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SELECTED ISSUES RULES OF WEIGHT CONTROL AIRCRAFT

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Abstract

In the era of dynamic development of the sciences, uninterrupted security is a priority for each of the sectors of transport. Flight safety depends on many factors that determine the quality and number of operations performed and functioning air transport system whereas the means of transport which is the aircraft. By factors must be understood as any action case, condition or situation where the existence or non-existence increases the probability of failure of the flight. The technical and organizational complexity of air transport system, a multitude of aviation personnel, the operation of the aircraft in various weather conditions are sources of various factors affecting flight safety. This article presents one of the very important things that must be done before every flight - the balance of the aircraft, which is a way of determining the centre of gravity plane COG, moreover, in the article also describes the weight of the passenger. Exemplified filled sheet loading and balance for Boeing B737-400 with the necessary tables, indexes, aimed at normalizing the data. Presented article is an introduction to the issue of control of the weight of the aircraft, taking into account the mass of passengers and their impact on the respective position of the centre of gravity of the aircraft.

Keywords: *balancing plane, the centre of gravity of the airplane, the weight of the load*

1. Introduction

Air transport in Poland, as well as in the world, is one of the most developing branches of transport. The main objective of air transport is to ensure safe and efficient movement of people and goods while minimizing costs. Aviation is a multi-faceted concept; one of the issues is the process of loading and balance of the aircraft, which determine the position of the centre of gravity of the aircraft after being loaded. Taking flight with a centre of gravity located outside the permissible is not compatible with the provisions and prohibited.

It is the act of loading and balance is responsible for the correct operation of the aircraft and the safe and economical performance of flights. That is why it becomes essential to analyse the weight of cargo in terms of balance of the aircraft. Changes in mass of loads for example. Passengers have a significant impact on the way of loading, moreover, being only one of many masses taken into account when balancing the aircraft also have a bearing on the size of the remaining cargo approved for the flight.

2. Rules of the aircraft balancing

Balancing plane is considered the case of a flight on which the aircraft moves along a straight track at constant speed. This case occurs when the resultant external forces acting on the aircraft shown in Fig. 1 and moments from these forces in balance, i.e. Thrust (T) is equal to the force of resistance (D) and lift (L) is equal to the force of gravity (Q).

By definition, a moment is product of the force and the arm on which the force acts. While the balance between the thrust and the drag force is practically easy to achieve (level flight at a constant speed), it balances the lift and gravity forces is more difficult. This is due to the fact that the centre of gravity COG is dependent on the loading plane, and the position of the centre of pressure, the point of application of the lift from the speed at which the aircraft is flying, i.e. is different for different aircraft speed.

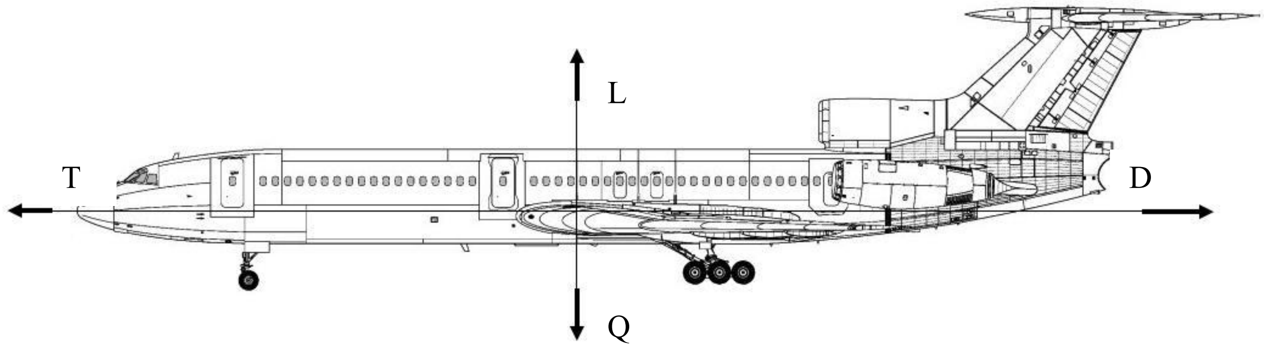

Fig. 1. The distribution of forces on the example of the aircraft

These points usually do not overlap, so arises the so-called couple that gives you time causing drooping or mess nose of the aircraft. Prevents horizontal tail, fitted to the aircraft. It evokes the power of F_H balancing this moment, as presented in Fig. 2.

