Boeing B737-800SF (AEI)

Weight and Balance System for DemoAir

Substantiation Report B737-800SF (AEI)

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1 Introduction

1.1 Summary

This document is produced by Flyware as a quality assurance document in regards to calculations performed. It describes the preparation and use of weight and balance control method for the aircraft.

The airline is responsible to clear any loading method with their local regulatory authority.

The weight and balance system will:

- Ensure that the aircraft is safely loaded
- Provide an aircraft center of gravity at Take-Off with sufficient accuracy to enable the elevator trim to be set correctly
- Account for approved fuel management procedures

The system is based on the following criteria:

- Crew and authorized personnel locations in accordance with aircraft interior layout.
- Approved fuel and loading usage as per document **D0XXXXX-XX1** Rev **XX** related to Configuration G, E[X] assigned.
- Cargo data as shown
- Center of gravity limits for this aircraft as per X-XXX REV P Dated 22-JUL-2023 (referred to in this report as AEI W&B manual) **CONFIGURATION X** page 01-00-00 page 26.
- Calculations of indexes and moments according to arm values in inches.

1.2 Reference Data

- Weight and Balance Manual, Boeing Document No. per **D0XXXXX-XX1** Rev **XX** (referred to in this report as Standard W&B manual).
- Weighing Report as per values provided by Demo Air.

- AEI Weight and balance supplement document R-1006 REV P Dated 22-JUL-2023 (referred to in this report as AEI W&B manual).

1.3 General

The Weight and Balance System provides a means of

a) Determining the actual Zero Fuel, Take-Off and Landing weight of the aircraft, by adding or subtracting elements of weight to the Dry Operating Weight (DOW).
It is the operator's responsibility to ensure that the DOW is appropriate to the aircraft condition, and the operator's requirements at that time.

b) Determining the balance of the aircraft by summating index units, by means of index tables and scales, to give a Zero Fuel index to check for safe loading; and a Take-Off index, from which a Take-Off trim setting may be calculated.

A safe loading balance envelope has been developed from the certificated center of gravity limits and a load and trim sheet has been prepared to permit the addition of passenger, cargo and fuel weight and index units.

When summation of the index units places the aircraft center of gravity within the safe loading envelope, a safe operation is assured.

The Weight and Balance System, as described in this document, is valid only for the interior layout as detailed in section 4.1, 4.2 and 0 of this report. Any other layout will require the recalculation of the curtailed center of gravity limits and index units.

2 Basic Information

2.1 Reference datum and Balance arm

Reference datum is the point where the Balance Arm (B.A.) (also called horizontal arm) is equal to zero. The reference datum for this aircraft is located 540 in. (inches) forward of the front spar (see Figure 1). The balance arm (B.A.) is used to locate components and complete calculation of the aircraft for weight and balance purposes.

The Reference Station (Ref. Sta.) (also called C.G. B.A.) is a true measure from the reference datum and is used in index calculations. Reference station used in following calculations is located at **658.26 in** (LEMAC plus 20% of the length of MAC). Note that for this aircraft inch values are used for calculations and meters are given as reference only.

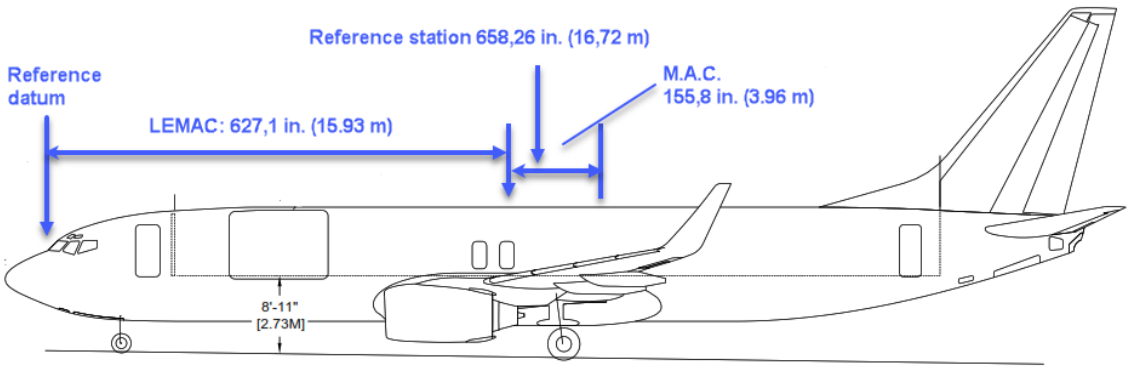

Figure 1 Reference station.

2.2 Mean Aerodynamic Chord (MAC)

The Mean Aerodynamic Chord/Reference Chord (MAC/RC) is a wing reference distance with a length of 155.8 inches from the Leading edge of the Mean Aerodynamic Chord (LEMAC) is at balance arm 627,1 in. (see Figure 1).

Note that inches (in.) values are used for all calculations and formulas as no meter (m) values are given by Boeing in the weight and balance manual in regards to calculation.

Conversion of the aircraft center of gravity from balance arm, in inches, to a percentage of Mean Aerodynamic Chord (%MAC) is derived using the following formula:

$$\%\,MAC\; = \frac{(Balance\ Arm - \;627.1)\;x\;100}{155.8}$$

The reverse conversion of the aircraft center of gravity from a percentage of Mean Aerodynamic Chord (%MAC) to balance arm, in inches, is derived using the following formula:

$$Balance\ Arm\; = \frac{(155.8\; \times \%MAC)}{100} + 627.1$$

2.3 Index Unit formula

It is often more convenient to compute balance effects of combined loads in index units instead of moments. Index is a value with no unit. Two constants appear in the formula for index values:

- C: Constant that is set to scale the index values.
- K: Constant that is set so that the final Zero Fuel, Take-Off and Landing index values are never negative.

The value of these constants depends on the aircraft type and from the WMB for this aircraft the following value has been set,

- C = 45000
- K = 45

To determine the Index for a complete aircraft the following formula is used:

$$Index\; = \frac{Aircraft\ Weight\ (kg)\; \times (Balance\ Arm - Ref.Sta)}{45000} + 45$$

To determine the index of an item the following formula is used:

$$Index = \frac{Item\ Weight\ (kg) \times (Balance\ Arm - Ref.Sta)}{45000}$$

3 Limitations

3.1 Maximum Design Weight Limitations

Maximum Design Taxi Weight (MRW)	79.242 kg
Maximum Design Take-Off Weight (MTOW)	79.015 kg
Maximum Design Landing Weight (MLW)	66.360 kg
Maximum Design Zero Fuel Weight (MZFW)	62.731 kg

Ref: AEI Weight and balance supplement document R-1006 REV P Dated 22-JUN-2023, CONFIGURATION X, PAGE 26 , 01-00-00.

3.2 Center of Gravity Limits

When prepared for flight the center of gravity of the aircraft must always lie between the forward and aft limits defined in the Aircraft Weight and Balance Manual or equivalent document. shows the certified envelope for **MSN 34799**, configuration E and G as stated in WBM Supplement page 01-00-00 Page 8. *Ref: AEI Weight and balance supplement document R-1006 REV P Dated 22-JUN-2023, CONFIGURATION X, PAGE 26 , 01-00-00.*

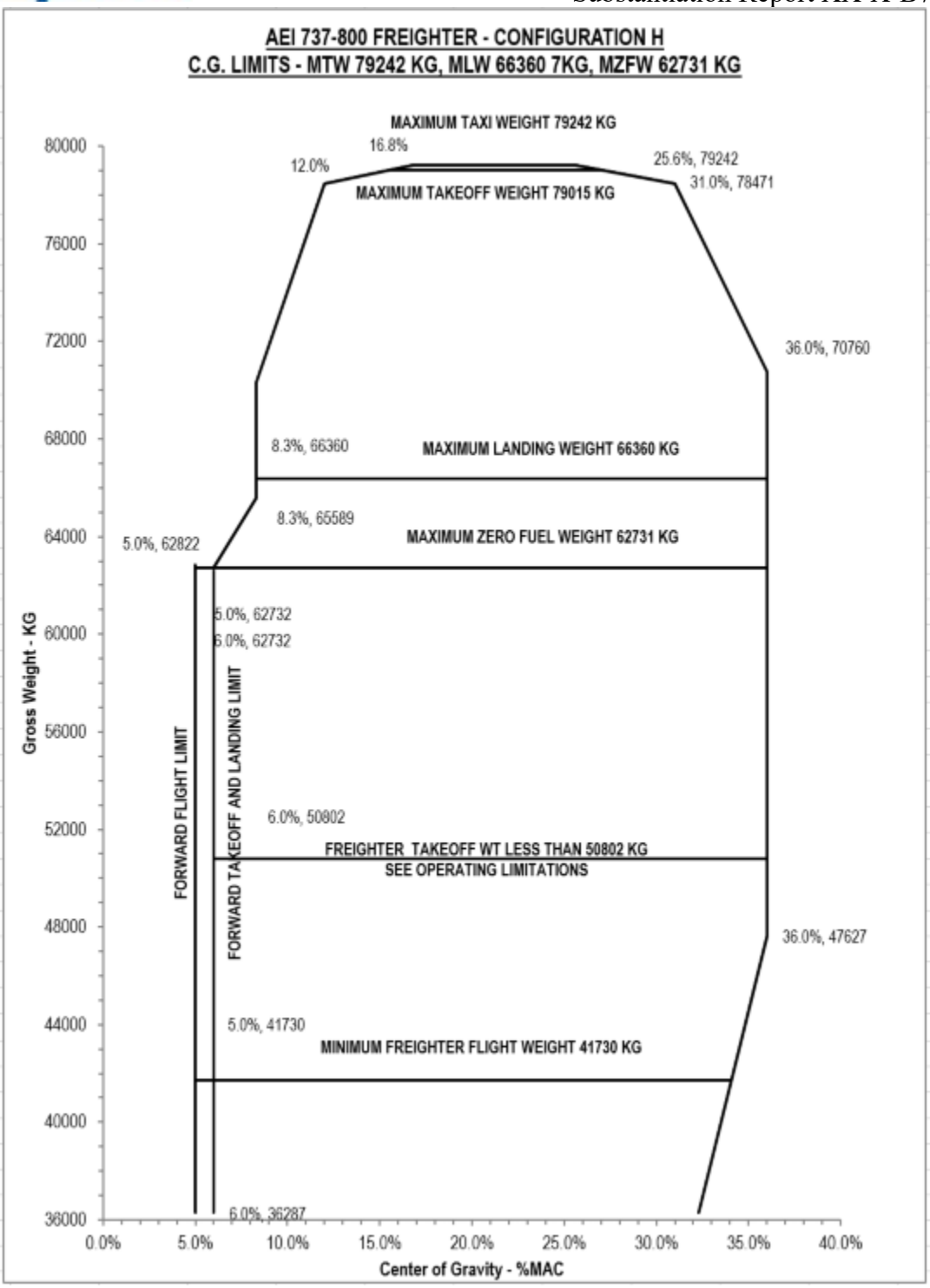

Figure 2: Assigned Envelope, %MAC vs. Weight (KG.).

The envelope is converted from %MAC (%RC) data to index values. Table 1 shows the calculated index values. Please note that Aft Take-Off Limit -26000 LB Thrust Rating is used.

Take-Off certified envelope							
FWD Limit							
Limit	**Weight (lbs.)**	**Weight (kg.)**	**Arm (in)**	**Harm (in)**	**Index**	**Moment (kg.in.)**	**%MAC**
TO	79.999	**36.287**	636,4	-21,8	27,41	23.094.789	**6,0%**
TO	91.999	**41.730***	636,4	-21,8	24,77	26.558.975	**6,0%**
TO	111.999	**50.802****	636,4	-21,8	20,38	32.332.831	**6,0%**
TO	138.300	**62.732**	636,4	-21,8	14,59	39.925.656	**6,0%**
TO	138.499	**62.822**	636,4	-21,8	14,55	39.982.936	**6,0%**
TO	144.599	**65.589**	640,0	-18,2	18,43	41.979.019	**8,3%**
TO	146.299	**66.360**	640,0	-18,2	18,12	42.472.484	**8,3%**
TO	155.999	**70.760**	640,0	-18,2	16,34	45.288.622	**8,3%**
TO	172.999	**78.471**	645,8	-12,5	23,27	50.676.258	**12,0%**
TO	174.198	**79.015**	651,1	-7,2	32,41	51.445.698	**15,4%**
TX	174.698	**79.242**	653,3	-5,0	36,22	51.766.770	**16,8%**
Aft Limit							
Limit	**Weight (lbs.)**	**Weight (kg.)**	**Arm (in)**	**Harm (in)**	**Index**	**Moment (kg.in.)**	**%MAC**
TO	79.999	**36.287**	677,4	19,2	60,45	24.581.663	32,3%
TO	91.999	**41.730***	680,6	22,3	65,70	28.400.658	**34,3%**
TO	104.999	**47.627**	683,2	24,9	71,38	32.538.195	36,0%
TO	111.999	**50.802****	683,2	24,9	73,14	34.707.317	36,0%
TO	155.999	**70.760**	683,2	24,9	84,20	48.342.383	36,0%
TO	172.999	**78.471**	675,4	17,1	74,89	52.999.156	31,0%
TO	174.198	**79.015**	669,4	11,2	64,64	52.896.180	**27,2%**
TX	174.698	**79.242**	667,0	8,7	60,36	52.853.210	25,6%

Table 1: CONFIGURATION X envelope TakeOff.

