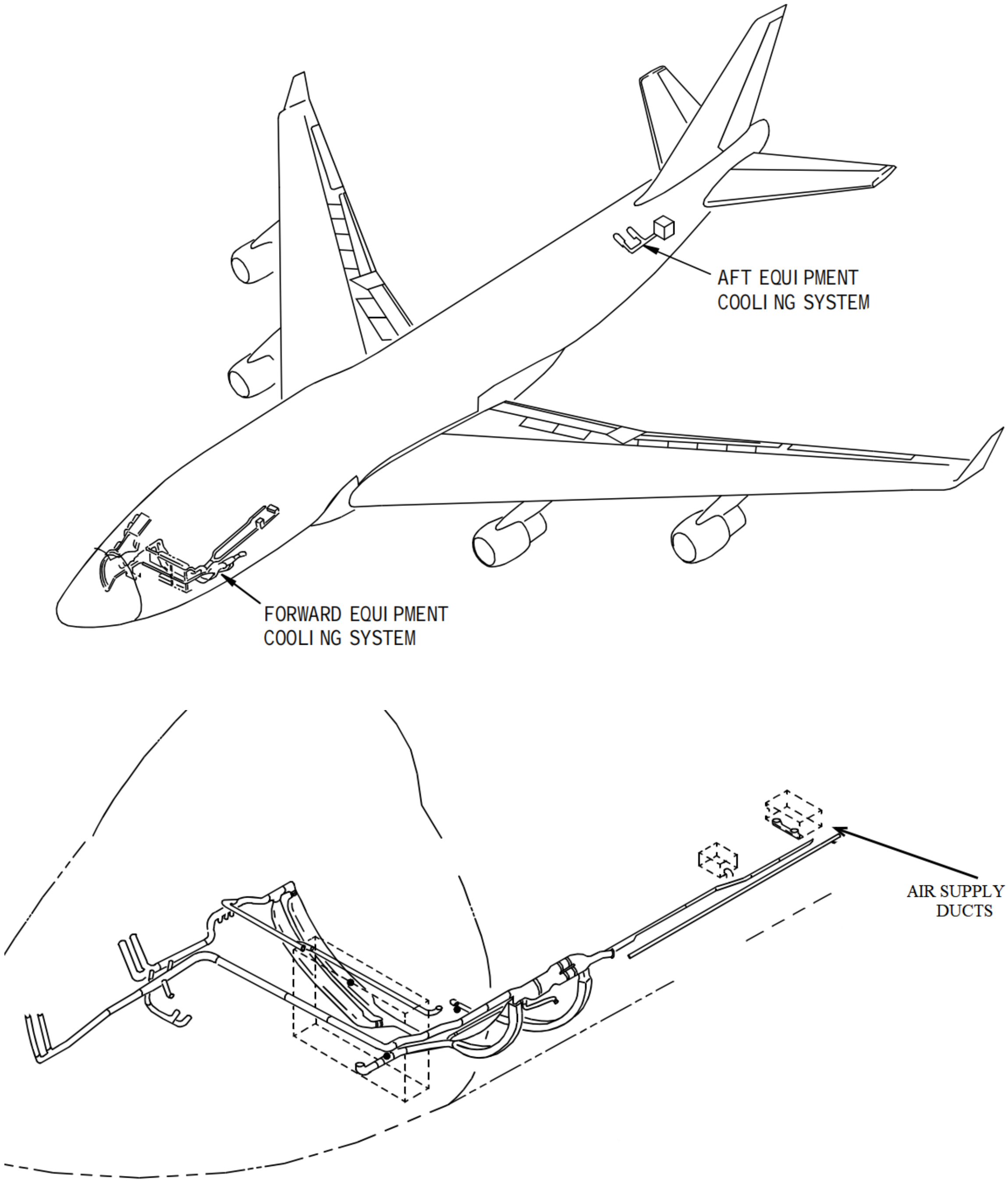

Figure 2.11 Air supply ducts installation

h) Install heating system in the FWD lower lobe cargo compartment.

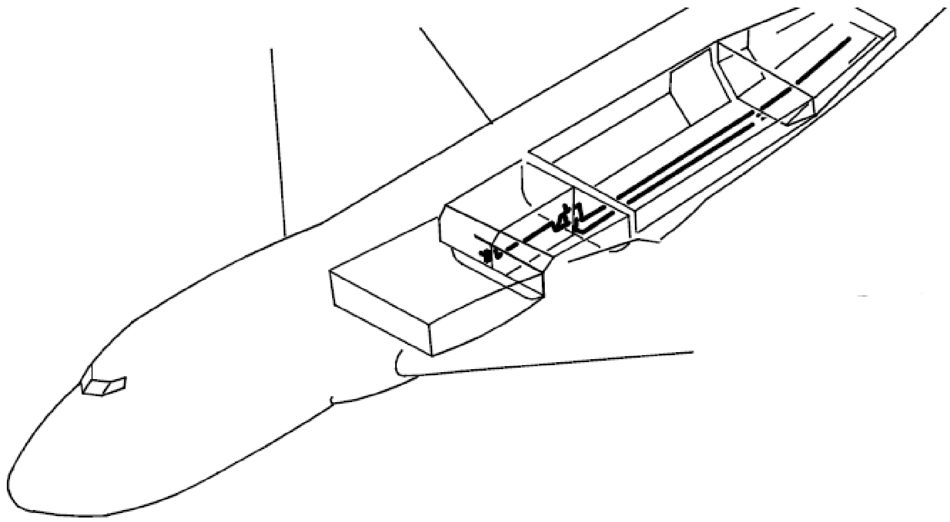

Figure 2.12 FWD heating system installation

2. Fire Protection system

The fire protection system for the cargo airplane includes the following:

- engine fire detection and extinguishing
- APU fire detection and extinguishing
- lover cargo smoke detection and fire extinguishing
- main deck cargo smoke detection and fire extinguishing
- wheel well fire detection
- wing leading edge duct leak detection
- APU duct overheat detection
- crew rest area smoke detection
- lavatory smoke detection and extinguishing
- portable extinguishers

For this purpose, it is needed to do these steps:

a) Install sensors in the FWD E/E compartment, cargo compartment and flight deck. It is all related to the Zone A.

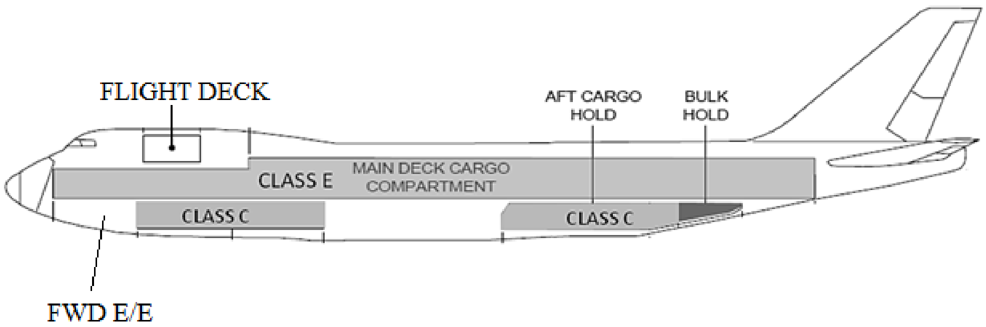

Figure 2.13 FWD sensors installation

b) Install sensors for temperature in the cargo compartments.

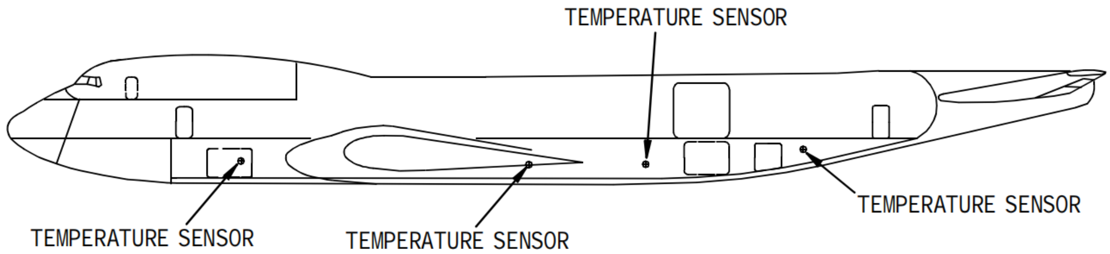

Figure 2.14 Temperature sensors installation

c) Install smoke detectors in the FWD and AFT main deck cargo compartments, FWD and AFT lower lobe cargo compartments.