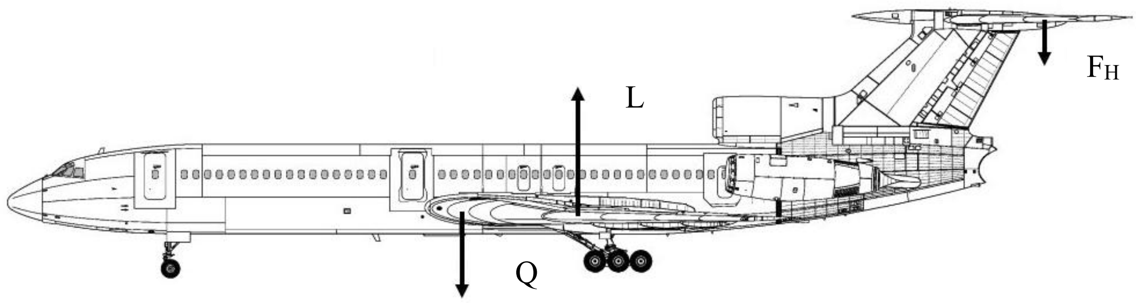

Fig. 2. The distribution of forces on the example of the aircraft

In this case (relative to any point):

$$L + Q + F_H = 0,$$
$$M(L) + M(Q) + M(F_H) = 0, \tag{1}$$

where:
L – lift force,
Q – gravity force,
F_H – horizontal stabilizer force,
M(L) – moment of lift force,
M(Q) – moment of gravity force,
$M(F_H)$ – moment of horizontal stabilizer force.

The strength of the horizontal stabilizer (F_H) depends on the inclination angle of the stabilizer. This angle is limited, strictly defined range. For this reason, the moment of force from the pair of L and Q cannot exceed a specified size precisely – the limited value F_H force.

Position of the centre of pressure determines the aerodynamic aircraft, on which the user has no control. Consequently, only by controlling the position of the centre of gravity of the airplane (COG) via a respective load, you can provide the desired balance of torques on the fly [1, 5-7].

3. COG location

An airplane in flight can be manoeuvred by the pilot using the aerodynamic control surfaces, the elevator, rudder or ailerons. As the control surfaces change the amount of force that each surface generates, the aircraft rotates about a point called the centre of gravity. The centre of gravity is the average location of the weight of the aircraft.

Location COG is defined in the following units:

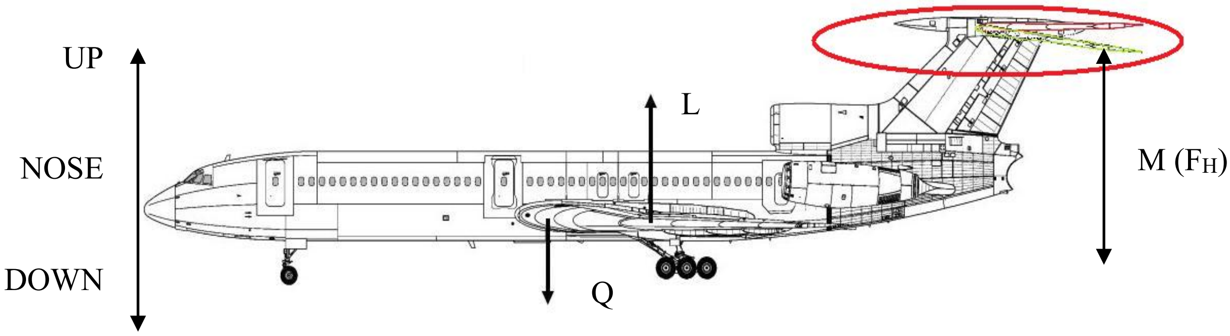

Fig. 3. The principle of operation of the horizontal tail of the aircraft

1. % MAC (Mean Aerodynamic Chord) – percentage of the mean aerodynamic chord.

By definition, the chord is a line connecting the nose wing profile of the trailing edge. In contrast, mean aerodynamic chord of the wing is MAC imaginary chord replacement wings with a rectangular contour with the same properties as the aerodynamic wing real. MAC value and permissible extreme front and rear extreme position of centre of gravity in percentages MAC for specific cargo plane is determined by the manufacturer of the aircraft.