* MINIMUM FLIGHT WEIGHT. MINIMUM FLIGHT WEIGHT 41730 KG INCLUDES CREW,PANTRY AND BALLAST.

** TAKE OFF WEIGHT LESS THAN 50802 KG RESTRICTED TO LOADING ONLY CARGO DECK POS A5 THRU A7 AND OR M5 THRU M7.

In-flight certified envelope							
FWD Limit							
Limit	Weight (lbs.)	Weight (kg.)	Arm (in)	Harm (in)	Index	Moment (kg.in.)	%MAC
IF	79,999	**36,287**	634.9	-23.4	26.15	23,038,253	**5.0%**
IF	138,300	**62,732**	634.9	-23.4	12.42	39,827,919	**5.0%**
IF	138,499	**62,822**	636.4	-21.8	14.55	39,982,936	**6.0%**
IF	144,599	**65,589**	640.0	-18.2	18.43	41,979,019	**8.3%**
IF	155,999	**70,760**	640.0	-18.2	16.34	45,288,622	**8.3%**
IF	172,999	**78,471**	645.8	-12.5	23.27	50,676,258	**12.0%**
IF	174,198	**79,015**	651.1	-7.2	32.41	51,445,698	**15.4%**
Aft Limit							
Limit	**Weight (lbs.)**	**Weight (kg.)**	**Arm (in)**	**Harm (in)**	**Index**	**Moment (kg.in.)**	**%MAC**
IF	79,999	**36,287**	677.4	19.2	60.45	24,581,663	**32.3%**
IF	104,999	**47,627**	683.2	24.9	71.38	32,538,195	**36.0%**
IF	155,999	**70,760**	683.2	24.9	84.20	48,342,383	**36.0%**
IF	172,999	**78,471**	675.4	17.1	74.89	52,999,156	**31.0%**
IF	174,198	**79,015**	669.4	11.2	64.64	52,896,180	**27.2%**

Table 2 CONFIGURATION X envelope inFlight Envelope

Landing certified envelope							
FWD Limit							
Limit	**Weight (lbs.)**	**Weight (kg.)**	**Arm (in)**	**Harm (in)**	**Index**	**Moment (kg.in.)**	**%MAC**
LD	79.999	**36.287**	636,4	-21,8	27,41	23.094.789	6,0%
LD	91.999	**41.730**	636,4	-21,8	24,77	26.558.975	6,0%
LD	138.300	**62.732**	636,4	-21,8	14,59	39.925.656	6,0%
LD	144.599	**65.589**	640,0	-18,2	18,43	41.979.019	8,3%
LD	146.299	**66.360**	640,0	-18,2	18,12	42.472.484	8,3%
Aft Limit							
Limit	**Weight (lbs.)**	**Weight (kg.)**	**Arm (in)**	**Harm (in)**	**Index**	**Moment (kg.in.)**	**%MAC**
LD	79.999	**36.287**	677,4	19,2	60,45	24.581.663	32,3%
LD	91.999	**41.730**	680,6	22,3	65,70	28.400.658	34,3%
LD	104.999	**47.627**	683,2	24,9	71,38	32.538.195	36,0%
LD	138.298	**62.731**	683,2	24,9	79,75	42.857.066	36,0%
LD	146.299	**66.360**	683,2	24,9	81,76	45.336.356	36,0%

Table 3 CONFIGURATION X Landing Envelope

Zero Fuel certified envelope							
FWD Limit							
Limit	Weight (lbs.)	Weight (kg.)	Arm (in)	Harm (in)	Index	Moment (kg.in.)	%MAC
ZF	79,999	**36,287**	636.4	-21.8	27.41	23,094,789	6.0%
ZF	91,999	**41,730**	636.4	-21.8	24.77	26,558,975	6.0%
ZF	138,298	**62,731**	636.4	-21.8	14.59	39,925,656	6.0%
Aft Limit							
Limit	Weight (lbs.)	Weight (kg.)	Arm (in)	Harm (in)	Index	Moment (kg.in.)	%MAC
ZF	79,999	**36,287**	677.4	19.2	60.45	24,581,663	32.3%
ZF	91,999	**41,730**	680.6	22.3	65.70	28,400,658	**34.3%**
ZF	104,999	**47,627**	683.2	24.9	71.38	32,538,195	36.0%
ZF	138,298	**62,731**	683.2	24.9	79.75	42,857,066	36.0%

Table 4 CONFIGURATION X ZeroFuel Envelope

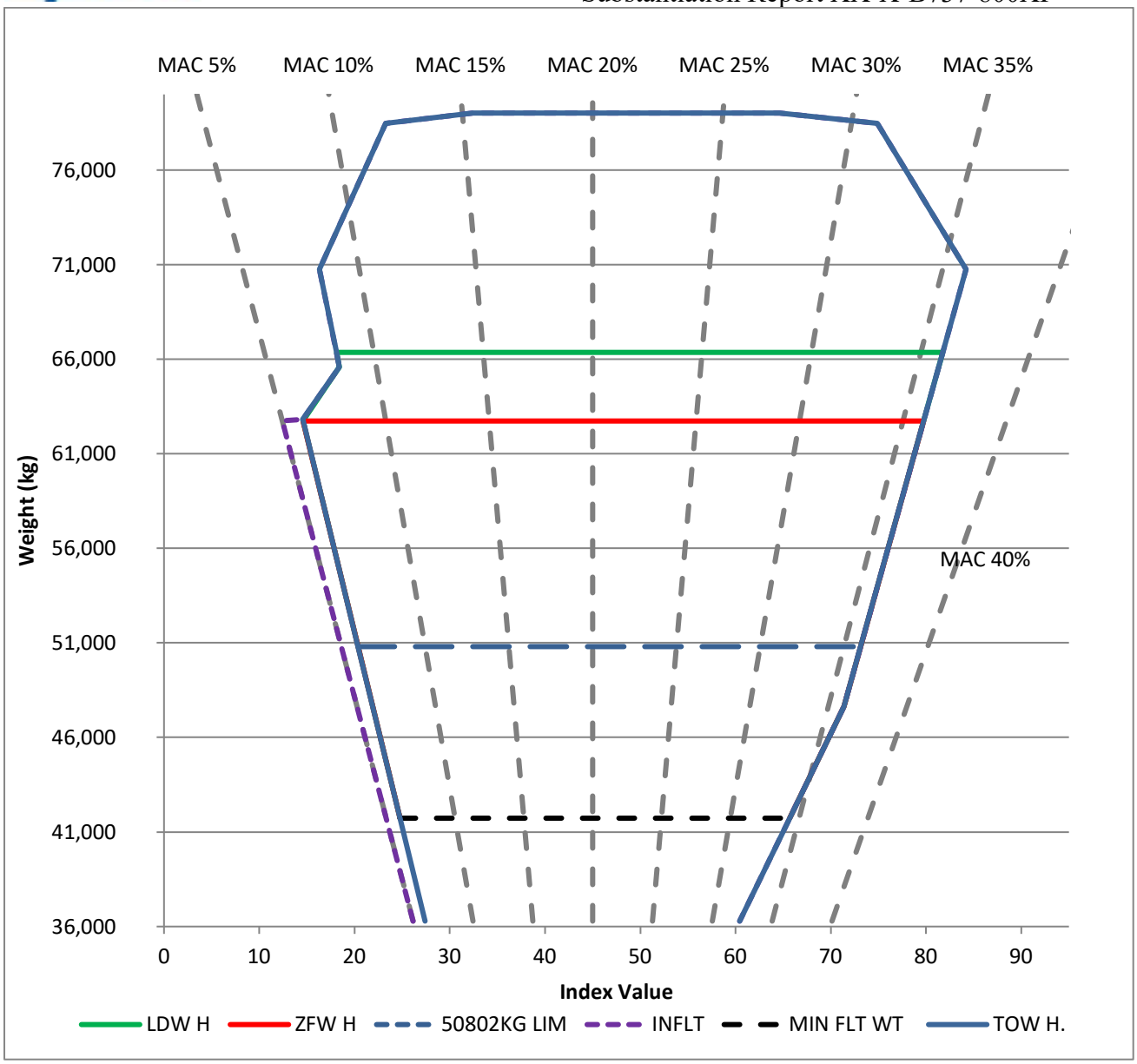

Figure 3: CONFIGURATION X Envelope, index value vs. weight.

4 Information used in calculations

4.1 Crew and Authorized Personnel weights and locations.

Crew and Supernumerary weights and locations are shown in Table 5: Crew and Authorized Personnel weights and locations.

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This information is According to the AEI W&B manual, 01-40-00, Page 2, Sep 28th, 2018, and the checklist filled out by operator. The weight of the crew is as per DemoAir definition.

Description	No. Seats	Weight (kg)	Arm (in)	Index/unit
Pilot	2	119	32,0	-0,013917
Observer (1st)	1	119	67,0	-0,013139
Observer (2nd)	1	119	60,0	-0,013295
Authorized Personnel LD1	2	119	116,0	-0,012050
Authorized Personnel LD2	3	119	146,0	-0,011384

Table 5: Crew and Authorized Personnel weights and locations.

4.2 Main Deck Load Locations and Limitation

Unit Load device unit locations and limitations for cargo loading are shown in

This information is According to the AEI W&B manual, Loading Configuration A,B,L and M. RESTRICTIONS FOR TAKE OFF WT LESS THAN **50802 KG** IS RESTRICTED TO LOADING ONLY CARGO DECK POS A5 THRU A7 AND OR M5 THRU M7.

Main deck loading configurations:

Main Deck Loading Configurations	Qty and ULD Base Size
A	Eleven (11) 88"x125"
B	Eleven (11) 88"x108"
M	Ten (10) 96"x125"
Y	Twenty-two (22) 88"x61.5"
P12 - Common to all configurations	One (1) 60.4"x61.5" or One (1) 53"x88" or One (1) 61.5"x88"
Engine Pallet	One (1) 125"x96"

Figure 4 Loading configurations

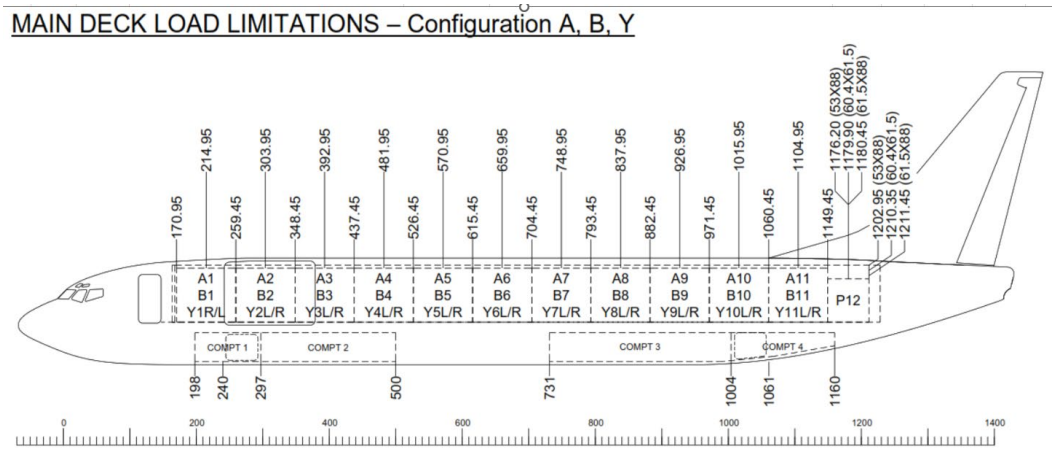

Figure 5: Main deck load locations, Configuration A,B AND Y

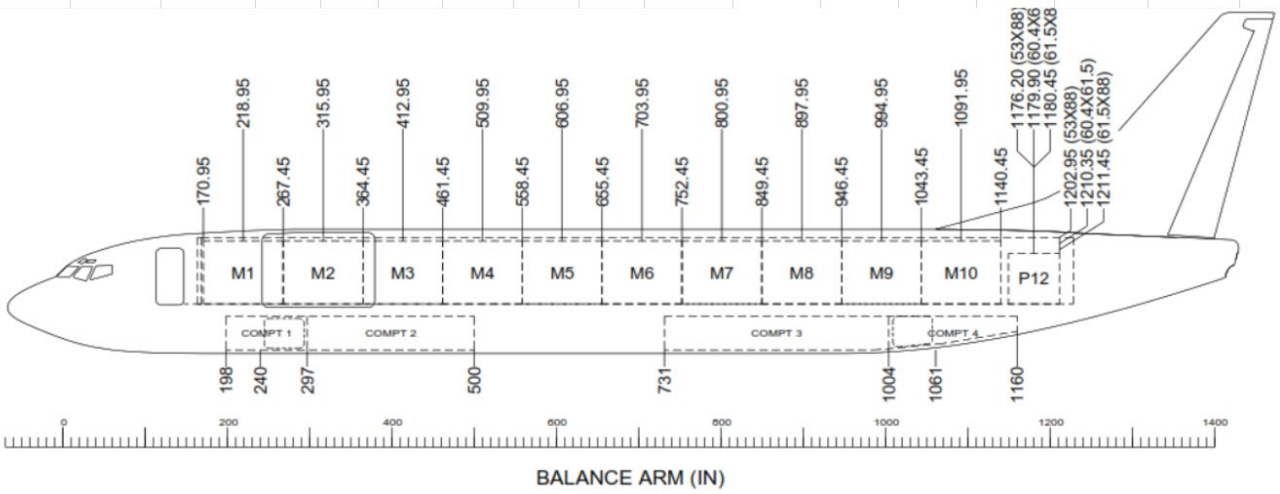

Figure 6: Main deck load locations, Configuration M.