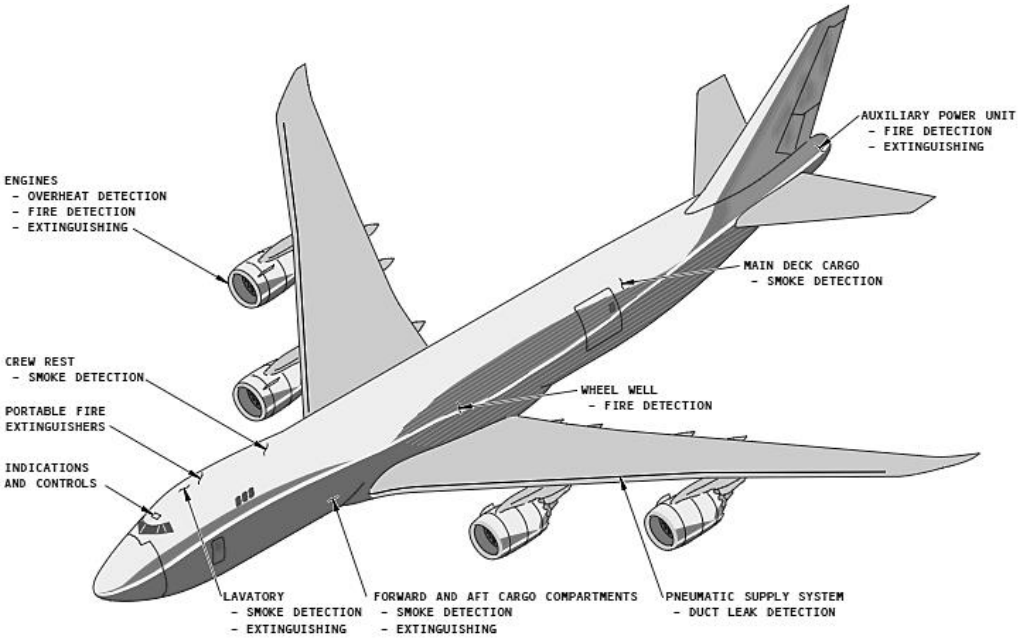

Figure 2.15 Smoke detectors installation

d) Install tubing for fire extinguishing system in the FWD lower lobe cargo compartment.

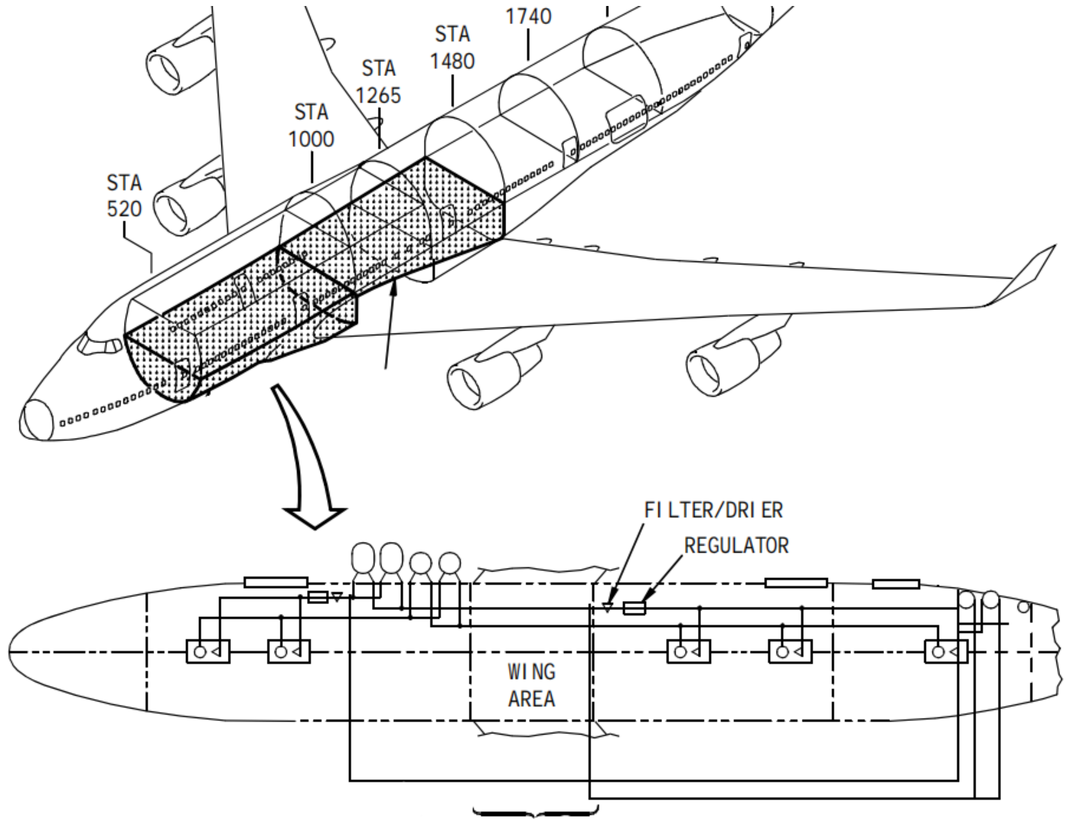

Figure 2.16 FWD fire extinguishing system installation

e) Install tubing for fire extinguishing system in the AFT lower lobe cargo compartment.

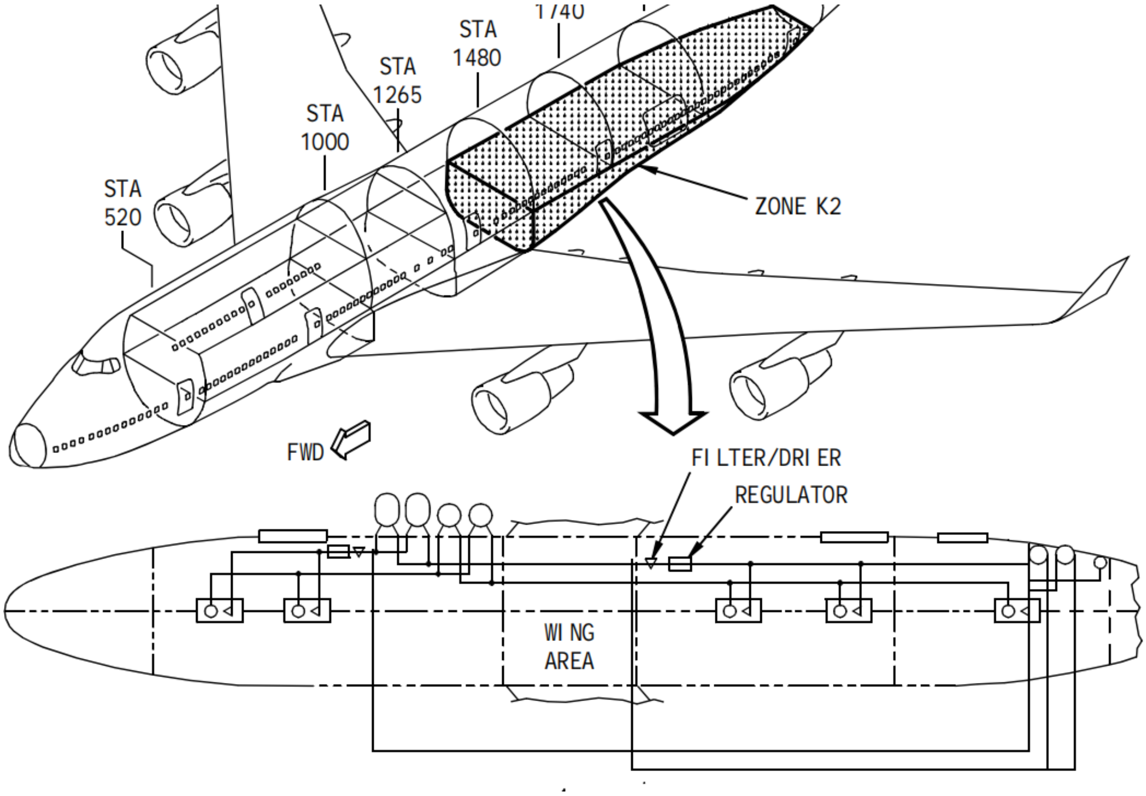

Figure 2.17 AFT fire extinguishing system installation

f) Install the bottle for fire extinguishing system in the AFT and FWDF cargo compartments.

The cargo fire extinguishing system is a gaseous smothering type system. The cargo fire extinguishing bottle keeps pressurized Halon to extinguish a forward or aft cargo compartment fire.