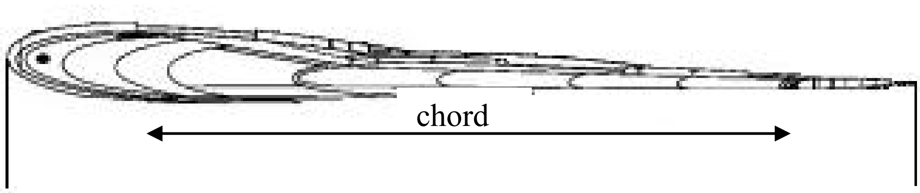

Fig. 4. The chord wings

Assuming the length of the MAC as 100% may determine a location of the centre of gravity is located on the chord as % MAC, as has been presented in Fig. 5.

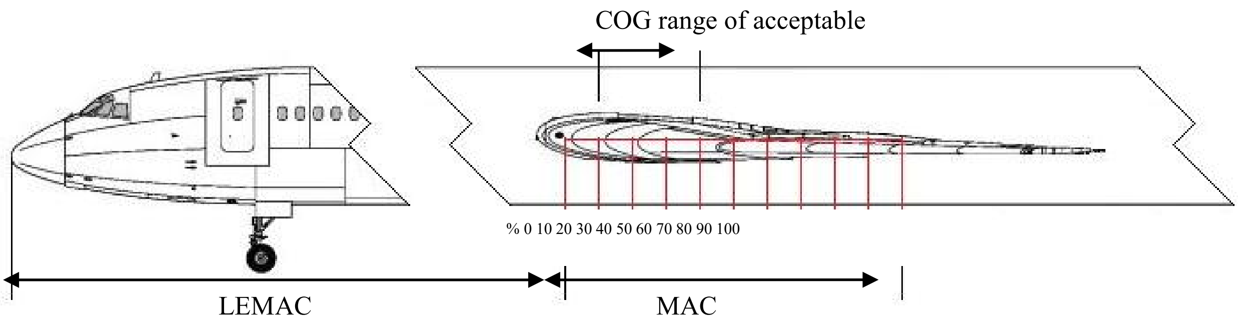

Fig. 5. Graphical representation of the allowable position COG

2. Index – unit unitless.

This unit expresses the impact of the component forces of gravity to change the position of centre of gravity depending on the location of these forces in relation to the contractual point of reference point called Ref. Station. In other words, Index is the equivalent moment of component forces of gravity relative to the Ref. Station.

Ref. Station is a conventional reference point (specified by the manufacturer of the aircraft) with respect to which are calculated moments of the constituent forces of gravity from all the elements of the aircraft and cargo.

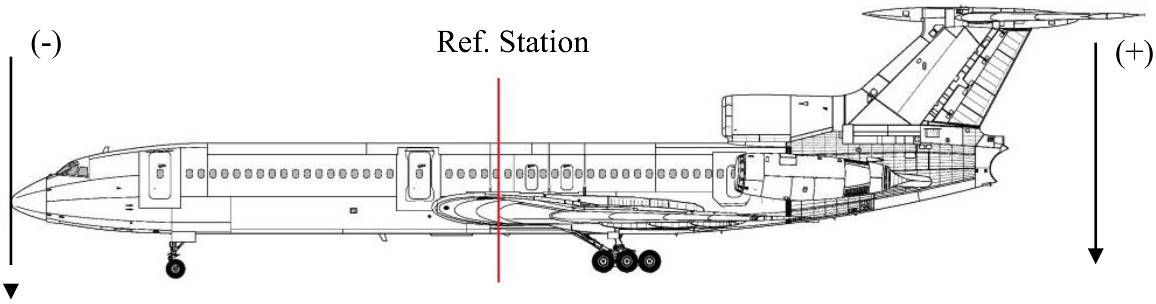

Fig. 6. Graphic location Ref Station

Depending on the position of the load relative to the Ref. Station, arms have the following values:

- arms measured from Ref. Station towards the nose of the aircraft have negative
- arms measured from Ref. Station toward the tail of the aircraft have positive values.

Therefore, any cargo in the aircraft, depending on its location corresponds to the positive or negative value of the index, showing the impact of the charge on the change of the centre of gravity [6, 7].

Conversion index on % MAC is made on the chart, showing the value of % MAC as a function of specific weight aircraft and indexes.

Below are example tables, indexes for aircraft Boeing B737-400, which contain information on passengers, baggage, fuel, pantry indifferent flights version.