	12 uld version							
	BAY	Max Weight (kg)	ULD max fit (in)	Arm (in) Center	Arm (in) FWD	Arm (in) AFT	Harm (in)	Index/ weight-unit
	A1	1.814	88*125	214,95	170,95	259,45	-443,3	-0,009851
door	A2	2.948	88*125	303,95	259,45	348,45	-354,3	-0,007874
	A3	2.948	88*125	392,95	348,45	437,45	-265,3	-0,005896
	A4	2.948	88*125	481,95	437,45	526,45	-176,3	-0,003918
	A5	3.628	88*125	570,95	526,45	615,45	-87,31	-0,001940
	A6	3.628	88*125	659,95	615,45	704,45	1,690	0,000038
	A7	2.948	88*125	748,95	704,45	793,45	90,7	0,002015
	A8	2.948	88*125	837,95	793,45	882,45	179,7	0,003993
	A9	2.948	88*125	926,95	882,45	971,45	268,7	0,005971
	A10	2.948	88*125	1.015,95	971,45	1.060,45	357,7	0,007949
	A11	1.814	88*125	1.104,95	1.060,45	1.149,45	446,7	0,009926
	P12	1.133	61.5*88	1.180,45	1.149,45	1.211,45	522,2	0,011604
		24.494	**MAX COMBINED LIMIT CARGO UPPER DECK**					
	- SUBTRACT 88.4 KG FOR EACH PAX SITTING ON 9G BARRIER							

Table 6: Main deck load limitation, Configuration A.

	12 uld version							
	BAY	Max Weight (kg)	ULD max fit (in)	Arm (in) Center	Arm (in) FWD	Arm (in) AFT	Harm (in)	Index/ weight-unit
	B1	1.542	88*108	214,95	170,95	259,45	-443,3	-0,009851
door	B2	2.041	88*108	303,95	259,45	348,45	-354,3	-0,007874
	B3	2.041	88*108	392,95	348,45	437,45	-265,3	-0,005896
	B4	2.041	88*108	481,95	437,45	526,45	-176,3	-0,003918
	B5	2.494	88*108	570,95	526,45	615,45	-87,31	-0,001940
	B6	2.494	88*108	659,95	615,45	704,45	1,690	0,000038
	B7	2.041	88*108	748,95	704,45	793,45	90,7	0,002015
	B8	2.041	88*108	837,95	793,45	882,45	179,7	0,003993
	B9	2.041	88*108	926,95	882,45	971,45	268,7	0,005971
	B10	2.041	88*108	1.015,95	971,45	1.060,45	357,7	0,007949
	B11	1.542	88*108	1.104,95	1.060,45	1.149,45	446,7	0,009926
	P12	1.133	61.5*88	1.180,45	1.149,45	1.211,45	522,2	0,011604
		24.494	**MAX COMBINED LIMIT CARGO UPPER DECK**					
	- SUBTRACT 88.4 KG FOR EACH PAX SITTING ON 9G BARRIER							

Table 7 Main deck load limitation, Configuration B.

	22 uld version + P12								
	BAY		Max Weight (kg)	ULD max fit (in)	Arm (in) Center	Arm (in) FWD	Arm (in) AFT	Harm (in)	Index/ weight-unit
	Y1L	Y1R	907	88x61.5	214,95	170,95	259,45	-443,3	-0,009851
door	Y2L	Y2R	1.133	88x61.5	303,95	259,45	348,45	-354,3	-0,007874
	Y3L	Y3R	1.133	88x61.5	392,95	348,45	437,45	-265,3	-0,005896
	Y4L	Y4R	1.133	88x61.5	481,95	437,45	526,45	-176,3	-0,003918
	Y5L	Y5R	1.133	88x61.5	570,95	526,45	615,45	-87,31	-0,001940
	Y6L	Y6R	1.133	88x61.5	659,95	615,45	704,45	1,690	0,000038
	Y7L	Y7R	1.133	88x61.5	748,95	704,45	793,45	90,7	0,002015
	Y8L	Y8R	1.133	88x61.5	837,95	793,45	882,45	179,7	0,003993
	Y9L	Y9R	1.133	88x61.5	926,95	882,45	971,45	268,7	0,005971
	Y10L	Y10R	1.133	88x61.5	1.015,95	971,45	1.060,45	357,7	0,007949
	Y11L	Y11R	907	88x61.5	1.104,95	1.060,45	1.149,45	446,7	0,009926
	P12		1.133	88x61.5	1.180,45	1.149,45	1.211,45	522,2	0,011604
			24.494	MAX COMBINED LIMIT CARGO UPPER DECK					
	- SUBTRACT 88.4 KG FOR EACH PAX SITTING ON 9G BARRIER								

Table 8 Main deck load limitation, Configuration Y.

	11 ULD VERSION								
	BAY	Max Weight (kg)	ULD max fit (in)	Arm (in) Center	Arm (m) Center	Arm (in) FWD	Arm (in) AFT	Harm (in)	Index/ weight-unit
	M1	2494	96*125	**218,95**	5,56	170,95	267,45	-439,3	-0,009762
door >>>	M2	2948	96*125	**315,95**	8,03	267,45	364,45	-342,3	-0,007607
	M3	2948	96*125	**412,95**	10,49	364,45	461,45	-245,3	-0,005451
	M4	2948	96*125	**509,95**	12,95	461,45	558,45	-148,3	-0,003296
	M5	3628	96*125	**606,95**	15,42	558,45	655,45	-51,31	-0,001140
	M6	3628	96*125	**703,95**	17,88	655,45	752,45	45,7	0,001015
	M7	2948	96*125	**800,95**	20,34	752,45	849,45	142,7	0,003171
	M8	2948	96*125	**897,95**	22,81	849,45	946,45	239,7	0,005326
	M9	2948	96*125	**994,95**	25,27	946,45	1043,45	336,7	0,007482
	M10	2494	96*125	**1091,95**	27,74	1043,45	1140,45	433,7	0,009638
	P12	1133	61,5*88	**1180,45**	29,98	1149,45	1211,45	522,2	0,011604
	24494		**MAX COMBINED LIMIT CARGO MAIN DECK**						
	- SUBTRACT 88.4 KG FOR EACH PAX SITTING ON 9G BARRIER								
	ENGINE PALLET OVERLAPS FROM M5 TO M6 2 POS								
M5-M6	**ENG**	**3628**	96*125	**620,95**	15,77	558,45	684,45	-37,31	-0,000829

Table 9: Main deck load limitation, Configuration M.

4.3 Lower Deck Compartments

Lower deck cargo compartment's locations and limitations are shown in Table 12 Lower cargo compartments setup and calculations DemoAir

DemoAir has divided the lower compartments into holds 1, 2 that are in the forward compartment and hold 3 and 4 that are located in the aft lower cargo compartment. Hold 1 contains bay 1A and 1B. Hold 4 contains 4A and 4B.

This information is according to the standard W&B manual,

- Boeing WBM reference 1-60-011, Page 1 of 2, Jul 29th, 2014.

WBM LAYOUT	Weight (kg)	Volume (ft2)	Volume (m2)	FWD Arm (in)	AFT Arm (in)	Max weight (kg)	Volume (ft2)
1A	552	105	2.97	198.0	240.0	3,558	672.0
1B	336	50	1.42	240.0	297.0		
2	2,670	517	14.64	297.0	500.0		
3	3,467	733	20.76	731.0	1,004.0	4,037	869.0
4A	258	50	1.42	1,004.0	1,061.0		
4B	312	86	2.44	1,061.0	1,160.0		

Table 10 Lower compartment Bay WBM setup and index calculations

WBM FORWARD AND AFT CARGO HOLD								
name	Max weight (kg)	Volume (ft2)	Arm (in) FWD	Arm (in) AFT	Arm (in) Center	Harm (in) Center	Inpex/unit	Name
FWD HOLD	3,558	672	198.0	500.0	349.0	- 309.3	- 0.006872	FWD
AFT HOLD	4,037	869	731.0	1,160.0	945.5	287.2	0.006383	AFT

Table 11 Lower cargo compartment FWD and AFT compartments WBM setup and index calculations

Compartments lower deck setup for DemoAir							
Hold	Max weight (kg)	Max Volume (ft2)	Arm (in) FWD	Arm (in) AFT	Arm (in) Center	Harm Center (in)	Index/ weight-unit
1 - FWD	888	155	198.0	297.0	247.5	- 410.8	- 0.009128
2 - FWD	2,670	517	297.0	500.0	398.5	- 259.8	- 0.005772
3 - AFT	3,467	733	731.0	1,004.0	867.5	209.2	0.004650
4 - AFT	570	136	1,004.0	1,160.0	1,082.0	423.7	0.009416

Table 12 Lower cargo compartments setup and calculations DemoAir

4.4 Cumulative loading limit

Main and lower deck maximum cumulative weights are shown.

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This information is according to the AEI W&B manual Supplement,

- 01-60-00, Page 6, Feb 26th, 2019, CONFIG, A,B,Y
- 01-60-00, Page 7, Feb 26th, 2019.CONFIG M

The low lower holds are accounted for in the table below as a fraction due to alignment using the following formula:

(BAY ARM FWD - BAY ARM AFT)/ (CUMULATIVE LIMIT ARM - FWD BAY ARM)

Configuration A-B Y(L+R)			
Forebody Cumulative Load Limit			
Arm (in)	**Arm (m)**	**Cumulative Weight (kg)**	**Bay/Hold assignment**
170,95	4,34	-	-
259,45	6,59	3.742	A1+H1(62%)
348,45	8,85	6.010	A1+A2+H1+H2(25%)
437,45	11,11	8.845	A1+A2+A3+H1+H2(69%)
526,45	13,37	11.339	A1+A2+A3+A4+H1+H2
615,45	15,63	13.063	A1+A2+A3+A4+A5+H1+H2
Aftbody Cumulative Load Limit			
Arm (in)	**Arm (m)**	**Cumulative Weight (kg)**	**Bay/Hold assignment**
704,45	17,89	14.968	P12+A11+A10+A9+A8+A7+H4+H3
793,45	20,15	12.473	P12+A11+A10+A9+A8+H4+H3(77%)
882,45	22,41	9.298	P12+A11+A10+A9+H4+H3(45%)
971,45	24,67	6.350	P12+A11+A10+H4+H3(12%)
1060,45	26,94	3.855	P12+A11+H4(64%)

Table 13: Cumulative load limit, Configuration A.

Configuration B			
Forebody Cumulative Load Limit			
Arm (in)	**Arm (m)**	**Cumulative Weight (kg)**	**Bay/Hold assignment**
170,95	4,34	-	-
259,45	6,59	3.742	B1+H1(62%)
348,45	8,85	6.010	B1+B2+H1+H2(25%)
437,45	11,11	8.845	B1+B2+B3+H1+H2(69%)
526,45	13,37	11.339	B1+B2+B3+B4+H1+H2
615,45	15,63	13.063	B1+B2+B3+B4+B5+H1+H2
Aftbody Cumulative Load Limit			
Arm (in)	**Arm (m)**	**Cumulative Weight (kg)**	**Bay/Hold assignment**
704,45	17,89	14.968	P12+B11+B10+B9+B8+B7+H4+H3
793,45	20,15	12.473	P12+B11+B10+B9+B8+H4+H3(77%)
882,45	22,41	9.298	P12+B11+B10+B9+H4+H3(45%)
971,45	24,67	6.350	P12+B11+B10+H4+H3(12%)
1060,45	26,94	3.855	P12+B11+H4(64%)

Table 14: Cumulative load limit, Configuration B.