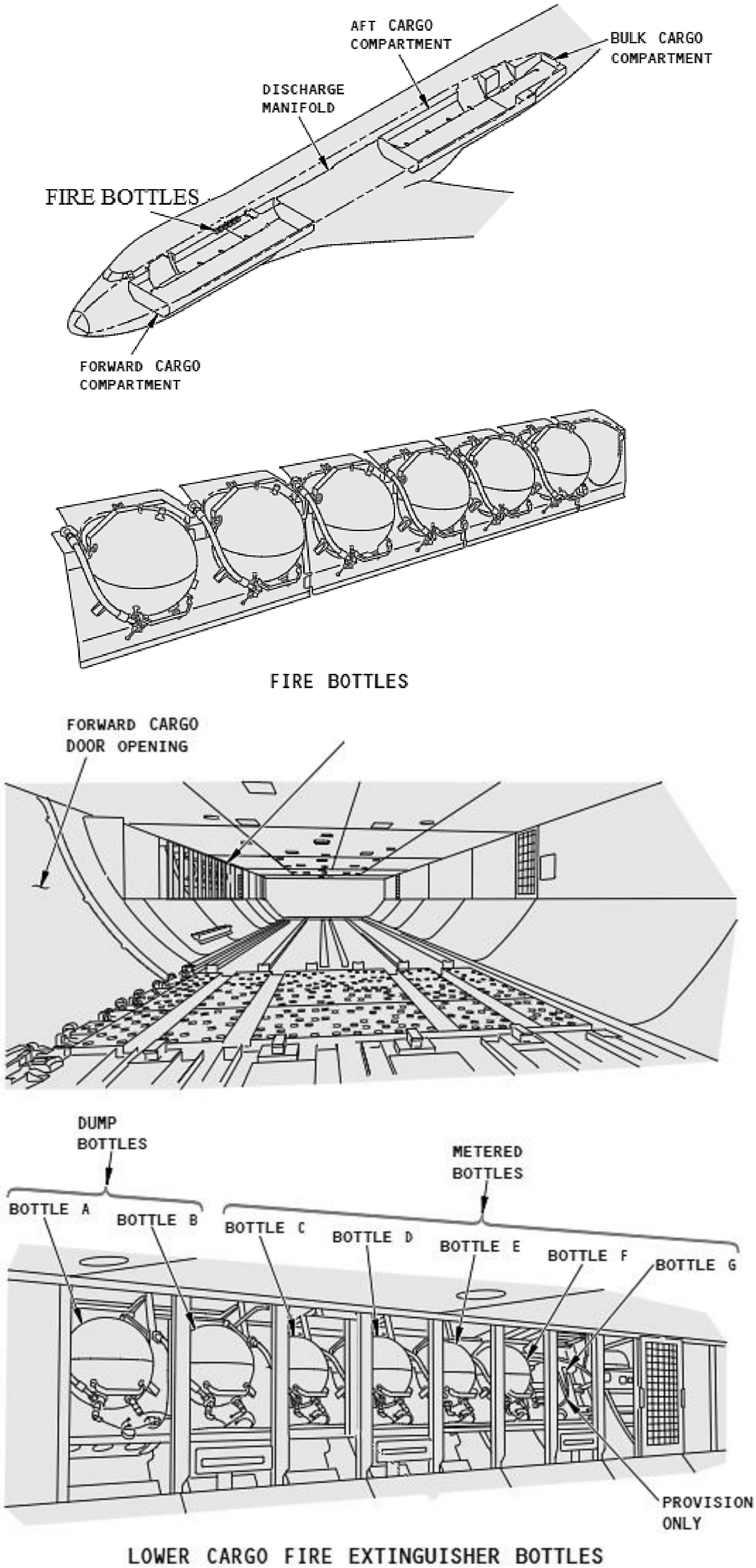

Figure 2.18 Fire extinguishing bottle installation

3. The electrical, avionics and communication systems for a converted freighter;

There must be a means for checking the Electrical Wiring Interconnection System (EWIS) and replacing its components if necessary to maintain airworthiness.

4. The hydraulics and flight control systems for a converted freighter.

5. The modification of the software.

After all changes are done the following functional tests need to be performed:

Continuity Checks, Voltage and Phase Sequence Test, AC External Power Test, Main Battery Test, Operational Test of the APU Battery, APU Battery Charging Inhibit Test, and millions of others.

CONCLUSION TO PART 2

This chapter is intended for practical application during aircraft reconfiguration, which includes issues of documentation, design, and structural changes.

The Boeing 747-400 was considered as a sample of reconfigured aircraft. The company Antonov was taken as the performer of the customer's duties.

Description of the features of the reconfiguration of the aircraft were described as follows: the algorithm of the order process for the manufacturer, release of certain TC, STS, to be followed by design changes: removal of passenger equipment, entertainment systems, installation of cargo loading equipment, floor reinforcement, installation of a roller floor for cargo handling, installation of a reinforced cockpit door, installation of stairs, deactivation of entrance doors that are no longer needed, window covering, installation of new cargo doors, as well as the following changes of the systems that have been made to the aircraft.

Based on the analysis, detailed changes in systems, components, designs and receiving the necessary updated certification, respectively, were identified.

PART 3. WEIGHT CHARACTERISTICS CHANGES

Payload has mainly two aspects: weight and volume. The weight of the payload will mainly influence the aircraft's maximum take-off weight, however, the payload volume and geometry affect primarily the design of the fuselage. The aircraft performance requirements may be divided into two groups:

1. Range and endurance
2. Maximum speed, rate of climb, take-off run, stall speed, ceiling, and turn performance.

Range and endurance are largely fuel dependent, while other performance requirements are not primarily a function of fuel weight. Thus, endurance and range requirements will mainly influence the aircraft's maximum take-off weight and required fuel weight. In contrast, other performance requirements affect engine design, landing gear design, and wing design.

In order to withstand the additional load, the airframe itself and the floors must be reinforced. This is done after an engineering stress analysis to coordinate with the center of balance and weight constraints.

The structural justifications are applicable up to the following maximum weights:

Maximum Seating Capacity: 2 Pilots plus 1 Person on approved seats within approved seating areas for observers and supernumeraries.

Stability and controllability are important properties of an airplane, determining the possibility and safety of flight, required efforts of the pilot and automatic devices during control, and the comfort level of crew and passengers in flight.

When investigating stability and controllability, an airplane is considered a material body, and its motion is described by equations of motion of the center of mass and rotation around the center of mass.

Since the airplane becomes reconfigured its loading can vary greatly, it is necessary to strictly monitor the center of gravity position and pitch trim position.

Before loading cargo, handling staff must determine such data as weight, dimensions, the center of gravity, and contact areas of individual cargo items for use in cargo placement, and for better operation, this may also include manual reconciliation of flight data monitoring, other data sources such as loadsheet and weight and balance systems.

The airplane's center of gravity must be within a certain range along the wing's MAC length to provide the required degree of static stability and controllability.

The position of the center of gravity may change during aircraft operation as fuel is depleted, as well as when the aircraft is loaded. The rear center of gravity should be the closest as much to provide the minimum necessary margin of static stability for the airplane, which is determined by the intended use of the airplane.

The maximum allowable frontal centering of an airplane is determined by the efficiency of its longitudinal controls (balancing), so that the higher the efficiency of longitudinal controls, the more allowable the frontal centering of the airplane, hence the range of its operational centering will be acceptable.

The basic requirements for airplane layout are the following:

- The layout should be the best possible way to meet the operational and technical requirements of the airplane;

- Each unit (load) of the airplane should be arranged so that it most effectively performs its functions;

- The layout of the airplane must ensure the ease of control and maintenance of the main systems and assemblies, as well as the simplicity of removing and installing parts and assemblies;

- The technological partitioning of the design shall provide a wide front of work in production, as well as the convenience of the general assembly of the airplane;

- A reinforced layout should provide less structural weight with sufficient stiffness and strength.

Cargo in the cabin complicates weight and balance requirements as some operational areas, require adding ballast to the cabin. Cargo loading must be planned so that the center of gravity of the loaded aircraft is within operational limits. Due to this, let’s calculate the difference in center of gravity position from passenger to cargo configuration.

3.1 Center of gravity of the equipped wing determination

The weight of an equipped wing includes the mass of its structure, the mass of equipment placed on the wing, and the mass of fuel. No matter where it is attached (to the wing or to the fuselage), the main landing gear and the front landing gear are included in the weight registry of the equipped wing. The mass register contains names of the objects, the masses themselves, and the coordinates of their center of gravity. The starting point of the given coordinates of centers of mass is selected by the nose point projection of the mean aerodynamic chord (MAC) on the XOY plane. Positive values of the coordinates of the centers of mass are taken for the tail part of the airplane.

We assume that our projected plane is symmetrical on the Y-axis, so we determine only the coordinates of the center of gravity X. Coordinates of the center of power for the equipped wing are calculated by the formula:

$$X_w = \frac{\sum m'_i * X'_i}{\sum m'_i} \qquad (3.1)$$

where Xi – equipped wing center of gravity coordinate;

$\sum$mi – sum of total mass of the equipped wing.

According to performed calculations (Appendix A), weight characteristics will be the following:

1. Passenger configuration will be the same as cargo:

Table 3.1 - Trim sheet of the equipped wing masses

№	Object name	Mass		Center of gravity coordinates X_i, m	Moment of mass, kg·m
		Units	Total mass m_i, kg		
1.	Wing (structure)	0,09975	32699,25	3,61	118202,87
2.	Fuel system, 40%	0,00424	1389,92	3,61	5024,36

Table 3.1 (continued) - Trim sheet of the equipped wing masses

3.	Airplane control, 30%	0,00120	393,37	4,99	1961,36
4.	Electrical equipment, 30%	0,00621	2035,71	0,83	1691,68
5.	Anti-ice and air-conditioning system, 50%	0,01	3278,12	0,83	2724,12
6.	Hydraulic system, 50%	0,00645	2114,38	4,99	10542,34
7.	Power Plant, 80%	0,07585	24863,88	-1,2	-29836,66
8.	Equipped wing without landing gear and fuel	0,20370	66774,65	1,65	110310,07
9.	Nose landing gear	0,00417	1366,65	-27,04	-36959,63
10.	Main landing gear	0,03752	12299,83	4,16	51105,81
11.	Fuel	0,32109	105257,16	3,61	380488,83
	Total	0,56648	185698,29	2,72	504945,07

The equipped wing center of gravity coordinate X_w is equal:

$X_w = \sum m_i \cdot X_i / \sum m_i =$ 2, 72 m

3.2 Center of gravity of the equipped fuselage determanation

Origin of the coordinates is chosen in the projection of the nose of the fuselage on the horizontal axis. For the axis X the construction part of the fuselage is given. The example list of the objects for the aircraft, which engines are mounted in the rear part of fuselage, is given in table 2.2.