Tab. 1. Tables of indexes for baggage and cargo in individual trunks aircraft

BAGGAGE – CARGO INDEX TABLES							
COMPT. 1		COMPT. 2		COMPT. 3		COMPT. 4	
Weight (kg)	Index Units	Weight (kg)	Index Units	Weight (kg)	Index Units	Weight (kg)	Index Units
0-40	0	0-66	0	0-80	0	0-40	0
41-120	- 1	67-198	- 1	81-240	1	41-120	1
121-200	- 2	199-330	- 2	241-401	2	121-201	2
201-280	- 3	331-462	- 3	402-561	3	202-282	3
281-360	- 4	463-594	- 4	562-721	4	283-362	4
361-440	- 5	595-726	- 5	722-882	5	363-443	5
441-520	- 6	727-859	- 6	883-1042	6	444-524	6
521-600	- 7	860-991	- 7	1043-1203	7	525-604	7
601-680	- 8	992-1123	- 8	1204-1363	8	605-685	8
681-761	- 9	1124-1255	- 9	1364-1524	9	686-765	9
762-841	- 10	1256-1387	- 10	1525-1684	10	766-846	10
842-921	- 11	1388-1519	- 11	1685-1844	11	847-927	11
922-1001	- 12	1520-1651	- 12	1845-2005	12	928-1007	12
1002-1081	- 13	1652-1784	- 13	2005-2165	13	1008-1088	13
1082-1161	- 14	1785-1916	- 14	2166-2326	14	1089-1125	14
				2327-2486	15		
1162-1241	- 15	1917-2048	- 15	2487-2647	16		
1242-1245	- 16	2049-2059	- 16	2648-2807	17		
				2808-2967	18		
				2968-3062	19		

Tab. 2. Tables of indexes to passengers in case of flight standard and holiday

PAX INDEX TABLE									
ALL FLIGHTS EXCEPT HOLIDAY CHARTERS					HOLIDAY CHARTERS ONLY				
COMPT. A 48 Max PAX		COMPT. B 48 Max PAX	COMPT. C 52 Max PAX		COMPT. A 48 Max PAX		COMPT. B 48 Max PAX	COMPT. C 52 Max PAX	
PAX	Index Unit		PAX	Index Unit	PAX	Index Unit		PAX	Index Unit
1	- 1		1-2	1	1-2	- 1		1-2	1
2-3	- 2		3	2	3	- 2		3	2
4	- 3		4	3	4-5	- 3		4-5	3
5	- 4		5-6	4	6	- 4		6	4
6-7	- 5		7	5	7-8	- 5		7-8	5
8	- 6		8	6	9	- 6		9	6
9	- 7		9-10	7	10	- 7		10-11	7
10-11	- 8		11	8	11-12	- 8		12	8
12	- 9		12	9	13	- 9		13-14	9
13	- 10		13-14	10	14-15	- 10		15	10
14-15	- 11		15	11	16	- 11		16-17	11
16	- 12		16-17	12	17-18	- 12		18	12
17	- 13		18	13	19	- 13		19-20	13
18-19	- 14		19	14	20-21	- 14		21	14
20	- 15		20-21	15	22	- 15		22-23	15
21	- 16		22	16	23-24	- 16		24	16
22-23	- 17		23	17	25	- 17		25-26	17
24	- 18		24-25	18	26-27	- 18		27	18
25	- 19	No index change	26	19	28	- 19	No index change	28-29	19
26-27-	- 20		27	20	29	- 20		30	20
28	- 21		28-29	21	30-31	- 21		31-32	21
29	- 22		30	22	32	- 22		33	22
30-31	- 23		31-32	23	33-34	- 23		34-35	23
32	- 24		33	24	35	- 24		36	24
33	- 25		34	25	36-37	- 25		37-38	25
34-35	- 26		35-36	26	38	- 26		39	26
36	- 27		37	27	39-40	- 27		40-41	27
37	- 28		38	28	41	- 28		42	28
38	- 29		39-40	29	42-43	- 29		43-44	29
39-40	- 30		41	30	44	- 30		45	30
41	- 31		42	31	45-46	- 31		46-47	31
42	- 32		43-44	32	47	- 32		48	32
43-44	- 33		45	33	48	- 33		49-50	33
45	- 34		46-47	34					
46	- 35		48	35				51	34
47-48	- 36		49	36					
			50-51	37					

Tab. 3. Table generalized crew weights and indices depending on the composition of the crew

INDEX AND WEIGHT CORRECTION TABLE FOR CREW								
Cockpit Crew/Cabin Crew	2/6	2/5	2/4	2/0	3/6	3/5	3/4	3/0
Weight (kg)	620	545	470	170	705	630	555	255
Index Units	- 1	- 2	- 3	- 3	- 3	- 4	- 5	- 5

These tables are used primarily to normalize the data necessary for a proper balance of the aircraft. The data indexes to enter the balance sheet of the aircraft to determine the two main indices, namely mass index at zero fuel – Zero Fuel Index, and to start mass index – Take off Index. Based on the graph taking into account the above index is a certain way to balance the aircraft by determining the % MAC.