Configuration M			
Forebody Cumulative Load Limit			
Arm (in)	**Arm (m)**	**Cumulative Weight (kg)**	**Bay/Hold assignment**
170,95	4,34	-	-
267,45	6,79	3.855	M1+H1(70%)
364,45	9,26	6.463	M1+M2+H1+H2(33%)
461,45	11,72	9.638	M1+M2+M3+H1+H2(81%)
558,45	14,18	12.020	M1+M2+M3+M4+H1+H2
655,45	16,65	13.834	M1+M2+M3+M4+M5+ENG+H1+H2
Aftbody Cumulative Load Limit			
Arm (in)	**Arm (m)**	**Cumulative Weight (kg)**	**Bay/Hold assignment**
752,45	19,11	13.721	P12+M10+M9+M8+M7+H4+H3(92%)
849,45	21,58	10.432	P12+M10+M9+M8+H4+H3(57%)
946,45	24,04	7.257	P12+M10+M9+H4+H3(21%)
1043,45	26,50	4.309	P12+M10+H4(75%)

Table 15: Cumulative load limit, Configuration M.

Forebody Cumulative Load Limit			
Arm (in)	**Arm (m)**	**Cumulative Weight (kg)**	**Bay/Hold assignment**
170,95	4,34	-	-
259,45	6,59	3.742	Y1+H1(62%)
348,45	8,85	6.010	Y1+Y2+H1+H2(25%)
437,45	11,11	8.845	Y1+Y2+Y3+H1+H2(69%)
526,45	13,37	11.339	Y1+Y2+Y3+Y4+H1+H2
615,45	15,63	13.063	Y1+Y2+Y3+Y4+Y5+H1+H2
Aftbody Cumulative Load Limit			
Arm (in)	**Arm (m)**	**Cumulative Weight (kg)**	**Bay/Hold assignment**
704,45	17,89	14.968	P12+Y11+Y10+Y9+Y8+Y7+H4+H3
793,45	20,15	12.473	P12+Y11+Y10+Y9+Y8+H4+H3(77%)
882,45	22,41	9.298	P12+Y11+Y10+Y9+H4+H3(45%)
971,45	24,67	6.350	P12+Y11+Y10+H4+H3(12%)
1060,45	26,94	3.855	P12+Y11+H4(64%)

Table 16: Cumulative load limit, Configuration Y.

4.5 Balance Arms, Index Units and weights used for calculations

All Balance Arms (B.A.) are measured to aircraft center of gravity datum. C.G. centroid is used for calculations.

Note that inch values are used for all calculations.

Description	Weight (kg)	C.G. (in) Centroid	Index Impact
Crew - Pilot(s)	119	32,00	-1,66
Crew - Observer (1st)	119	67,00	-1,56
Crew - Observer (2nd)	119	60,00	-1,58
Authorized Personnel LD1 POS by door	119	116,00	-1,43
Authorized Personnel LD2 POS by cargo bulkhead	119	146,00	-1,35
ULD POS A1,B1,Y1LR	100	214,95	-0,99
ULD POS M1	100	218,95	-0,98
ULD POS A2,B2,Y2LR	100	303,95	-0,79

ULD POS M2	100	315,95	-0,76
ULD POS A3,B3,Y3LR	100	392,95	-0,59
ULD POS M3	100	412,95	-0,55
ULD POS A4,B4,Y4LR	100	481,95	-0,39
ULD POS M4	100	509,95	-0,33
ULD POS A5,B5,Y5LR	100	570,95	-0,19
ULD POS M5	100	606,95	-0,11
ULD POS A6,B6,Y6LR	100	659,95	0,00
ULD POS M6	100	703,95	0,10
ULD POS A7,B7,Y7LR	100	748,95	0,20
ULD POS M7	100	800,95	0,32
ULD POS A8,B8,Y8LR	100	837,95	0,40
ULD POS M8	100	897,95	0,53
ULD POS A9,B9,Y9LR	100	926,95	0,60
ULD POS M9	100	994,95	0,75
ULD POS A10,B10,Y10LR	100	1.015,95	0,79
ULD POS M10	100	1.091,95	0,96
ULD POS A11,B11,Y11LR	100	1.104,95	0,99
ULD POS P12	100	1.180,45	1,16
CARGO Hold 1 - FWD	100	247,50	-0,91
CARGO Hold 2 - FWD	100	398,50	-0,58
CARGO Hold 3 - AFT	100	867,50	0,46
CARGO Hold 4 - AFT	100	1.082,00	0,94

Table 17: Weights and Index units used for calculation.

4.6 Fuel

The following tables provides the distribution of fuel as a function of kilograms (kg). Fuel has been calculated with fuel density of 0.8 kg/L. The fuel burn sequence is wing tanks 1st burn and center tank 2nd burn (Standard burn procedure).

This information is according to the standard W&B manual, pages 1-24-001, Page 2 of 2, Aug 5th, 2004, and 1-24-021, Page 2 of 2, Apr 8th, 1998.

Weight	L	ARM	Index	Weight	L	ARM	Index	Weight	L	ARM	Index
0	0	0	0	8121	10151	696.7	6.93	16441	20551	650.9	-2.71
320	400	610.2	-0.01	8441	10551	693.3	6.58	16761	20951	650.2	-3
640	800	656.7	-0.02	8761	10951	690.1	6.2	17081	21351	649.4	-3.36
960	1200	657.1	-0.02	9081	11351	687.1	5.82	17401	21751	648.6	-3.73
1280	1600	657.9	-0.01	9401	11751	684.2	5.42	17721	22151	647.9	-4.1
1600	2000	658.7	0.02	9721	12151	681.5	5.02	18041	22551	647.1	-4.46
1920	2400	659.4	0.05	10041	12551	679	4.62	18361	22951	646.4	-4.83
2240	2800	660.6	0.12	10361	12951	676.7	4.25	18681	23351	645.7	-5.2
2560	3200	661.4	0.18	10681	13351	674.4	3.84	19001	23751	645.1	-5.56
2880	3600	662.6	0.28	11001	13751	672.4	3.46	19321	24151	644.2	-6.03
3200	4000	663.4	0.37	11321	14151	670.5	3.08	19641	24551	643.6	-6.4
3520	4400	664.6	0.5	11641	14551	668.7	2.7	19961	24951	643	-6.77
3840	4800	666.1	0.67	11961	14951	667	2.32	20281	25351	642.2	-7.25
4160	5200	668.1	0.91	12281	15351	665.4	1.94	20601	25751	641.4	-7.74
4480	5600	670.1	1.18	12601	15751	664	1.6	20819 **(2)**	26024	640.9	-8.02
4800	6000	672	1.47	12921	16151	662.5	1.22				
5120	6400	674.4	1.84	13241	16551	661.1	0.84				
5440	6800	676.8	2.24	13561	16951	660	0.52				
5760	7200	679.1	2.67	13881	17351	658.7	0.14				
6080	7600	681.9	3.19	14201	17751	657.5	-0.23				
6400	8000	685	3.8	14521	18151	656.6	-0.55				
6720	8400	688.2	4.47	14841	18551	655.5	-0.92				
7040	8800	691.3	5.17	15161	18951	654.4	-1.29				
7360	9200	694.9	5.99	15481	19351	653.6	-1.6				
7680	9600	698.8	6.92	15801	19751	652.7	-1.97				
7801 **(1)**	9751	700.2	7.27	16121	20151	651.7	-2.34				

1) Wing tanks full
2) All tanks full

Table 18: Fuel consumption and index values.

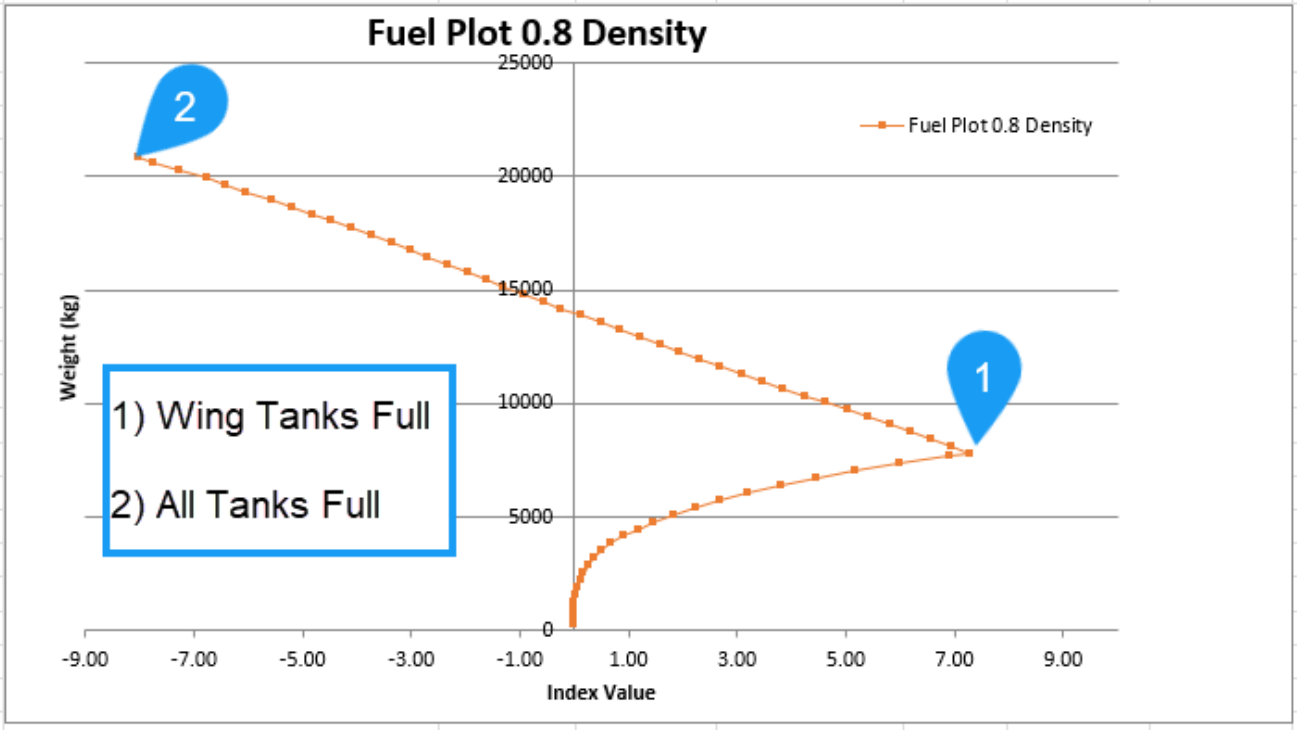


Figure 7: Fuel index movement plotted at fuel density 0.8 kg/L

4.7 Stab Trim Units for calculations

The following tables provides inflection point data for the Take-Off Trim Settings versus Airplane Center of Gravity at specific weight. For intermediate values not presented in the standard W&B manual, linear interpolation is used. Table for 26K thrust rating used.

This information is according to the standard W&B manual,for E,V,W

- 1-06-011, Page 2 of 26, Dec 1st, 2005.
- 1-06-011, Page 3 of 26, Dec 1st, 2005.

	%MAC - Flaps 1 & 5										
Weights	**6**	**8,5**	**9,0**	**11**	**16**	**20**	**24**	**26**	**32,5**	**34,4**	**36**
36.287 - 45.359	**6,20**	5,87	5,80	5,53	4,86	4,32	3,79	3,52	**2,65**	**2,65**	**2,65**
50.000	**6,61**	6,26	6,19	5,91	5,22	4,66	4,10	3,82	2,91	**2,65**	**2,65**
60.000	**7,49**	7,11	7,03	6,73	5,97	5,36	4,75	4,45	3,46	3,17	**2,93**
70.000	**8,30**	7,89	7,81	7,48	6,66	6,01	5,35	5,03	3,96	3,65	**3,39**
80.000	**8,50**	**8,50**	8,42	8,08	7,23	6,55	5,87	5,53	4,42	4,10	**3,83**
81.646	**8,50**	8,50	**8,50**	8,16	7,31	6,63	5,95	5,60	4,50	4,17	**3,90**

Table 19: Take-Off Trim Setting for Flaps 1 & 5.

	%MAC - Flaps 10, 15 & 25										
Weights	**6**	**8**	**10,7**	**11**	**16**	**24**	**26,5**	**30,4**	**33**	**35,6**	**36**
36.287 - 45.359	**5,30**	5,01	4,61	4,56	3,83	**2,65**	**2,65**	**2,65**	**2,65**	**2,65**	**2,65**
50.000	**6,17**	5,81	5,33	5,28	**4,38**	3,06	**2,65**	**2,65**	**2,65**	**2,65**	**2,65**
60.000	**7,68**	7,21	6,58	6,51	**5,33**	3,84	3,38	**2,65**	**2,65**	**2,65**	**2,65**
70.000	**8,50**	**8,50**	7,64	7,55	**5,96**	4,40	3,92	3,16	**2,65**	**2,65**	**2,65**
80.000	**8,50**	**8,50**	8,50	8,39	**6,59**	4,98	4,48	3,70	3,17	**2,65**	**2,65**
81.646	**8,50**	**8,50**	8,50	8,50	**6,70**	5,08	4,57	3,78	3,26	2,73	**2,65**

Table 20: Take-Off Trim Setting for Flaps 10, 15 & 25.