The central gravity coordinates of the equipped fuselage are determined by formulas:

$$X_f = \frac{\sum m'_i * X'_i}{\sum m'_i} \qquad (3.2)$$

where Xi – fuselage center of gravity coordinate;

$\sum mi$ – sum of total mass of fuselage.

From the drawings for the reconfiguration airplane B_{MAC} = 8.31 m.

1. Passenger configuration:

Table 3.2 - Trim sheet of the equipped fuselage masses

№	Objects names	Mass		Center of gravity coordinates Xi, m	Moment of mass, kg·m
		Units	Total mass m_i, kg		
1.	Fuselage	0,08150	26716,68	35,3	943098,73
2.	Horizontal tail unit	0,01269	4159,93	63,2	262907,85
3.	Vertical tail unit	0,01262	4136,98	64,38	266339,25
4.	Radar	0,0013	426,16	1,68	715,94
5.	Radio equipment	0,0018	590,06	3,74	2206,83
6.	Instrument panel	0,0031	1016,22	5,37	5455,05
7.	Fuel system, 60%	0,00636	2084,88	32,5	67758,74
8.	Power Plant, 20%	0,018962	6215,97	34,06	211715,98
9.	Aero navigation equipment	0,0026	852,31	4,26	3630,85
11.	Airplane control, 70%	0,0028	917,87	35,3	32400,94
12.	Hydraulic system, 50%	0,00645	2114,38	49,42	104493,03
13.	Electrical equipment, 70%	0,01449	4749,99	35,3	167674,85
14.	Non-typical equipment	0,0091	2983,09	25,3	75472,16
15.	Furnishing and thermal equipment	0,0058	1901,31	42,7	81185,92
16.	Anti-ice and air-conditioning system, 50%	0,01	3278,12	56,48	185148,22
17.	Passenger equipment	0,02043	6695,56	35,3	236353,27
18.	Cockpit equipment	0,00108	352,39	24,71	8707,75
19.	Service load	0,00551	1806,24	43,67	78878,68
20.	Additional equipment	0,00914	2996,2	47,34	141840,19

Table 3.2 (continued) - Trim sheet of the equipped fuselage masses

21.	Equipped fuselage without payload	0,225722	73994,38	38,868	2875984,22
22.	Passengers	0,12468	40871,60	35,30	1442767,49
23.	Baggage	0,07481	24522,96	31,77	779094,44
24.	Crew	0,008312	2724,77	24,71	67329,15
Total		0,433522	142113,71	36,35	5165175,3

The fuselage center of gravity coordinate X_f is equal:

$X_f = \sum m_i \cdot X_i / \sum m_i = 36,35$ m

2. Cargo configuration

Table 3.3 - Trim sheet of the equipped fuselage masses

№	Objects names	Mass		Center of gravity coordinates Xi, m	Moment of mass, kg·m
		Units	Total mass m_i, kg		
1.	Fuselage	0,08150	26716,68	35,3	943098,73
2.	Horizontal tail unit	0,01269	4159,93	63,2	262907,85
3.	Vertical tail unit	0,01262	4136,98	64,38	266339,25
4.	Radar	0,0013	426,16	1,68	715,94
5.	Radio equipment	0,0018	590,06	3,74	2206,83
6.	Instrument panel	0,0031	1016,22	5,37	5455,05
7.	Fuel system, 60%	0,00636	2084,88	32,5	67758,74
8.	Power Plant, 20%	0,018962	6215,97	34,06	211715,98
9.	Aero navigation equipment	0,0026	852,31	4,26	3630,85
11.	Airplane control, 70%	0,0028	917,87	35,3	32400,94
12.	Hydraulic system, 50%	0,00645	2114,38	49,42	104493,025

Table 3.3 (continued) - Trim sheet of the equipped fuselage masses

13.	Electrical equipment, 70%	0,01449	4749,99	35,3	167674,85
14.	Non-typical equipment	0,0091	2983,09	25,3	75472,16
15.	Anti-ice and air-conditioning system, 50%	0,01	3278,12	56,48	185148,22
17.	Cargo equipment	0,02043	6695,56	35,3	236353,27
18.	Cockpit equipment	0,00065	211,44	24,71	5224,65
19.	Service load	0,00150	491,72	43,67	21473,33
20.	Additional equipment	0,005	1639,06	47,34	77593,1
21.	Equipped fuselage without payload	0,211342	69280,44	38,53	2669662,76
22.	Cargo	0,22114	72492,68	33,54	2510899,12
23.	Crew	0,001039	340,6	24,71	8416,14
Total		0,433522	142113,71	36,51	5188978,03

The fuselage center of gravity coordinate X_f is equal:

$X_f = \sum m_i \cdot X_i / \sum m_i = 36,51$ m

After we determined the center of gravity of fully equipped wing and fuselage, we construct the moment equilibrium equation relatively fuselage nose:

$$m_f \cdot x_f + m_w \cdot (x_{MAC} + x_w) = m_0 \cdot (x_{MAC} + C) \qquad (3.3)$$

where m_0 – aircraft takeoff mass, kg;

m_f – mass of equipped fuselage, kg;

m_w – mass of equipped wing, kg;

C – distance from mean aerodynamic chord leading edge to the center of gravity point, determined by the designer.

C = (0,22...0,25) B_{MAC} – low wing;

From here we determined the wing MAC leading edge position relative to fuselage, means X_{MAC} value by formula:

$$X_{MAC} = \frac{m_f X_f + m_w X_w - m_0 C}{m_0 - m_w} \qquad (3.4)$$

$$X_{MAC} = \frac{m_f X_f + m_w X_w - m_0 C}{m_0 - m_w} = 35,47\ m$$

$$X_C = \frac{X_i - X_{MAC}}{b_{MAC}} \cdot 100\% \quad (3.5)$$

Table 3.4 - Calculation of center of gravity positioning variants for passenger configuration

Objects names	Mass m_i, kg	Center of gravity coordinates X_i, m	Moment of mass, kg·m
Equipped wing (without fuel and landing gear)	66774,65	37,12	2478806,86
Nose landing gear (extended)	1366,65	8,43	11515,38
Main landing gear (extended)	12299,83	39,63	487380,92
Fuel	105257,16	39,08	4113960,12
Equipped fuselage (without payload)	73994,38	38,87	2875984,22
Passengers	40871,6	35,30	1442767,49
Baggage	24522,96	31,77	779094,44
Crew	2724,77	24,71	67329,15
Main landing gear (retracted)	12299,83	39,63	487380,92
Nose landing gear (retracted)	1366,65	7,58	10363,84
Reserve fuel	10525,72	39,08	411396,01

Table 3.5 - Calculation of center of gravity positioning variants for cargo configuration

Objects names	Mass m_i, kg	Center of gravity coordinates X_i, m	Moment of mass, kg·m
Equipped wing (without fuel and landing gear)	66774,65	37,12	2478806,86
Nose landing gear (extended)	1366,65	8,43	11515,38
Main landing gear (extended)	12299,83	39,63	487380,92
Fuel/fuel reserve	105257,16	39,08	4113960,12
Equipped fuselage (without payload)	69280,44	38,53	2669662,76
Cargo	58868,81	35,30	2078068,88
Crew	13623,87	31,77	432830,25
Main landing gear (retracted)	340,60	24,71	8416,14
Nose landing gear (retracted)	12299,83	39,63	487380,92
Reserve fuel	1366,65	7,58	10363,84

Table 3.6 - Airplanes center of gravity position variants for passenger configuration

Variants of the loading	Mass m_i, kg	Moment of the mass, kg· m	Center of mass X_i, m	Centering, X_c, %
Take off mass (LG extended)	327812,00	12256838,58	37,39	23,10
Take off mass (LG retracted)	327812,00	12255687,05	37,39	23,06
Landing weight (LG extended)	233080,56	8554274,48	36,70	15,81
Ferry version	262417,44	10034976,66	38,24	33,34
Parking version	154435,51	5853687,39	37,90	29,29

Table 3.7 - Airplanes center of gravity position variants for cargo configuration

Variants of the loading	Mass m_i, kg	Moment of the mass, kg· m	Center of mass X_i, m	Centering, X_c, %
Take off mass (LG extended)	327812,00	12280641,31	37,46	23,98
Take off mass (LG retracted)	327812,00	12279489,77	37,46	23,93
Landing weight (LG extended)	233080,56	8578077,20	36,80	16,04
Ferry version	255319,33	9769742,19	38,26	33,63
Parking version	149721,57	5647365,92	37,72	27,07

CONCLUSION TO PART 3

In this part of the diploma work, the importance of changes in the weight characteristics of the aircraft during reconfiguration was considered. The position of the masses of the main parts of the aircraft was calculated and the characteristic of the position of the center of mass of the aircraft for the passenger and converted cargo aircraft was determined.

During the analysis of reconfiguration of the aircraft, changes in the weights of furniture and thermal equipment, crew, service load and additional equipment were assumed. Also, the weight of passengers was removed from the calculations and the weight of loading equipment and cargo was added.

All calculations make it possible to introduce new systems and cargo equipment into the reconfigured aircraft.

According to the results of calculations, it is possible to transport cargo with the weight of 72, 5 tons with the required degree of static stability and controllability of the aircraft for a safe and comfortable flight.

6. LABOR PROTECTION

4.1 Dangerous and harmful production factors that occur during the analysis of aircraft reconfiguration

The purpose of labor protection is to minimize the possibility of injury or illness to the employee by providing comfort for maximum productivity.