Tab. 4. Table indexes of pantry depending on storage

INDEX CORRECTION FOR PANTRY			
FWD GALLEY G1+G2+G7		AFT GALLEY G3A+G4B	
Weight (kg)	Index Units	Weight (kg)	Index Units
0-32	0	0-31	0
33-96	- 1	32-94	1
97-161	- 2	95-157	2
162-225	- 3	158-220	3
226-289	- 4	221-283	4
290-354	- 5	284-345	5
355-418	- 6	346-408	6
419-483	- 7	409-471	7
484-547	- 8	472-534	8
548-611	- 9	535-597	9
612-676	- 10	598-660	10
677-740	- 11	661-723	11
741-805	- 12	724-786	12
806-869	- 13	787-849	13
870-933	- 14	850-912	14
934-998	- 15	913-975	15
999-1062	- 16	976-1037	16
1063-1127	- 17	1038-1100	17
1128-1169	- 18	1101-1163	18
		1164-1226	19
		1227-1247	20

Tab. 5. Table indexes of fuel

FUEL INDEX TABLE	
Weight (kg)	Index Units
0-500	0
501-1500	- 1
1501-2500	- 2
2501-5000	- 3
5001-7000	- 4
7001-7500	- 3
7501-8000	- 2
8001-8500	- 1
8501-9000	0
9001-9111*	+ 1
9112-10000	0
10001-10500	- 1
10501-11000	- 2
11001-12000	- 3
12001-12500	- 4
12501-13000	- 5
13001-13500	- 6
13501-14500	- 7
14501-15000	- 8
15001-15500	- 9
15501-16000	- 10
16001-16140**	- 11
* Tanks 1+2 Full ** Tanks 1+2+Center Tank Full	

In addition, knowing the weight off the aircraft and above. Take off index is determined the position of the stabilizer during take-off. The figure below shows, for example, filled sheet balance Boeing B737-400, which is the final effect of the loading and balance of the aircraft [2-4].