5 Limit Curtailment Corrections

5.1 General

To ensure that the aircraft is always loaded within the certified envelope, the center of gravity limits are curtailed to allow for:

- In-Flight crew and submarines movements.
- Center of gravity movements due to fuel loading and usage.
- Landing gear movements (Honeywell High Capacity Steel Brakes).
- Flap retraction movements.

Together these define the allowable range for center of gravity for use with the index unit loading system.

5.2 Operational flight envelope

The determination of the aircraft C.G. position using a paper or computerized trim sheet is affected by inaccuracy on the influence of item loading on the final aircraft C.G. position. Furthermore, the aircraft C.G. position changes during flight because of different items moving.

Before flight the aircraft C.G. position must be checked against the three certified envelopes, Take-Off, Landing and In-Flight. Due to the C.G. position uncertainties some margins must be determined between the certified envelopes and the ones used on the trim sheet: the operational limits.

On the balance chart the three operational limits are not represented because even if the Take-Off C.G. position check against its corresponding limit can be done after a manual or computerized computation, the determination of the Landing C.G. and furthermore the In-Flight C.G. positions on a paper document is much more difficult, it is impossible to check these C.G. positions against their corresponding C.G. limits.

Two limits are represented on the trim sheet:

- Operational Take-Off limit
- Operational Zero Fuel limit

The Zero Fuel limit is determined to ensure that during the whole flight and at Landing the aircraft C.G. remains within the limits.

5.3 Margins Determination Method

To determine the aircraft ZFW, TOW and C.G. positions during flight one needs to know the following:

- Aircraft C.G. position and weight before loading any item.
- Weight and position of each item loaded on the aircraft (cargo, Authorized personnel, fuel, any additional item).
- Possible C.G. movements due to moving items during flight.

Operational margins are the sum the total possible inaccuracy and the possible aircraft C.G. movements due to Landing gear movements, flap retraction movements and In-Flight crew and authorized personnel movements.

The method is to determine the influence that each lack of precision or each C.G. movement will have on the aircraft final C.G. position. This influence can be quantified as the difference between the trim sheet final index and the index that would result of a calculation with no accuracy.

Instead of using the index value the following method uses the moment and evaluate difference between the aircraft moment determined using the trim sheet (assumed) and the real one.

Operational margins = (Real Aircraft Moment) - (Assumed Aircraft Moment)

Note: Inaccuracies and movements can shift the aircraft C.G. forward or aft. If the C.G. shifts forward the C.G. B.A. decreases and so the resulting moment also decreases. The inaccuracy shifting the C.G. B.A. forward reduces the aircraft total moment so this inaccuracy or movement results in a negative moment.

C.G. moves ***FWD***	moment < 0
C.G. moves ***AFT***	moment > 0

5.4 Crew and Supernumerary In-Flight Movements Corrections

The movement of crew and authorized personnel In-Flight causes movement in the aircraft center of gravity which is accounted for in below calculations. The following assumptions are made:

- Crew members are located at their respective seats during Take-Off and Landing.
- Authorized personnel positions are not allowed to move during Take-Off and Landing.

Forward Movement Corrections

FWD CABIN CORRECTIONS			
Weight (kg)	**Arm (in)**		**Moment (kg.in)**
1 Pilot moving from Forward Lavatory to pilot seat			
119	89,4	32,0	-6.831
1 Pilot Moving from Galley G1 to pilot seat			
119	82,0	32,00	-5.950
1 Loadmaster moving from Sub2 position to OBS (2nd) seat			
119	116,0	60,0	-6.664
1 Loadmaster moving from POS A5 to Galley G3			
119	571,0	146,0	-50.569
1 Loadmaster moving from Sub2 position to Galley G1			
119	116,0	82,0	-4.046
		TOTAL:	**-74.060**

Table 21: Forward In-Flight Cabin Movement Corrections.

Aft Movement Corrections

AFT CABIN CORRECTIONS			
Weight (kg)	**Arm (in)**		**Moment (kg.in)**
1 Pilot moving from Pilot seat to forward Lavatory			
119	32,0	89,4	6.831
1 Pilot Moving from pilot seat to Galley G3			
119	32,0	146,0	13.566
1 Loadmaster moving from forward Lavatory to Galley G3			
119	89,4	146,0	6.735
1 Loadmaster moving from OBS (2nd) POS to G3 Seat			
119	60,00	146,0	10.234
		TOTAL:	**37.366**
			0,830356

Table 22: Aft In-Flight Cabin Movement Corrections.

5.5 Landing Gear Retraction Moment

The following table provides moment changes caused by retraction of the Landing gear from the taxi position (gear down) to the flight position (retracted, gear up).

Landing gear retraction	
Name	**Moment kg.in**
Nose landing gear	-6580
Main landing gear	-14020
sum	-20600

Table 23: Landing Gear Retraction Moment.

The curtailments are derived by reversing to signs of the moment calculated above. Curtailment due to Landing gear retraction = **+20.600 kg.in.** This information is according to the standard W&B manual, Honeywell High Capacity Steel Brakes (28 Ply Bias Tires), page, 1-08-001, Page 2 of 2, Aug 29th, 2018.

5.6 Flaps Retraction Moment

The following table provides the moment changes caused by retraction of the leading edge (L.E.) and the trailing edge (T.E.) flaps.

Cockpit indication Slats/Flaps	Moments			
	LE FLAPS	TE FLAPS	Total	Max
40 to 30	0	-380	-380	-5930
40 to 25	0	-1920	-1920	
40 to 15	0	-1990	-1990	
40 to10	0	-2760	-2760	
40 to 5	1990	-3910	-1920	
40 to 2	1990	-6370	-4380	
40 to 1	1990	-7060	-5070	
40 to 0	5750	-11680	-5930	

Table 24: Flaps Retraction Moment.

The curtailments are derived by selecting the worst case (-5.930) and reversing the signs of the moment calculated above.

Curtailment due to Flaps retraction = **+5.930** Moments (kg.in). This information is according to the standard W&B manual, page, 1-08-001, Page 2 of 2, Aug 29th, 2018.

5.7 Main deck and lower deck Cargo moment variation

It is assumed that main deck ULDs are uniformly loaded. When they are uniformly loaded the ULD´s center of gravity will coincide with the position´s datum balance arm. However, a safety margin is calculated for upper and lower deck based on the below formula.

$$\text{Cargo Variation Moment} = \sum_{i=1}^{n} \text{Weight}_i \times (\text{B.A.}_i - \text{Compartment Datum B.A.})$$

n = Number of items of cargo

BAY COMPARTMENT	MAX WT CODE A (PAG)	MAX WT CODE B(MIL')	Arm (in) FWD	Arm (in) AFT	CTR ARM (IN)	section ARM	CARGO VARIATION KG.IN	Cargo Variation Moment (kg.in) pr Bay	Total Kg.in worst case
A1	1814	1542	170,95	259,45	214,95	437,70	-222,8	-404068,5	806323
A2	2948	2041	259,45	348,45	303,95		-133,8	-394295	
A3	2948	2041	348,45	437,45	392,95		-44,8	-131923	
A4	2948	2041	437,45	526,45	481,95		44,3	130449	
A5	3628	2494	526,45	615,45	570,95		133,3	483431	
A6	3628	2494	615,45	704,45	659,95		222,3	806323	
A7	2948	2041	704,45	793,45	748,95	912,70	-163,8	-482735	348741,5
A8	2948	2041	793,45	882,45	837,95		-74,8	-220363	
A9	2948	2041	882,45	971,45	926,95		14,3	42009	
A10	2948	2041	971,45	1.060,45	1015,95		103,3	304381	
A11	1814	1542	1.060,45	1.149,45	1104,95		192,3	348741,5	
P12	1133	1133	1.149,45	1.211,45	1180,45		267,8	303360,75	

Table 25 Cargo Variation calculation upper deck

BULK HOLD - LOWER CARGO DECK LOOSE LOADS								
BULK HOLD	MAX WT	FORWARD ARM	AFT ARM	CENTER ARM	CARGO VARIATION KG.IN	Correction pr bay kg. IN	Cargo Variation Moment (kg.in)	Total Kg.in worst case
H1	888	198	247,5	298,25	-50,8	-50,8	-45066,0	267667,5
H2	2670	297	398,5		100,3	100,3	267667,5	
H3	3467	731	867,5	906,5	-39,0	-39,0	-135213,0	100035,0
H4	570	1004	1082		175,5	175,5	100035,0	

Table 26 Cargo Variation calculation lower deck

CARGO CURTAILMENT VARIATION SUMMARY			
SECTION	KG IN WORST CASE		
FORWARD UPPER DECK	806323,0	AFT CORRECTIONS	
FORWARD LOWDER DECK	222601,5	10% Curtail	102892,45
TOTAL FWD	1028924,5	INDEX	2,286498889
SECTION	KG IN WORST CASE		
AFT UPPER DECK	348741,5	AFT CORRECTIONS	
AFT LOWER DECK	-35178,0	10% Curtail	31356,35
		INDEX	-0,696807778
TOTAL AFT	313563,5		

Table 27 Cargo Variation calculation summary total forward and aft curtail

5.8 Summary of Moments in Forward and Aft Case Corrections

Summary of moments and index values used in curtailed limit calculations for both forward and aft.

	FWD		
Movements	**In Flight (kg.in)**	**Take-off (kg.in)**	**Landing (kg.in)**
Crew Movement	-12.781		
Supernumerary Movement	-61.279,1		
FWD Cargo Variation Curtailment	102.892,5	102.892,5	102.892,5
Flap Retraction		5.930	5.930
Landing Gear Retraction	20.600		
Fuel	Variable	Variable	Variable
Total Moment Excl. Fuel	49.432,8	108.822	108.822
Total Index Excl. Fuel	**1,10**	**2,42**	**2,42**

	AFT		
Limit Case	**In Flight (kg.in)**	**Take-off (kg.in)**	**Landing (kg.in)**
Crew Movement	20.397		
Supernumerary Movement	16.969		
AFT Cargo Variation Curtailment	31.356	-31.356	-31.356
Flap Retraction		5.930	5.930
Landing Gear Retraction	20.600		
Fuel	Variable	Variable	Variable
Total Moment Excl. Fuel	89.322	-25.426	-25.426
Total Index Excl. Fuel	**1,98**	**-0,57**	**-0,57**

Table 28: Summary of moments/Index values used in curtailed limit calculations.

6 Operational Envelopes

6.1 Operational Limits Construction

To determine the curtailed limits the total index allowance corrections (section 5.8), for forward and aft limits respectively, is added to the certified envelopes.

In-Flight Operational Envelope				
Weight (kg)	**Index**	**Error Index**	**New Index**	**NEW %MAC**
FWD Curtailed Limit				
36,287	26.15	1.10	27.25	5.9%
62,732	12.42	1.10	13.52	5.5%
62,822	14.55	1.10	15.65	6.5%
65,589	18.43	1.10	19.53	8.8%
70,760	16.34	1.10	17.44	8.7%
78,471	23.27	1.10	24.36	12.4%
79,015	32.41	1.10	33.50	15.8%
AFT Curtailed Limit				
36,287	60.45	-1.98	58.47	30.7%
47,627	71.38	-1.98	69.40	34.8%
70,760	84.20	-1.98	82.21	35.2%
78,471	74.89	-1.98	72.90	30.3%
79,015	64.64	-1.98	62.65	26.5%

Table 29: In-Flight operational envelope.

Take-Off Operational Envelope				
Weight (kg)	**Index**	**Error Index**	**New Index**	**NEW %MAC**
FWD Curtailed Limit				
36.287	27,41	2,42	29,83	7,9%
41.730	24,77	2,42	27,19	7,7%
50.802	20,38	2,42	22,79	7,4%
62.732	14,59	2,42	17,01	7,1%
62.822	14,55	2,42	16,97	7,1%
65.589	18,43	2,42	20,85	9,4%
66.360	18,12	2,42	20,54	9,4%
70.760	16,34	2,42	18,75	9,3%
78.471	23,27	2,42	25,68	12,9%
79.015	32,41	2,42	34,82	16,3%
AFT Curtailed Limit				
36.287	60,45	-0,57	59,89	31,9%
41.730	65,70	-0,57	65,13	33,9%
47.627	71,38	-0,57	70,82	35,7%
50.802	73,14	-0,57	72,58	35,7%
70.760	84,20	-0,57	83,63	35,8%
78.471	74,89	-0,57	74,32	30,8%
79.015	64,64	-0,57	64,07	27,0%

Table 30: Take-Off operational envelope.