As well as improving working conditions increases productivity through the full and rational use of working time, it also preserves human health (both physical and emotional) and reduces the number of accidents. Regarding working conditions, according to Article 13 of the Law of Ukraine "On Labor Protection" [30], the employer must create working conditions in each workplace in accordance with regulations, as well as ensure compliance with the requirements of legislation on the rights of employees in the field of labor protection.

Let's consider the impact of the labor protection factor in the case of work during the tasks of this thesis project. During the analytical work, aviation personnel most often work with a laptop, on which they make records of changes in systems, software, maintenance rules, as well as the receiving of various documents and certificates, which in the future will allow the customer to perform reconfiguration of the aircraft. Premises, where the installation and further work with a computer is planned, must comply with the design documentation of the house, coordinated with the authorized state authorities. In addition, the employer must take into account the sanitary standards for lighting, requirements for microclimate parameters (temperature, relative humidity), the degree and strength of vibration, sound noise and fire resistance of the room, as well as the characteristics of electromagnetic, ultraviolet and infrared fields [31,32].

The main task in this situation is to analyze the results and make conclusions about further actions for constructive, documentation and regulatory change. Since engineers spend most of their time working at a computer, they face such harmful factors, as:

(a) physical:

- increased level of electromagnetic radiation;
- increased level of X-ray radiation;
- increased level of ultraviolet radiation;
- increased level of infrared radiation;
- increased level of static electricity;
- increased level of the dustiness of the air in the working zone;
- low or high humidity in the air of the working area;
- low or high mobility of the air in the working area;
- increased noise level in the workplace (from fans, processors, audio boards, printers);
- increased or decreased level of illumination;
- increased level of glare;
- uneven brightness distribution in the visual field;
- increased brightness of the light image;
- increased level of pulsation of the light flux;
- electric shock;

b) chemical:

- increased content of carbon dioxide, ozone, ammonia, phenol, formaldehyde in the air of the working area;

c) psychophysiological:

- visual strain;
- the stress of attention;
- intellectual stress;
- emotional stress;
- long-term static loads;
- the monotony of work;
- a large volume of information processed per unit of time;
- irrational organization of the workplace;

d) biological:

- increased content of microorganisms in the air of the working area.

In this case, let's look at one of the most dangerous factors that affect a person while working at a computer.

Any person has been faced with static electricity, that is, electricity caused by friction, in one way or another in everyday life. The increased level of static electricity is a physical hazardous industrial factor that occurs in rooms equipped with maintenance control panels, static currents most often occur when personnel touch any metal element in the workplace.

However, the main source of increased levels of static electricity when working at a computer is a monitor. On the screens of monitors, positive charges are accumulated under the action of the electron beam created by the electron beam tube.

At the formation of a charge with large electric potential and electric field of the raised intensity which is harmful to the person is created. People working in the zone of electrostatic field exposure have a variety of complaints: irritability, headache, sleep disturbance, loss of appetite, etc. When a person stays in such a field for a long time, functional changes in the central nervous, cardiovascular and other systems are observed.

Another big problem is that the working devices generate an increased level of electromagnetic fields - some types of radiation: X-rays, ultraviolet, radiofrequency, etc. The human body reaction to electromagnetic influences occurs at the cellular level, system level and in the body as a whole. The most dangerous are: effects on the cardiovascular system, on the nervous system, on the immune and endocrine systems, on the sexual system, etc. The greatest influence on the electromagnetic environment of any building in the industrial frequency range of 50 Hz has electrical equipment, namely the cable lines that supply electricity and other consumers of the building support systems.

Insufficient or excessive light, uneven lighting in the field of view, light pulsation, changes in the colors of illuminated objects cause visual fatigue and general fatigue; excessive brightness of light sources can cause headaches, eye pain, visual acuity disorder; glare - temporary glare; dirty windows and fixtures reduce illumination. Glare, sparkling lights or harsh shadows can cause a worker to become totally disoriented. All of these circumstances are potential risk factors for accidents or occupational injuries.

4.2 Structural and organizational and technical measures to reduce the impact of negative factors

The employer is prohibited from installing computers in rooms located in the basements of buildings. In order to avoid possible accidents and short circuits, no work requiring excessively humid processes is allowed near (above or below) the rooms where the computer will be operated. A suitable room must be equipped with central or individual heating, air conditioning or ventilation systems. But when installing these systems, make sure that heating batteries, water pipes, ventilation cables, etc., are securely hidden under protective shields, which will prevent the possible exposure of the worker to voltage.

Production equipment must be designed in such a way as to avoid the accumulation of static electricity in amounts that are dangerous for the worker - for this purpose, air humidifiers are used, and the floor is covered with antistatic linoleum.

In order to achieve the maximum level of health and safety when working with computers, working rooms should be equipped with first aid kits, automatic fire alarm systems and fire extinguishers. In a room where 5 or more computers work together, a service switch should be installed in a visible place, which, if necessary, will completely disconnect the electrical power of the room.

Discussing the location of computer installation and electronic equipment, it is also important to consider the location of the computer in relation to the working area of the engineer. These requirements will help to avoid the influence of negative factors when working at the electronic equipment, as well as to ensure maximum comfort and reduce the risk of injury:

1. The computer should be placed at least 1 m away from the walls, at least 1.5 m from each other, it should also be placed at least 1 m away from a heat source.

2. The workplace shall be positioned so that windows and lighting equipment, which are reflective, do not fall within the sight of the employee. To prevent glare on the screen of monitors, especially in summer and on sunny days, the monitor screen should be positioned so that the light from the window falls from the side, preferably to the left.

3. The screen surface should be 400-700 mm away from the user's eyes.

4. Viewing angle should be within 10-40 degrees. The most rational is to place the screen perpendicular to the operator's line of sight.

5. The keyboard should be placed on the table surface or a special stand at a distance of 100-300 mm from the edge turned to the user.

6. The height of the working surface of the table should be 680-720 mm, width not less than 500 mm.

7. The chair should provide the operator with comfortable working conditions and a rational physiological working posture during the process of work. The chair must provide the possibility to adjust the height of the seat surface, the angle of inclination of the back and the height of the backrest.

8. The chair must have a height of 400-500 mm, a width of at least 380 mm in width.

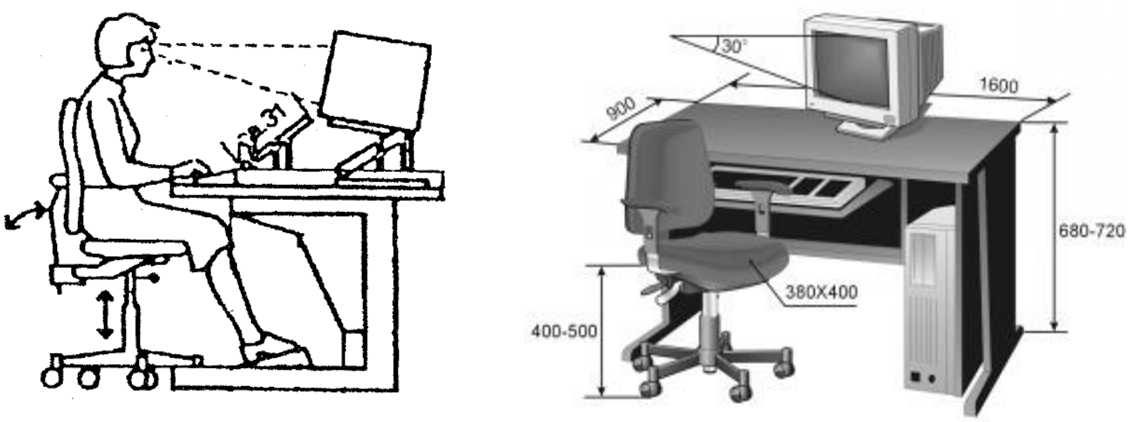

Figure 4.1 Recommended arrangement of elements in the workplace

Each room where the computer workstations will be set up must have elements of natural and artificial lighting. At the same time, easily adjustable blinds or curtains should be installed on the windows to allow workers to adjust the level of light in the room [31, 33].

Rational lighting of working areas and workplaces is one of the most important measures of production safety.

Normal room illumination (E_{min}) depends on the level of visual work performed in this room, which, in turn, is determined by the minimum size of the object of study. For the lighting technician at the lowest illumination of the room not less than 400 lux. The actual value of light is 200 - 250 lux. Total luminous flux is determined by the formula (4.1):

$$E_{gen} = \frac{E_n \cdot S \cdot k_1 \cdot k_2}{V} \qquad (4.1)$$

where:

E_n - normalized illumination, En = 400 lux;

S - the area of the room;

k_1 - coefficient, which takes into account ageing of lamps and illumination pollution (k1 = 1.2);

k_2 - coefficient, which takes into account unevenness of the lighting space (k_2 = 1.1);

V - coefficient of light flux, which is determined by the coefficient of interference of walls, working surfaces, walls, the geometry of the room, and types of illuminators (V = 0.7).

Room dimensions: A = 6 m, B = 3 m, H = 2.75 m. The area of the room is calculated by the formula (4.2):

$$S = A \cdot B \qquad (4.2)$$

$$S = 6 \cdot 3 = 18\ (m^2)$$

$$E_{gen} = \frac{400 \cdot 18 \cdot 1.2 \cdot 1.1}{0.7} = 13577{,}14\ (lux)$$

Selection of luminous flux ratio coefficients:

1. The coefficient of the ceiling painted with white paint ($R_{ceiling}$ is 70%);
2. Refractive index of white walls (R_{wall} is 55%);
3. Reflection coefficient of dark parquet floors (R_{floor} is 10%);
4. Space index (i).