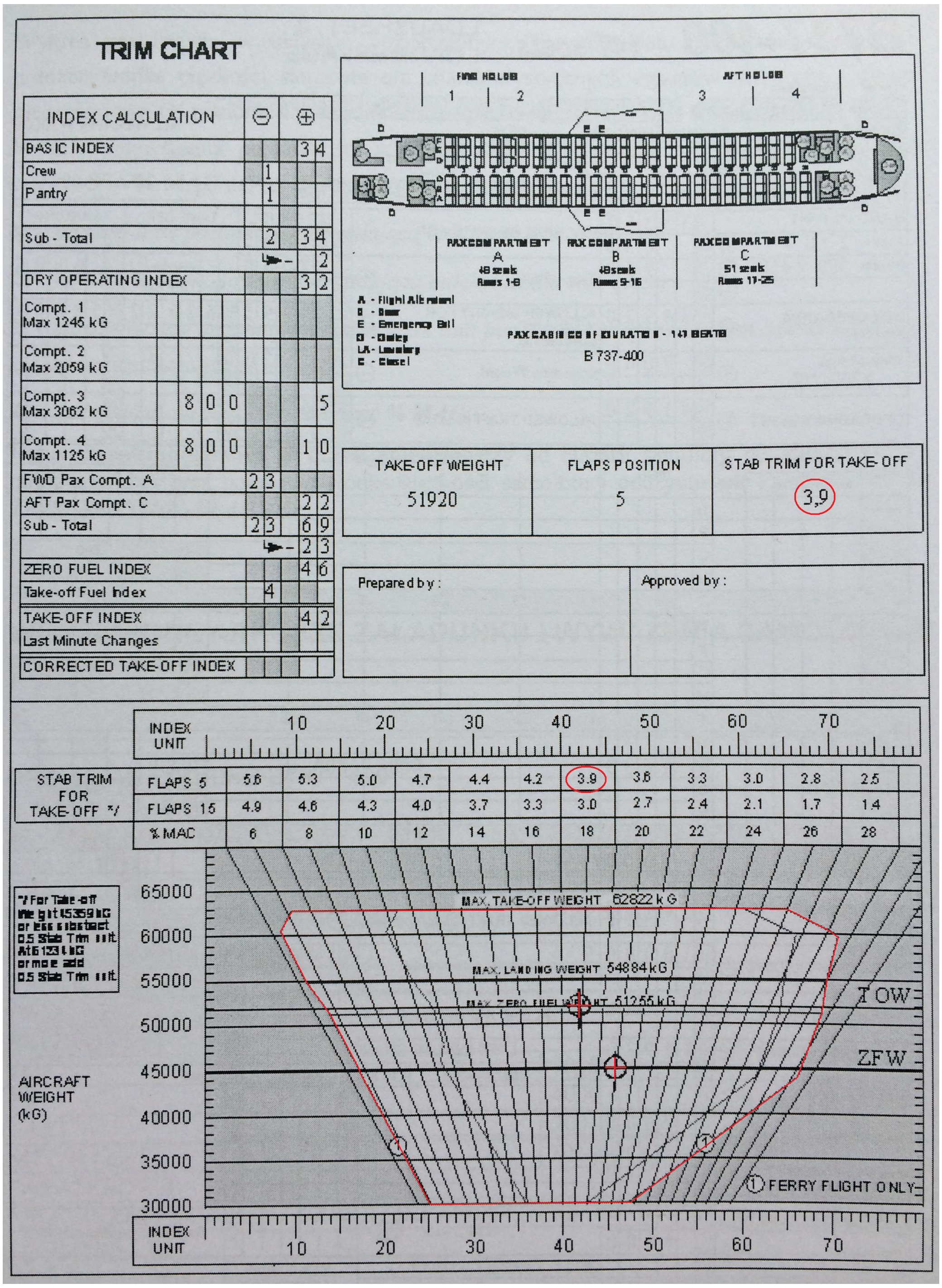

Fig. 7. Example of the completed balance sheet of the Boeing B737-400 aircraft

The purpose of this document is for the load controller to allocate the load, and the loader to confirm where the actual load is located on the aircraft. The load and trim sheet is prepared by the load controller detailing where the planned load is to be located in the holds, the loader then records where the actual load and weight is distributed in the holds. These sheets are communicated to the load controller enabling them to produce a load sheet that accurately reflects the actual weights and locations of the load.

4. Determination of weight of passengers

For calculations related to the preparation sheet loading and balance of the aircraft, the normal weight, specified in the procedure of IATA AHM 560.

If the weight of the crew shall be the total weight according to the configuration of the aircraft depending on the composition of the crew, the corresponding masses are presented in Tab. 3, the figure also includes a cabin luggage, but the mass of the crew baggage transported in the trunks is adopted on the basis of the actual value as checked recorded.

Average weight standard and alternative passengers are presented in Tab. 6. The weight accept standard for most flights (except holiday flights), and mass alternative is used in case of problems with the lifting capacity of trade. Masses however, these can be used only when the percentage of women in the total number of adult occupants of at least 23%.

Tab. 6. The standard mass for passengers on all flights except holiday charters

Passenger category	Standard weight [kg]	Alternate standard weight [kg]
man	84	88
woman	84	70
child 2-12 years	35	35
infant carried on a separate site passenger, aged less than 2 years	35	35
infant carried a common site with passengers, aged less than 2 years	0	0

For flights holiday (voyage charter) are part of the package holiday, the weight of standard and alternative passenger presented in Tab. 7, similarly in case of problems with the lifting capacity of the commercial select the weight of a standard alternative, provided that the percentage of women in the total number of adult occupants of at least 50%. On this cruise passengers free number (e.g. Employees forms do not exceed 5% of the seats installed in the airplane. The mass of the passenger cabin luggage includes 6 kg [6].

Tab. 7. The standard weight of passengers when flights cruises holiday charters

Passenger category	Standard weight [kg]	Alternate standard weight [kg]
man	76	83
woman	76	69
child 2-12 years	35	35
infant carried on a separate site passenger, aged less than 2 years	35	35
infant carried a common site with passengers, aged less than 2 years	0	0

5. Summary

This article presents one of the things that must be done before every flight – the balance of the aircraft, or method of determining the centre of gravity of the aircraft COG. Exemplified filled sheet loading and balance for Boeing B737-400 with the necessary tables, indexes, aimed at normalizing the data. In addition, specified in how to determine the total mass of passengers, depending on the type of operation, the standard or holiday charters.

The aim of the article is an introduction to the issue of control of the weight of the aircraft, taking into account the mass of passengers and their impact on the respective position of the centre of gravity of the aircraft, which results from the appropriate loading and balance.

Proper loading and balance of the airplane is one of the main factors determining the correct operation of the aircraft, safe and economical performance of flights.

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