Landing Operational Envelope				
Weight (kg)	**Index**	**Error Index**	**New Index**	**NEW %MAC**
FWD Curtailed Limit				
36.287	27,4	2,42	29,83	7,9%
41.730	24,8	2,42	27,19	7,7%
62.732	14,6	2,42	17,01	7,1%
65.589	18,4	2,42	20,85	9,4%
66.360	18,1	2,42	20,54	9,4%
AFT Curtailed Limit				
36.287	60,45	-0,57	59,89	31,9%
41.730	65,70	-0,57	65,13	33,9%
47.627	71,38	-0,57	70,82	35,7%
62.731	79,75	-0,57	79,19	35,7%
66.360	81,76	-0,57	81,20	35,8%

Table 31: Landing operational envelope.

The most restrictive points from Table 29, Table 30,Table 31 , therefore the most limiting one out of the three operational limits, forms the Operational envelope.

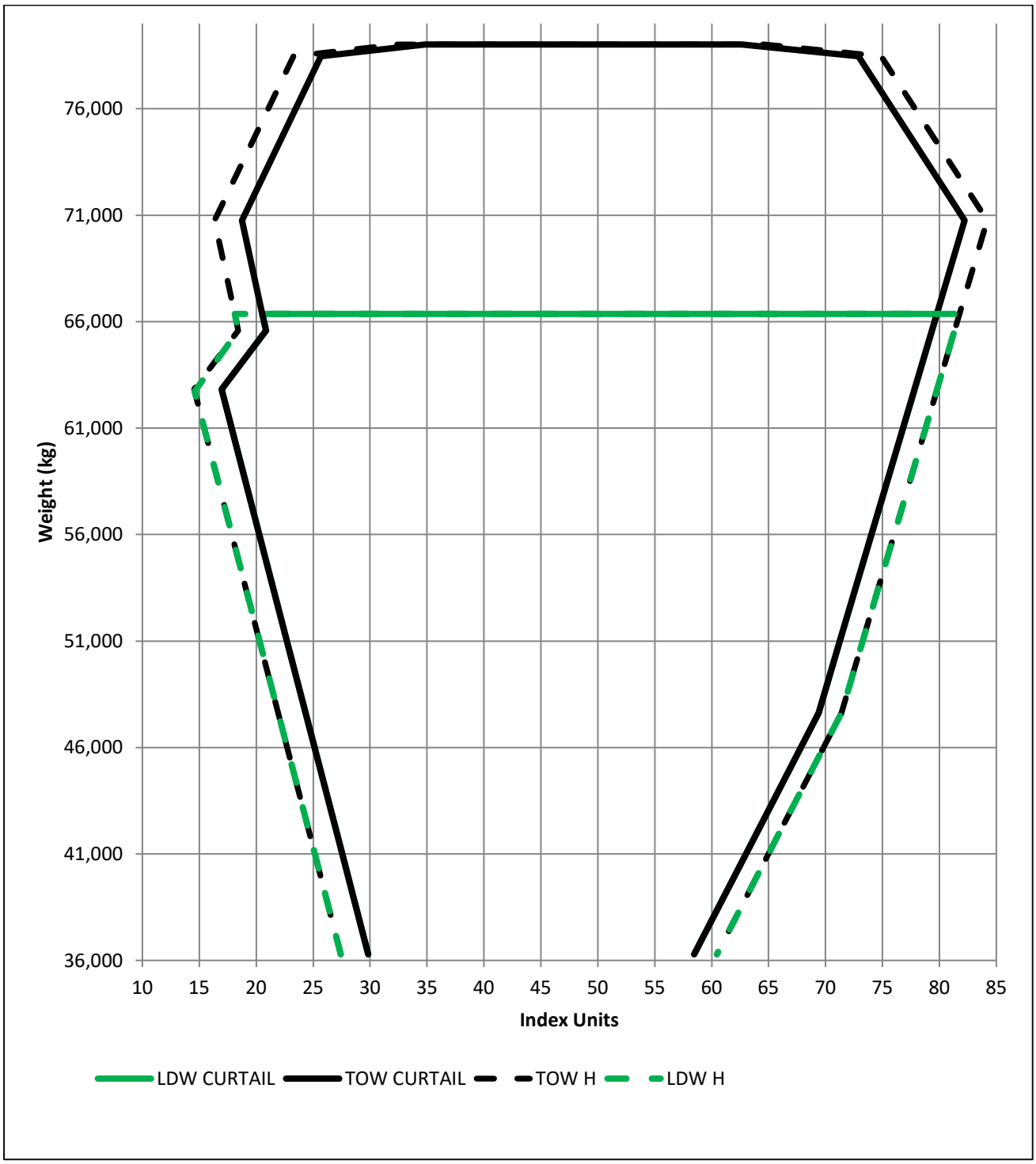


Figure 8: AEI envelope H vs. Operational envelope.

	Summary of Operational Curtailment				
	Weight (kg)	Index	Error Index	New Index	NEW %MAC
	FWD Curtailed Operational Limit				
TO/LD	36.287	27,41	2,42	29,83	7,9%
TO/LD	41.730	24,77	2,42	27,19	7,7%
TO/LD	50.802	20,38	2,42	22,79	7,4%
TO/LD	62.732	14,59	2,42	17,01	7,1%
TO/LD	62.822	14,55	2,42	16,97	7,1%
TO/LD	65.589	18,43	2,42	20,85	9,4%
TO/LD	66.360	18,12	2,42	20,54	9,4%
TO	70.760	16,34	2,42	18,75	9,3%
TO	78.471	23,27	2,42	25,68	12,9%
TO	79.015	32,41	2,42	34,82	16,3%
	AFT Curtailed Operational Limit				
TO/LD	36.287	60,45	-1,98	58,47	30,7%
TO/LD	41.730	65,70	-1,98	63,71	33,0%
TO/LD	47.627	71,38	-1,98	69,40	34,8%
TOLD	50.802	73,14	-1,98	71,16	34,9%
LD	62.731	79,75	-1,98	77,77	35,1%
LD	66.360	81,76	-1,98	79,78	35,1%
TO	70.760	84,20	-1,98	82,21	35,2%
TO	78.471	74,89	-1,98	72,90	30,3%
TO	79.015	64,64	-1,98	62,65	26,5%

Table 32: Operational Envelope.

6.2 Fuel Allowance corrections

Due to the shape of the fuel vector, it is necessary to modify the aft center of gravity limits for the moment effect of fuel loading and usage related to the Zero Fuel weight envelope. The shape of the fuel vector does not require modification of the forward center of gravity limits for the moment effect of fuel loading or usage. The Zero Fuel envelope is corrected to counter protect the aircraft in Take-Off configuration.

The most restrictive cases occur at the intersection of the mid weight of the fuel curve and the certificated Zero Fuel weight (ZFW) envelop. A critical point is identified and used as a correction factor for the Zero Fuel Weight (ZFW) envelope correction. Forward section requires no correction. Aft Zero Fuel weight envelope is corrected accordingly as shown Figure 9.

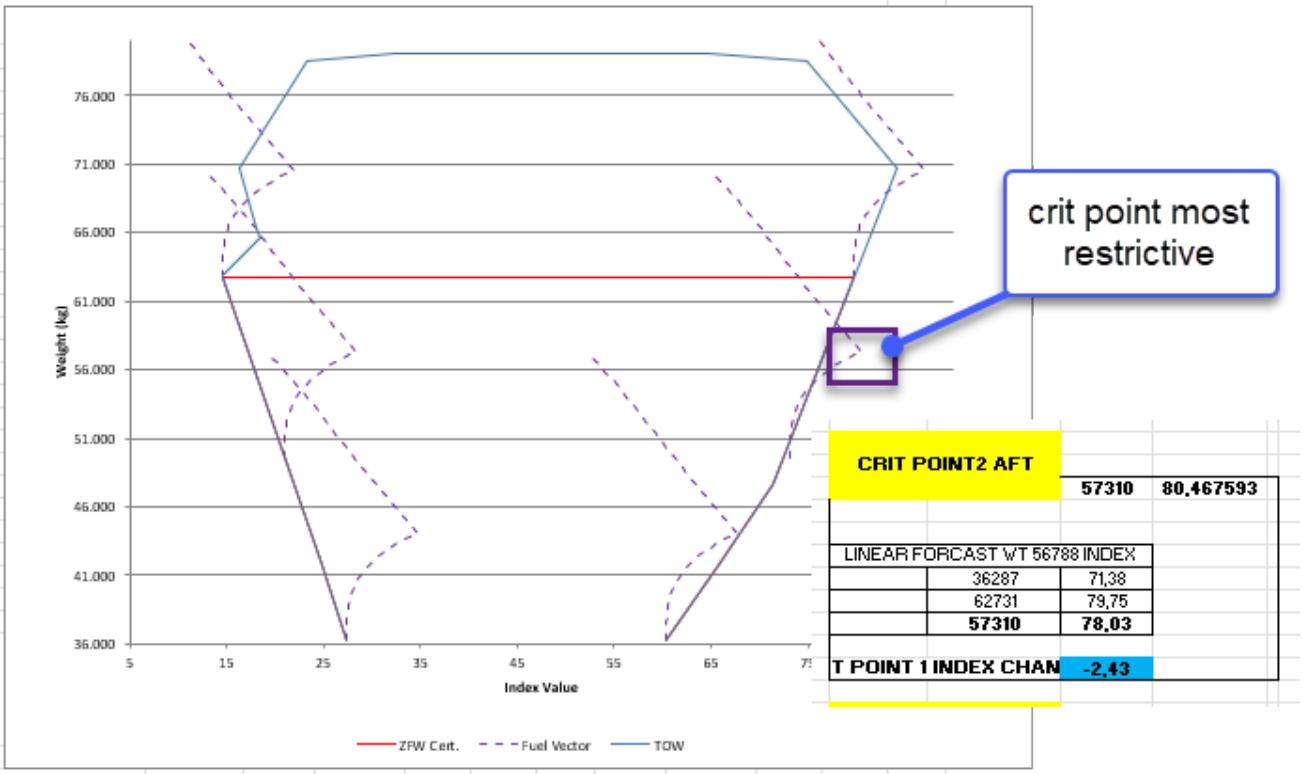


Figure 9: Fuel Vectors in ZFW certified envelope.

6.3 Zero Fuel Operational Limits Construction

The Zero Fuel limit design is based on the theoretical fuel vector at a chosen density. This Zero Fuel limit is used to ensure that flight CG all along the flight and Landing CG before Landing are within their own operational limits.

To ensure the Take-Off CG, Landing CG and In-Flight CG are within the allowed limits during the whole flight the following must be checked.

- The Zero Fuel CG is within the Zero Fuel Operational Limit
- And the Take-Off weight and Landing weight are compliant with the operational Take-Off and Landing maximum weight.

To derive the Zero Fuel operational limit each flight phase fuel vector is leaned against the certified In-Flight and Landing limits as shown in for Zero Fuel weight. This operation is done for Zero Fuel weight, from minimum aircraft weight to certified Zero Fuel weight. The final Zero Fuel limits in Table 33.

Zero Fuel Operational Curtailment				
Weight (kg)	**Index**	**Error Index**	**New Index**	**NEW %MAC**
FWD Curtailed Limit				
36.287	27,41	2,42	29,83	7,9%
62.731	14,59	2,42	17,01	7,1%
AFT Curtailed Limit				
36.287	60,45	-2,43	58,02	30,4%
47.627	71,38	-2,43	68,95	34,5%
62.731	79,75	-2,43	77,32	34,9%

Table 33: Zero Fuel Operational Envelope.