Effective room height is calculated by the formula (4.3):

$$h_p = H - h_n \qquad (4.3)$$

where:

h_n - is the height of the working surface above the floor (h_n is 0,7 m).

h_p = 2.75 - 0.7 = 2.05 (m)

The space index is calculated by the formula (4.4):

$$i = \frac{A \cdot B}{h_p \cdot (A+B)} \quad (4.4)$$

$$i = \frac{6 \cdot 3}{2.05 \cdot (6+3)} \approx 0.976$$

To provide full artificial lighting, the T8SE-180 LED incandescent lamps were chosen and the replacement of 18W fluorescent lamps with the 990 lm. The luminous flux of one T8SE-180 20W lamp is equal to E_l=1650 lm.

The required number of lamps can be determined by the formula (4.5):

$$N = \frac{E_{gen}}{E_l} \quad (4.5)$$

$$N = \frac{13577.14}{1650} = 8.2 \approx 8$$

$$W_{Fgen} = W_{FN} \cdot N_F \quad (4.6)$$

where:

W_{FN} - is the power of one fluorescent lamp;

N_F - number of fluorescent lamps.

$$W_{Fgen} = 18 \cdot 8 = 144 \text{ (W)}$$

The power of 8 LED lamps is calculated by the formula (4.7):

$$W_{LEDgen} = W_{LEDN} \cdot N_{LED} \quad (4.7)$$

where:

W_{LEDN} - the power of one LED lamp;

N_{LED} - number of LED lamps.

$$W_{LEDgen} = 20 \cdot 8 = 160 \text{ (W)}$$

The artificial lighting has been optimized. By introducing a new type of lamp, we have reduced the number of lamps required. Thus, the reduction of the number of lamps required is achieved through optimization.

4.3 Fire and explosion safety

Dangerous factors that occur in a fire and affect people and material goods are:

- Flames and sparks;
- elevated ambient temperature;
- toxic products of combustion and thermal decomposition;
- smoke;
- low concentration of oxygen.

Hazardous factors of fire manifest secondary and can affect people and material values may be debris, parts of destroyed devices, structures, facilities, units, radioactive and toxic substances and materials released from damaged devices and facilities, the emerging electric current when removing high voltage to conductive parts of structures, units, devices, fire extinguishing means [34].

Classification of facilities by fire and explosion risks should be made with regard to the permissible level of their fire hazard, as well as the probability of fire (detonation), taking into account the mass of combustible and highly flammable substances and materials. Explosive and fire-hazardous areas are located on the site and formed in emergency situations, as well as areas of possible harm to people and material assets.

Preventing the formation of a combustible environment shall be provided by one of the following methods or combinations of methods:

- the maximum possible under the conditions of technology and design, limiting the mass or volume of combustible substances, materials and the safe way of their placement;
- the maximum possible use of non-combustible and non-combustible substances and materials;
- isolation of the combustible environment;
- maintaining the safe concentration of the medium in accordance with the rules and regulations and other regulatory, technical, regulatory, and safety rules;
- maintaining the temperature and pressure of the medium, at which the spread of flame is excluded;

- maximum mechanization and automation of technological processes related to the circulation of flammable substances;

- installation of flammable equipment, if possible, in isolated rooms or in open areas.

The main factors characterizing the danger of explosion are the maximum pressure and temperature of the explosion, the rate of pressure increase during the explosion, the pressure at the front of the destructive shock wave, and the explosive properties of explosive media.

Organizational, administrative and technical measures to ensure explosion safety include the development of a system of guidance materials for visual means, regulations and standards for conducting technological processes, and rules for handling explosive substances and materials. An important factor is the organization of training, instructions and access to work for the personnel operating explosive production processes, control and supervision of compliance with the technological mode, rules and standards of safety, industrial sanitation and fire safety.

Equipment, devices and tools used to perform work on the aircraft reconfiguration analysis (workplace) must not obstruct the routes of movement of operating personnel, must be securely installed or secured to prevent falling in case of an accidental collision with them.

The laptop must have factory-provided protection against electric shock. Also, try to avoid working with damaged sockets and plugs.

4.4 Safety instructions when work at the computer

Before you start to work, check the following:

1. Location of computer components (monitor, printer, and other units).

2. Integrity of connecting cables.

3. Connect the computer components according to the wiring diagram.

4. The presence and condition of protective covers. Prepare your computer for disconnected operation.

5. Connect the computer sequentially according to the operating instructions.

During operating and time after work, do the following steps:

1. Do not connect or disconnect power connectors while the computer is on.

2. Turn off the computer monitor during work breaks

3. Do not leave your computer running unattended.

4. Report to the supervisor for the technical condition of the computer, all remarks, and malfunctions of the computer.

5. Turn off the computer in the sequence according to the operating instructions. Turn off the printer and other devices. Turn off the stabilizer if your computer is connected to a network through it. Pull the plugs out of the sockets.

6. Tidy up the workplace, remove unnecessary items and waste.

7. Put media in storage, if necessary.

CONCLUSION TO PART 4

The Occupational Safety and Health section provides a list of hazards and harmful factors that may happen during a review of the specifics of reconfiguring a passenger aircraft into a cargo aircraft.

After analyzing the hazardous and harmful factors that occur at work during the aircraft reconfiguration analysis, specific and constructive safety requirements were developed, which exclude injuries and improve the health and working conditions of technical personnel. There were proposed processes of measures to improve the health and safety management system and create working conditions that meet the requirements of regulations, which will improve the safety and efficiency of the engineering staff of the air base and were compared with current regulations. Also, calculations for the rational lighting of working areas and workplaces were provided.

7. ENVIRONMENTAL PROTECTION

5.1 ICAO requirements towards aircraft impact into the atmosphere

Ecological activity is one of the most relevant and necessary activities of modern humans. It includes all types and forms of human activities related to the rational solution of environmental problems, ecologization of social production, and all social activity.

In view of the serious environmental degradation over the past 100 years, all decisions related to the use of human and natural resources must be made in a way that takes into account their subsequent impact on the environment.

Nowadays, a lot of human economic activity harms nature and contributes to climate change. The only question is how much this or that type of activity contributes to this overall process.

The rapid growth of air traffic in the world, the increase in the total fleet of regular aircraft and their cargo capacity (passenger capacity), as well as the power of aircraft engines, the increasing congestion of the largest international hubs (hub airports with a high portion of connecting flights), makes the impact of civil aviation on the environment more evident and significant [35, 36, 37, 38].

Aircraft, like any system that uses energy from the oxidation of hydrocarbon fuel, releases the products of this process into the atmosphere, which change the natural atmosphere composition and are considered pollutants. Two types of hydrocarbon fuels are used in aviation: kerosene and gasoline. The main difference in the composition of the combustion products is that leaded gasoline used in piston airplanes produces lead in the exhaust gases, which is one of the undesirable components of air pollution [35, 39]. However, the role of airplanes with piston engines in modern aviation is insignificant and is constantly diminishing.

The fact that airplanes pollute the environment with their exhaust fumes is quite obvious and unquestionable. Aircraft engines create significant emissions from burning fossil fuels, producing noise, gases and particulate matter, raising ecologists' concerns about their global impact and their impact on local air quality.

Besides carbon dioxide, water vapor, nitrogen, and some other natural components of atmospheric air, kerosene combustion products contain carbon monoxide, various hydrocarbons (methane, acetylene, ethane, propane, benzene, toluene, etc.), aldehydes, nitrogen and sulfur oxides, soot particles that form a smoke plume behind the engine nozzle, as well as a number of other components formed in small quantities from the impurities present in kerosene. The levels of various hazardous substances in the air are regulated by maximum permissible concentrations. In aviation, emission limits are currently set for four harmful components: carbon monoxide (CO), unburned hydrocarbons (CnHm), nitrogen oxides (NOx), and soot particles (smoke).

Airplanes emit gases (water vapor, carbon dioxide, nitrogen oxides, or carbon monoxide − bonding with oxygen to become CO_2 upon release) and atmospheric particulates (incompletely burned hydrocarbons, sulfur oxides, black carbon), interacting among themselves and with the atmosphere [40]. However, the main cause of greenhouse gas emissions from aircraft is CO_2.

In 2018, global commercial operations emitted 918 million tons of CO_2, 2.4% of all CO_2 emissions: 747 million tons for passenger transport and 171 million tons for freight operations. Between 1940 and 2018, CO_2 emissions increased 6.8 times from 152 to 1,034 million tons per year. That means from 0.7% to 2.65% of all CO_2 emissions [41].

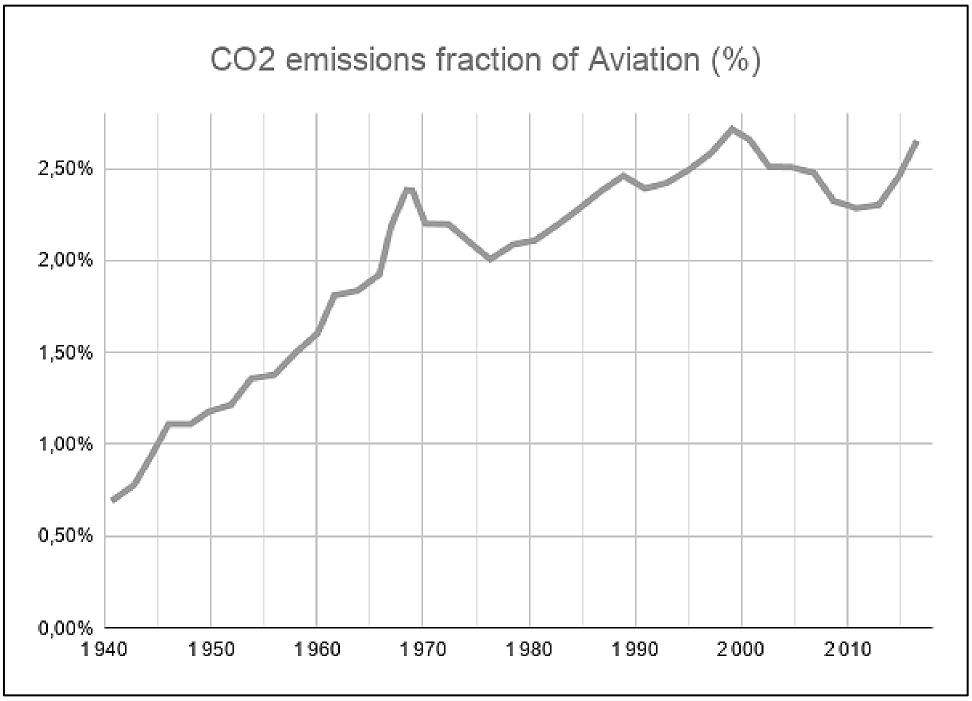

Figure 5.1 CO^2 emissions increasing during 1940 – 2018 [41]

Today aviation uses fossil fuels: about 5 million barrels of oil are burned per day. Flying, therefore, contributes approximately 3 percent of our carbon emissions to the atmosphere. There is currently no way to fly without burning tons of kerosene. Of course, airplanes are becoming more and more economical and environmentally friendly, but this is not enough to compensate for the increase in the number of flights.

In civil aviation, International Civil Aviation Organization (ICAO) standards on the emission of harmful substances are applied, which are periodically revised towards more stringent standards.

No doubt that the 2019 pandemic had a strong impact on air travel around the world. Borders of many countries were closed for a long time, tourist destinations and any travel were restricted. Thus, government restrictive actions had a strong impact on the decline in air travel and exhaust emissions, respectively.

The 2019 pandemic was blamed for the decline in air travel, not gradually, but almost immediately, and already in the spring of 2020, according to the IATA report [42] April month showed the following statistics: global air travel was about 95% below the level of 2019. In the new investigation by the Global Carbon Project, Stanford Earth Professor R.

Jackson and other co-authors found a 17% reduction in carbon dioxide (CO_2) emissions due to the global spread of the coronavirus pandemic [43].

Since aviation's impact on the environment remains an open issue, the ICAO and many other organizations are trying to reduce emissions and find alternatives to save the environment.

In 2001, the ICAO Assembly called on governments to promote and cooperate scientific research with the Intergovernmental Panel on Climate Change (IPCC) and other organizations involved in determining the contribution of aviation to environmental problems in the atmosphere and the need to take initiatives to understand these problems scientifically [44].

With a view to minimize the adverse effects of international civil aviation on the global climate, ICAO formulates policies, develops and updates Standards and Recommended Practices (SARPs) on aircraft emissions, and conducts outreach activities. These activities are conducted by the Secretariat and the Committee on Aviation and Environmental Protection (CAEP). The CAEP was created in 1983. Basically, these documents are issued in the form of Appendix 16, "Environmental Protection" [45, 46] to the Convention on International Civil Aviation.

In order to measure airport air quality, in 2007 the "Guidance Material on Fees for Aviation Emissions Related to Local Air Quality" was developed, which implied the introduction of fees levied by the state, specifically designed and applied to prevent or reduce the environmental impact on local air quality caused by the operation of civil aircraft [47]. The methodology for assessing aircraft engine emissions was outlined in the subsequently developed Document 9889, "Guide to Airport Air Quality" [48]. It formulated methods for evaluating aircraft engine emissions at the airport, based on consideration of three parameters.

The first parameter is the time, in minutes, that an aircraft actually spends to establish one of the takeoffs and landing cycle modes: during engine operation in low gas mode, during the landing approach, during climb and takeoff.

The second parameter is the emission index EI (mass of substance emitted during the combustion of a unit mass of fuel).

The third parameter is fuel consumption.

In the second edition of environmental protection [46] it is established that for the purpose of certification of aircraft engines, the following types of emissions are standardized: smoke, unburned hydrocarbons (HC), carbon monoxide (CO), nitrogen oxides (NOx).

In 2016, CAEP recommended two new standards: for carbon dioxide and nonvolatile particulate matter emissions. The recommended CO2 standard was proposed to encourage more efficient combustion technologies in aircraft production and is similar to existing standards for emissions and aircraft noise [45, 46]. The standards would apply to new type subsonic and turboprop aircraft models to be put into service from 2020, and to those already in service from 2023. If in-service models which do not yet meet the CO2 standards cannot be properly modified before 2028, they cannot be used after that date. Emissions will be regulated by the proposed Global Market-based System of Measures.

Exceeding the emission limits (emissions in 2019-2020 are assumed to be the base level) will be subject to a significant penalty, which will be used to restore the environment and compensatory measures. This approach to emissions limits is not new; it has been used in the European Union since the early 2000s [49]. For example, in April 2014, Germany fined 61 airlines from Russia and other countries for exceeding emission quotas by 2.7 million euros, 44 of which were based outside European territory [50].

5.2 What way the rebuild configuration can become environmentally friendly?

Although aviation is a relatively "clean" type of transportation in comparison to others, its effects on the climate and the environment can become significant over time because of ever-increasing air traffic resulting in increased pollution in the upper layers of the troposphere. Although estimates of such impacts are currently very uncertain, the International Civil Aviation Organization is taking steps to reduce the environmental impact of aviation.

To this end, new standards are being developed to strengthen emission requirements for aircraft in operation, as well as expanding the list of aviation emissions for which aircraft engines are certified. ICAO's Committee on Environmental Protection proposes the Global Market Measures mechanism as the main tool for regulating the negative impact of aviation on the atmosphere.

Experts identified several factors that influence the volume of emissions from air transportation. Accordingly, it is possible to name the measures that should be taken to reduce these volumes:

1. The development of new power plants with higher energy efficiency will show the result of improved performance and energy efficiency in the future.

The most promising for aviation, if we focus on reducing the carbon footprint and the emission of harmful substances into the atmosphere, is the use of electric and hybrid propulsion systems. What is a hybrid propulsion system? It is a combination of a piston or gas turbine engine with electric and battery power. Power plants of this type will provide a tangible reduction in the impact on the environment, or reduce it to zero in the case of electric ones.

The use of electricity provides an opportunity to reduce emissions, noise and fuel consumption - for example, you can use purely electric traction on the "taxiway" at the airport, then there will be no emissions on the ground.

In 2015-2016, the first manned round-the-world flight was made by Solar Impulse 2, a solar-powered electric plane [51]. The only restriction is that it has to take off during daylight hours.

2. Used fuels and other energy sources can be replaced by switching to alternative fuels and energy sources with low or zero greenhouse gas emissions.

The conversion of aircraft to low-carbon fuels - will reduce emissions even as air travel increases. The development of biofuels is in progress.

CONCLUSION TO PART 5

The results of the research presented in the work indicate that the development of civil aviation is impossible without comprehensive measures to reduce environmental pollution during the processes of operation and maintenance of air transport and to prevent the negative environmental consequences caused by pollution.

The priority tasks include the reduction of emissions of harmful substances by aircraft engines.

The solution to these problems is especially relevant for civil aviation. Regarding the emission of harmful substances, the requirements and possible options to reduce pollution in the airport areas, during the flight and its alternatives to reduce the impact on the environment and the population have been considered.

Solving these problems of global scale and importance is possible only on the basis of international cooperation and coordinated actions of all countries of the world community.

GENERAL CONCLUSION

In the course of this work, an analysis of the missions, goals, benefits of air transportation, as well as assumptions about the prospects for further development of this industry was conducted. Due to the rapid development of technology, we can confidently say that over time, air transportation will take a significant part of transportation around the world, replacing transportation by ship, road transport and trains. The reason for this is the ratio of price and speed of delivery, as well as the volume of transported cargo.

Based on this analysis, it was concluded that the need of cargo planes is quite high, moreover, considering that the demand for passenger transportation has decreased due to the pandemic, airlines can reduce the loss in budget by reconfiguring the passenger aircraft into a cargo aircraft.

As a result, the aim, research objectives, object, subject and methods were identified to develop a work devoted to the features of passenger into a cargo airplane reconfiguration.

The first step was to review the literature, scientific publications, certificates, airworthiness standards, etc., to determine the procedural aspects of aircraft reconfiguration and their compliance with ICAO, EASA and State Aviation Administration of Ukraine requirements. This knowledge gave a clear understanding of the algorithm for performing aircraft reconfiguration.

Thus, the second chapter of the diploma work considers in detail the process from the moment the customer sends information about the aircraft to the company where the new design will be created, till the work on the modification of the aircraft design and systems and execution of documents, airworthiness check by means of a test flight.