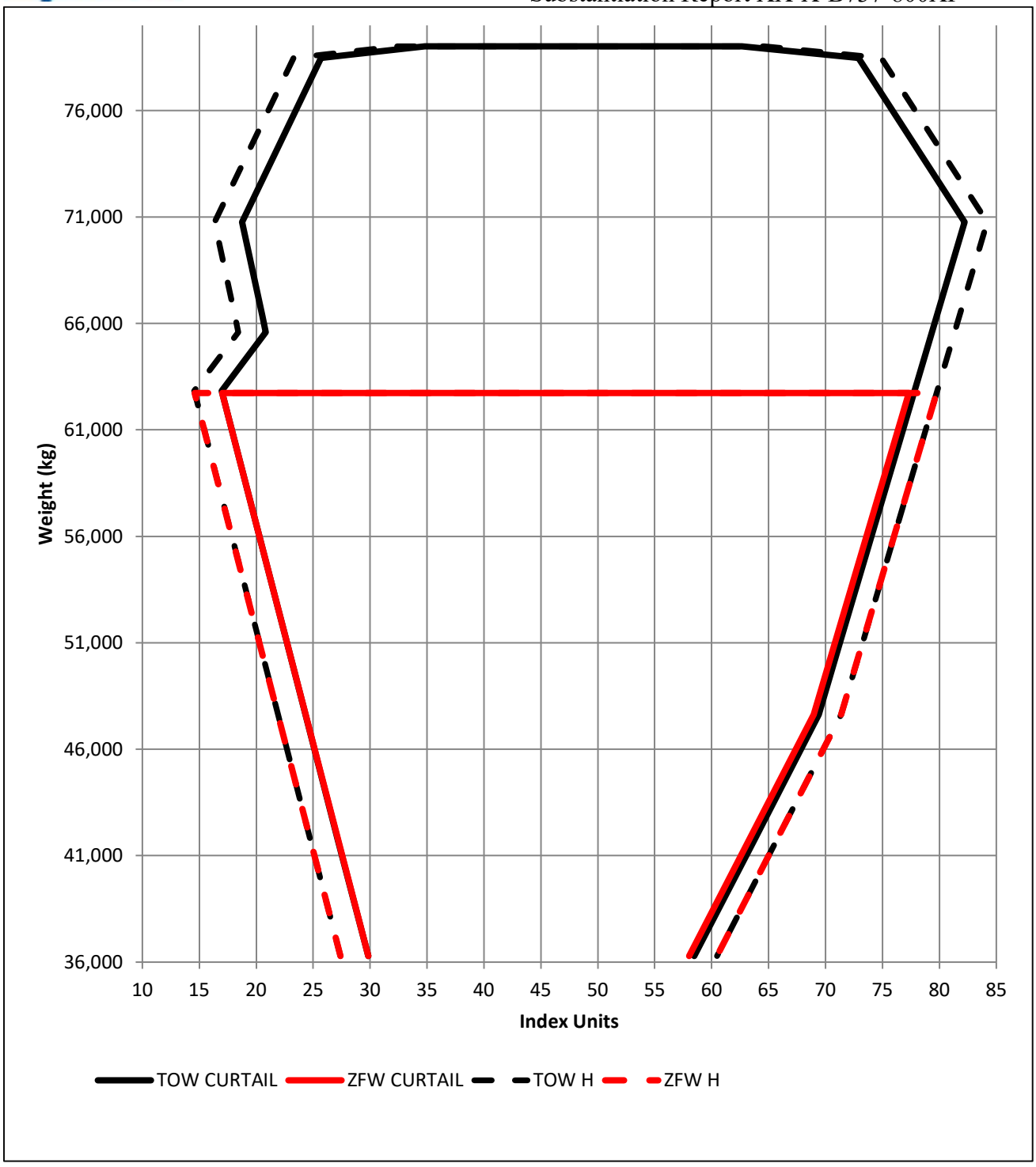


Figure 10: Take-Off, Landing, and Zero Fuel certified and curtailed envelopes.

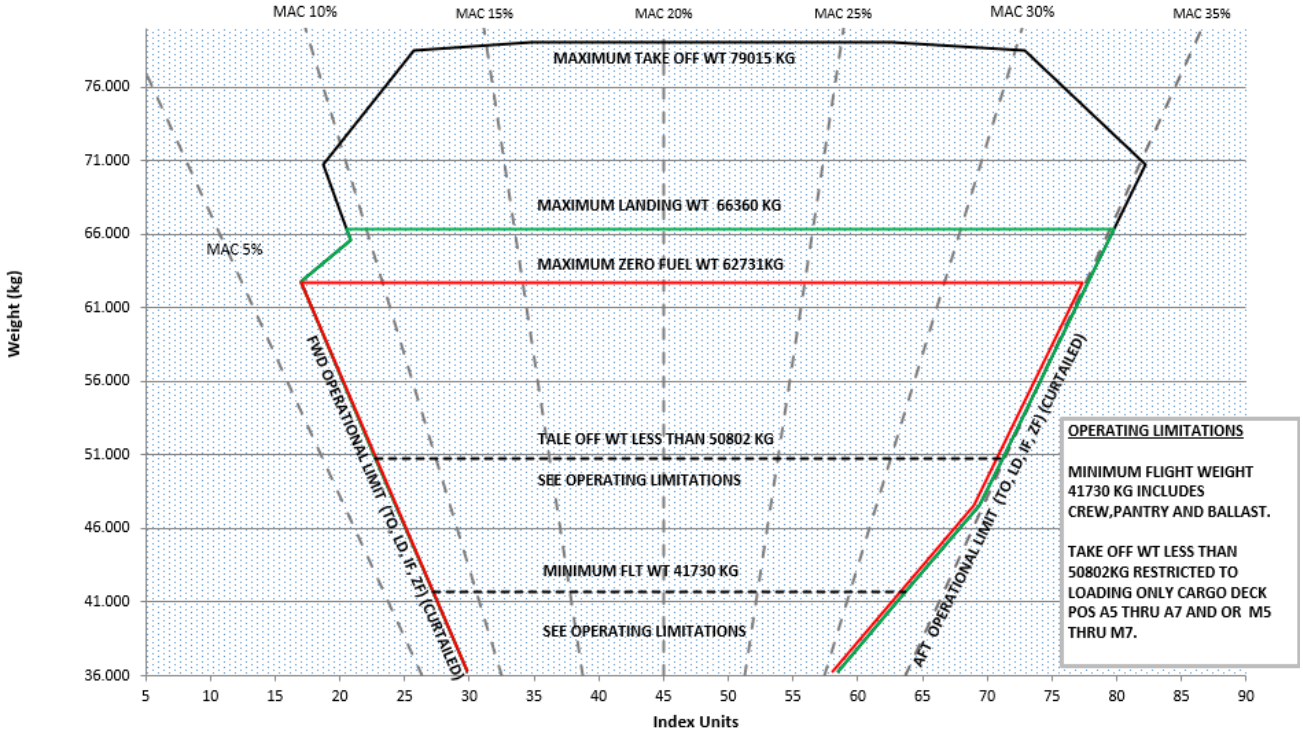


Figure 11: Operational Envelopes.

7 Description of Manual Load and Trim Sheet

The Manual Load and trim sheet are provided for:

- Calculation of the Zero Fuel, Take-Off and Landing weight, when electronic departure control system is not available.
- Index calculation to determine the position of the center of gravity of the loaded aircraft at Zero Fuel, Take-Off and Landing weight, when electronic departure system is not available.

7.1 User Instructions for Balance Chart and Index Table (AHM516)

The instructions below only reflect how to use the loadsheet and do not necessarily reflect the up-to-date data for AIRCRAF.

a) Enter flight details: Flight Number, Crew code, From, To and Date, CDB and FO (names or code).

b) Enter the Basic Weight and index.

c) Enter the crew weight and index.

d) Calculate the Dry Operating Weight (sum of b) and c)). NOTE EXAMPLE ONLY FOR BASIC WEGHT AND INDEX. Refer to AHM-565 for data related to up to date weight and index values.

Item		Weight	±	Index
BASIC WEIGHT	→	38365	+	28.6
Crew (FLT/OBS)	+	2380	-	3.3
DRY OPERATING WEIGHT	=	386053	+	25.3

Crew Loading Index Table

Extra Crew Member(s)	Weight	Index Units	Crew Comopsition	Weight	Index Units
Flight Crew	119,0	-1,7	2/0	238	-3,3
Observer #1	119,0	-1,6	3/0 (+1 obs)	323	-4,9
Observer #2	119,0	-1,6	4/0 (+2 obs)	408	-6,5
Authorized Personnel near door	119,0	-1,4	For Authorized Personnel add relevant wt		
Authorized Personnel (9G barrier)	119,0	-1,4	and index as per table left side		

e) Enter the Take-Off fuel weight and calculate the Operating weight (adding fuel weight to dry operating weight).

Item		Weight					±	Index		
BASIC WEIGHT	→	3	8	3	6	5	+	28	.	6
Crew (FLT/OBS)	+			2	3	8	-	3	.	3
DRY OPERATING WEIGHT	=	3	8	6	0	3	+	25	.	3
CORRECTED DOW	+								.	
ADJUSTED DRY OPERATING WT	=								.	
TAKE OFF FUEL	+		7	3	6	0	N/A			
OPERATING WEIGHT	=	4	5	9	6	3				

f) Enter Maximum Zero Fuel Weight (MZFW), or Restricted Zero Fuel Weight (RZFW) if applicable. Also re-enter the Take-Off fuel weight. Add these together and enter the combined weight.

	A Zero Fuel					B Take-Off	C Landing
Max strutural weights for	6	2	7	3	1		
Corrected max weight for							
Take-Off Fuel +		7	3	6	0	Trip Fuel +	
Allowed for Take-Off =	7	0	0	9	1		0

g) Enter Maximum Take-Off Weight (MTOW), or Restricted Take-Off Weight (RTOW) if applicable.

	A Zero Fuel					B Take-Off					C Landing
Max strutural weights for	6	2	7	3	1						
Corrected max weight for											
Take-Off Fuel +		7	3	6	0	Trip Fuel +					
Allowed for Take-Off =	7	0	0	9	1	7	9	0	1	5	0

h) Enter Maximum Landing Weight (MLW), or Restricted Landing Weight (RLDW) if applicable. Also enter the Trip fuel weight. Add these together and add the combined weight.

	A Zero Fuel					B Take-Off					C Landing				
Max strutural weights for	6	2	7	3	1						6	6	3	6	0
Corrected max weight for															
Take-Off Fuel +		7	3	6	0	Trip Fuel +						4	1	6	0
Allowed for Take-Off =	7	0	0	9	1	7	9	0	1	5	7	0	5	2	0

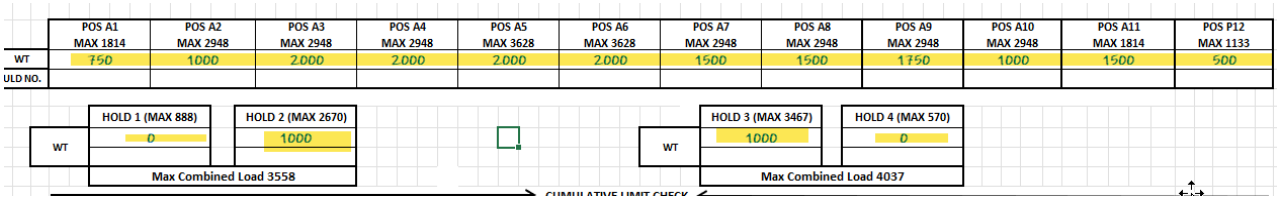
i) Find the allowed weight for Take-Off (use the lowest weight of the three weights).

	A Zero Fuel					B Take-Off					C Landing				
Max strutural weights for	6	2	7	3	1						6	6	3	6	0
Corrected max weight for															
Take-Off Fuel +		7	3	6	0	Trip Fuel +						4	1	6	0
Allowed for Take-Off =	7	0	0	9	1	7	9	0	1	5	7	0	5	2	0
(Lowest of A,B,C)															

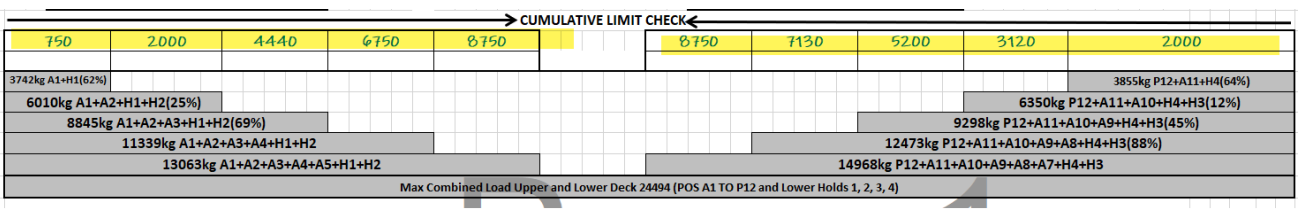
j) Enter the operating weight below the lowest weight found in previous step and the calculate the Allowed Traffic Load.