Structural changes include major structural changes necessary for the new configuration, such as: installing special systems necessary to perform cargo loading, modifying all systems because of the aircraft's new mission, removing everything no longer needed from the passenger aircraft, such as internal equipment and fittings, removing and deactivating passenger doors, reinforcing main deck cargo floor beams to meet cargo load requirements, installing the main deck cargo door, installation of portable oxygen equipment for use during in-flight cargo bay access, installation of 9g hard barrier/netting, modification of area behind cockpit, modification of cargo bay, conversion of main deck to "class E" cargo bay, modification of cockpit and onboard equipment as needed, installation of cargo loading system, installation of light window plugs, etc. The change in the air conditioning system was also considered in detail: the installation of new ducts, packs and valves for correct operation and avoiding a fire ignition or fire in the cargo compartments.

Calculation of changes in mass parts of systems, equipment and others was provided to determine the new center of gravity and new take-off weight of the aircraft, which corresponds to the projection of the design in accordance with the standards of airworthiness.

In the materials of the explanatory note also made calculations of the necessary illumination within the limits of acceptable standards for the section of labor protection. The issues related to environmental protection and the requirements of the ICAO norms are considered.

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Appendix A

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П Р О Е К Т
                    С А М О Л Е Т А   С   Т Р Д Д
                       НАУ,   кафедра  К Л А
   ПРОЕКТ    дипломный          Расчет выполнен    29.10.2021
   Исполнитель Кравченко В.Д.   Руководитель     Юцкевич С.С.

          ИСХОДНЫЕ ДАННЫЕ И ВЫБРАННЫЕ ПАРАМЕТРЫ
  Количество пассажиров                                        524.
  Количество членов экипажа                                    2.
  Количество бортпроводников или сопровождающих                10.
  Масса снаряжения и служебного груза                        4851.00 кг.
  Масса коммерческой нагрузки                               68120.00 кг.

  Крейсерская скорость полета                                850. км/ч
  Число "М" полета при крейсерской скорости                    0.7989
  Расчетная высота начала реализации полетов с крейсерской
  экономической скоростью                                      12.000 км
  Дальность полета с максимальной коммерческой нагрузкой      7000. км.
  Длина летной полосы аэродрома базирования                    2.95 км.

  Количество двигателей                                        4.
  Оценка по статистике энерговооруженности в квт/кг            2.5200
  Степень повышения давления                                  32.00
  Принятая степень двухконторности двигателя                  6.00
  Оптимальная степень двухконторности двигателя               5.00
  Относительная масса топлива по статистике                   0.2800

  Удлинение крыла                                              7.91
  Сужение крыла                                                4.10
  Средняя относительная толщина крыла                          0.160
  Стреловидность крыла по 0.25 хорд                           37.5  град.
  Степень механизированности крыла                             1.100
  Относительная площадь прикорневых наплывов                   0.100
  Профиль крыла - Суперкритический
  Шайбы УИТКОМБА - установлены
  Спойлеры - установлены

  Диаметр фюзеляжа                                           6.80 м.
  Удлинение фюзеляжа                                        10.30
  Стреловидность горизонтального оперения                   44.0 град.
  Стреловидность вертикального оперения                     48.0  град.


                  Р Е З У Л Ь Т А Т Ы   Р А С Ч Е Т А
                  НАУ, АКИ, КАФЕДРА "К Л А"
   Значение  оптимального  коэффициента  подъемной силы в расчетной точке
   крейсерского режима полета     Су        0.45138
   Значение коэффициента          Сх.инд.   0.00941

       ОПРЕДЕЛЕНИЕ КОЭФФИЦИЕНТА  Dм = Мкрит - Мкрейс
   Число Маха крейсерское               Мкрейс  0.79887
   Число Маха волнового кризиса         Мкрит   0.81752
   Вычисленное значение                 Dm      0.01865

     Значения удельных нагрузок на крыло в кПА(по полной площади):
               при взлете                         4.722
               в середине крейсерского участка    3.919
               в начале крейсерского участка      4.539
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Значение коэффициента сопротивления фюзеляжа и гондол	0.00727
Значение коэфф. профиль. сопротивления крыла и оперения	0.00945
Значение коэффициента сопротивления самолета:	
в начале крейсерского режима	0.02894
в середине крейсерского режима	0.02745

Среднее значение Cy при условном полете по потолкам	0.45138
Среднее крейсерское качество самолета	16.44499

Значение коэффициента Cy.пос.	1.417
Значение коэффициента (при скорости сваливания) Cy.пос.макс.	2.125
Значение коэффициента (при скорости сваливания) Cy.взл.макс.	1.743
Значение коэффициента Cy.отр.	1.272
Тяговооруженность в начале крейсерского режима	0.554
Стартовая тяговооруж. по условиям крейс. режима Ro.кр.	2.649
Стартовая тяговооруж. по условиям безопасного взлета Ro.взл.	2.177

Расчетная тяговооруженность самолета Ro 2.756

Отношение Dr = Ro.кр / Ro.взл Dr 1.217

УДЕЛЬНЫЕ РАСХОДЫ ТОПЛИВА (в кг/кН*ч):

взлетный	34.4877
крейсерский (характеристика двигателя)	56.9816
средний крейсерский при заданной дальности полета	59.4439

ОТНОСИТЕЛЬНЫЕ МАССЫ ТОПЛИВА:

аэронавигационный запас	0.03253
расходуемая масса топлива	0.28856

ЗНАЧЕНИЯ ОТНОСИТЕЛЬНЫХ МАСС ОСНОВНЫХ ГРУПП:

крыла	0.09975
горизонтального оперения	0.01269
вертикального оперения	0.01268
шасси	0.04169
силовой установки	0.09481
фюзеляжа	0.08150
оборудования и управления	0.1134
дополнительного оснащения	0.00914
служебной нагрузки	0.00552
топлива при Lрасч.	0.32109
коммерческой нагрузки	0.20780

Взлетная масса самолета "М.о" = 327812. кГ.

Потребная взлетная тяга одного двигателя 225.78 kH

Относительная масса высотного оборудования и противообледенительной системы самолета	0.0200
Относительная масса пассажирского оборудования (или оборудования кабин грузового самолета)	0.0115
Относительная масса декоративной обшивки и ТЗИ	0.0058
Относительная масса бытового (или грузового) оборудования	0.01
Относительная масса управления	0.0040
Относительная масса гидросистем	0.0129
Относительная масса электрооборудования	0.0207
Относительная масса локационного оборудования	0.0018

Относительная масса навигационного оборудования	0.0026
Относительная масса радиосвязного оборудования	0.0013
Относительная масса приборного оборудования	0.0031
Относительная масса топливной системы (входит в массу "СУ")	0.0106
Дополнительное оснащение:	
Относительная масса контейнерного оборудования	0.0064
Относительная масса нетипичного оборудования [встроенные системы диагностики и контроля параметров, дополнительное оснащение салонов и пр.]	0.0027

ХАРАКТЕРИСТИКИ ВЗЛЕТНОЙ ДИСТАНЦИИ

Скорость отрыва самолета	277.28 км/ч
Ускорение при разбеге	2.00 м/с*с
Длина разбега самолета	1481. м.
Дистанция набора безопасной высоты	472. м.
Взлетная дистанция	1953. м.

ХАРАКТЕРИСТИКИ ВЗЛЕТНОЙ ДИСТАНЦИИ ПРОДОЛЖЕННОГО ВЗЛЕТА

Скорость принятия решения	249.55 км/ч
Среднее ускорение при продолженном взлете на мокрой ВПП	0.78 м/с*с
Длина разбега при продолженном взлете на мокрой ВПП	1872.43 м.
Взлетная дистанция продолженного взлета	2344.64 м.
Потребная длина летной полосы по условиям прерванного взлета	2430.66 м.

ХАРАКТЕРИСТИКИ ПОСАДОЧНОЙ ДИСТАНЦИИ

Максимальная посадочная масса самолета	248840.	кг.
Время снижения с высоты эшелона до высоты полета по кругу	22.7	мин.
Дистанция снижения	53.56	км.
Скорость захода на посадку	246.19	км/ч.
Средняя вертикальная скорость снижения	1.99	м/с
Дистанция воздушного участка	515.	м.
Посадочная скорость	231.19	км/ч.
Длина пробега	728.	м.
Посадочная дистанция	1244.	м.
Потребная длина летной полосы (ВПП + КПБ) для основного аэродрома	2077.	м.
Потребная длина летной полосы для запасного аэродрома	1766.	м.

ПОКАЗАТЕЛИ ЭФФЕКТИВНОСТИ САМОЛЕТА

Отношение массы снаряженного самолета к массе коммерческой нагрузки	2.2229
Масса пустого снаряженного с-та приход. на 1 пассажира	288.98 кг/пас.
Относительная производительность по полной нагрузке	449.56 км/ч
Производительность с-та при макс. коммерч. нагрузке	55866.8 кг*км/ч
Средний часовой расход топлива	11082.657 кг/ч
Средний километровый расход топлива	13.51 кг/км
Средний расход топлива на тоннокилометр	198.376 г/(т*км)
Средний расход топлива на пассажирокилометр	22.7549 г/(пас.*км)
Ориентировочная оценка приведен. затрат на тоннокилометр	0.3474$/(т*км)