	A Zero Fuel					B Take-Off					C Landing				
Max strutural weights for	6	2	7	3	1						6	6	3	6	0
Corrected max weight for															
Take-Off Fuel +		7	3	6	0	Trip Fuel +						4	1	6	0
Allowed for Take-Off =	7	0	0	9	1	7	9	0	1	5	7	0	5	2	0
(Lowest of A,B,C)															
Operating Weight -	4	5	9	6	3										
Allowed Traffic Load =	2	4	1	2	8										

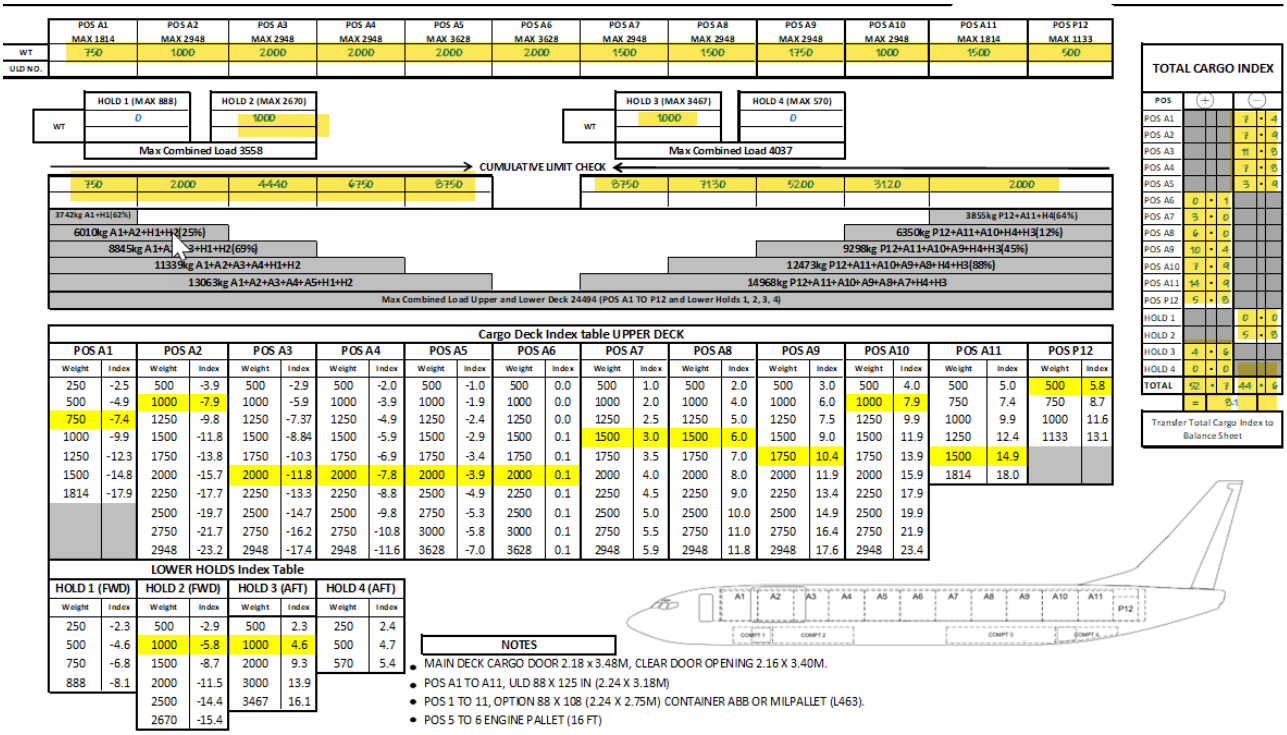
k) On the load planner and Cargo index table. Enter details of freight for each bay and calculate total cargo weight and index. Make sure that total payload does not exceed allowed traffic load. Complete combined load calculations by adding all loads and make sure limits are not exceeded for maximum combined load.



l) Next complete cumulative check for each position per instructions on form.



m) At last, select index values according to weight of bay (upper cargo bays or lower cargo holds) and complete the Total Cargo Index table to find the total cargo index for payload.



	POS A1 MAX 1814	POS A2 MAX 2948	POS A3 MAX 2948	POS A4 MAX 2948	POS A5 MAX 3628	POS A6 MAX 3628	POS A7 MAX 2948	POS A8 MAX 2948	POS A9 MAX 2948	POS A10 MAX 2948	POS A11 MAX 1814	POS P12 MAX 1133
WT	750	1000	2000	2000	2000	2000	1500	1500	1350	1000	1500	500
ULD NO.												

	HOLD 1 (MAX 888)	HOLD 2 (MAX 2670)	HOLD 3 (MAX 3467)	HOLD 4 (MAX 570)
WT	0	1000	1000	0
	Max Combined Load 3558		Max Combined Load 4037	

CUMULATIVE LIMIT CHECK

750	2000	4440	6750	8750	8750	7130	5200	3120	2000

3742kg A1+H1(62%)
3855kg P12+A11+H4(64%)
6010kg A1+A2+H1+H2(25%)
6350kg P12+A11+A10+H4+H3(12%)
8845kg A1+A2+A3+H1+H2(69%)
9298kg P12+A11+A10+A9+H4+H3(45%)
11339kg A1+A2+A3+A4+H1+H2
12473kg P12+A11+A10+A9+A8+H4+H3(88%)
13063kg A1+A2+A3+A4+A5+H1+H2
14968kg P12+A11+A10+A9+A8+A7+H4+H3
Max Combined Load Upper and Lower Deck 24494 (POS A1 TO P12 and Lower Holds 1, 2, 3, 4)

TOTAL CARGO INDEX

POS	+			−		
POS A1				7	.	4
POS A2				7	.	4
POS A3				11	.	8
POS A4				7	.	0
POS A5				5	.	4
POS A6	0	.	1			
POS A7	3	.	0			
POS A8	6	.	0			
POS A9	10	.	4			
POS A10	7	.	8			
POS A11	14	.	8			
POS P12	5	.	8			
HOLD 1				0	.	0
HOLD 2				5	.	8
HOLD 3	4	.	6			
HOLD 4	0	.	0			
TOTAL	52	.	7	44	.	6
	=			8.1		

Transfer Total Cargo Index to Balance Sheet

Cargo Deck Index table UPPER DECK

POS A1		POS A2		POS A3		POS A4		POS A5		POS A6		POS A7		POS A8		POS A9		POS A10		POS A11		POS P12	
Weight	Index	Weight	Index	Weight	Index	Weight	Index	Weight	Index	Weight	Index	Weight	Index	Weight	Index	Weight	Index	Weight	Index	Weight	Index	Weight	Index
250	-2.5	500	-3.9	500	-2.9	500	-2.0	500	-1.0	500	0.0	500	1.0	500	2.0	500	3.0	500	4.0	500	5.0	500	5.8
500	-4.9	1000	-7.9	1000	-5.9	1000	-3.9	1000	-1.9	1000	0.0	1000	2.0	1000	4.0	1000	6.0	1000	7.9	750	7.4	750	8.7
750	-7.4	1250	-9.8	1250	-7.37	1250	-4.9	1250	-2.4	1250	0.0	1250	2.5	1250	5.0	1250	7.5	1250	9.9	1000	9.9	1000	11.6
1000	-9.9	1500	-11.8	1500	-8.84	1500	-5.9	1500	-2.9	1500	0.1	1500	3.0	1500	6.0	1500	9.0	1500	11.9	1250	12.4	1133	13.1
1250	-12.3	1750	-13.8	1750	-10.3	1750	-6.9	1750	-3.4	1750	0.1	1750	3.5	1750	7.0	1750	10.4	1750	13.9	1500	14.9		
1500	-14.8	2000	-15.7	2000	-11.8	2000	-7.8	2000	-3.9	2000	0.1	2000	4.0	2000	8.0	2000	11.9	2000	15.9	1814	18.0		
1814	-17.9	2250	-17.7	2250	-13.3	2250	-8.8	2500	-4.9	2250	0.1	2250	4.5	2250	9.0	2250	13.4	2250	17.9				
		2500	-19.7	2500	-14.7	2500	-9.8	2750	-5.3	2500	0.1	2500	5.0	2500	10.0	2500	14.9	2500	19.9				
		2750	-21.7	2750	-16.2	2750	-10.8	3000	-5.8	3000	0.1	2750	5.5	2750	11.0	2750	16.4	2750	21.9				
		2948	-23.2	2948	-17.4	2948	-11.6	3628	-7.0	3628	0.1	2948	5.9	2948	11.8	2948	17.6	2948	23.4				

LOWER HOLDS Index Table

HOLD 1 (FWD)		HOLD 2 (FWD)		HOLD 3 (AFT)		HOLD 4 (AFT)	
Weight	Index	Weight	Index	Weight	Index	Weight	Index
250	-2.3	500	-2.9	500	2.3	250	2.4
500	-4.6	1000	-5.8	1000	4.6	500	4.7
750	-6.8	1500	-8.7	2000	9.3	570	5.4
888	-8.1	2000	-11.5	3000	13.9		
		2500	-14.4	3467	16.1		
		2670	-15.4				

NOTES

- MAIN DECK CARGO DOOR 2.18 x 3.48M, CLEAR DOOR OPENING 2.16 X 3.40M.
- POS A1 TO A11, ULD 88 X 125 IN (2.24 X 3.18M)
- POS 1 TO 11, OPTION 88 X 108 (2.24 X 2.75M) CONTAINER ABB OR MILPALLET (L463).
- POS 5 TO 6 ENGINE PALLET (16 FT)

n) Proceed to **Balance Chart** and enter the Total cargo weight and index.

o) Enter the Total extra crew weight and index if applicable.

p) Enter the payload fuel weight and index if applicable (Ballast fuel DO NOT USE IF NOT CARRIED).

		Weight					±	Index		
TOTAL CARGO / INDEX	→	1	9	5	0	0	+	8	.	1
EXTRA CREW and INDEX	+								.	
PAYLOAD FUEL AND INDEX	+								.	
NOTE: DETAILS ON LOAD PLAN	LMC ±								.	

q) Calculate the Total traffic load weight and index.

TOTAL CARGO / INDEX	→	1	9	5	0	0	+	8	.	1
EXTRA CREW and INDEX	+								.	
PAYLOAD FUEL AND INDEX	+								.	
NOTE: DETAILS ON LOAD PLAN LMC	±								.	
									.	
TOTAL TRAFFICE LOAD / INDEX	=	1	9	5	0	0	+	8	.	1

r) Calculate Zero Fuel Weight (ZFW) by adding together the Total Traffic Load and the Dry Operating Weight (weight and index), to ensure that the ZFW limitation is not exceeded.

Item		**Weight**					**±**	**Index**		
BASIC WEIGHT	→	3	8	3	6	5	+	28	.	6
Crew (FLT/OBS)	+			2	3	8	-	3	.	3
DRY OPERATING WEIGHT	=	3	8	6	0	3	+	25	.	3
CORRECTED DOW	+								.	
ADJUSTED DRY OPERATING WT	=								.	
TAKE OFF FUEL	+		7	3	6	0	**N/A**			
OPERATING WEIGHT	=	4	5	9	6	3				
		Weight					**±**	**Index**		
TOTAL CARGO / INDEX	→	1	9	5	0	0	+	8	.	1
EXTRA CREW and INDEX	+								.	
PAYLOAD FUEL AND INDEX	+								.	
NOTE: DETAILS ON LOAD PLAN LMC	±								.	
									.	
TOTAL TRAFFICE LOAD / INDEX	=	1	9	5		0	+	8	.	1
									.	
Dry Operating Weight and Index	+	3	8	6	0	3	+	25	.	3
	+								.	

s) Enter Take-Off fuel and index.

t) Calculate Take-Off Weight and Index by adding together the Zero Fuel weight and index and the Take-Off fuel weight and index, to ensure that the TOW limitation is not exceeded.

Item		Weight					±	Index		
BASIC WEIGHT	→	3	8	3	6	5	+	28	.	6
Crew (FLT/OBS)	+			2	3	8	-	3	.	3
DRY OPERATING WEIGHT	=	3	8	6	0	3	+	25	.	3
CORRECTED DOW	+								.	
ADJUSTED DRY OPERATING WT	=								.	
TAKE OFF FUEL	+		7	3	6	0	N/A			
OPERATING WEIGHT	=	4	5	9	6	3				
		Weight					±	**Index**		
TOTAL CARGO / INDEX	→	1	9	5	0	0	+	8	.	1
EXTRA CREW and INDEX	+								.	
PAYLOAD FUEL AND INDEX	+								.	
NOTE: DETAILS ON LOAD PLAN	LMC ±								.	
									.	
TOTAL TRAFFICE LOAD / INDEX	=	1	9	5	0	0	+	8	.	1
									.	
Dry Operating Weight and Index	+	3	8	6	0	3	+	25	.	3
	+								.	
ZERO FUEL WEIGHT / INDEX	=	5	8	1	0	3	+	33	.	4
	LMC ±								.	
MAX 62731	=	5	8	1	0	3	+	33	.	4
Take-off fuel and index	+		7	3	6	0	+	6	.	0
Ramp: fuel							N/A			
TAKE-OFF WEIGHT / INDEX		6	5	4	6	3	+	39	.	4
	LMC ±								.	
MAX 79015	=	6	5	4	6	3	+	39	.	4

u) Enter the estimated weight of trip fuel.

v) Calculate Landing weight by subtract estimated trip fuel (burn fuel) from the TOW and check the estimated Landing weight is within limits of maximum allowed.

TOTAL TRAFFICE LOAD / INDEX	=	1	9	5	0	0	+	8	.	1
									.	
Dry Operating Weight and Index	+	3	8	6	0	3	+	25	.	3
	+								.	
ZERO FUEL WEIGHT / INDEX	=	5	8	1	0	3	+	33	.	4
LMC	±								.	
MAX 62731	=	5	8	1	0	3	+	33	.	4
Take-off fuel and index	+		7	3	6	0	+	6	.	0
Ramp: fuel							N/A			
TAKE-OFF WEIGHT / INDEX		6	5	4	6	3	+	39	.	4
LMC	±								.	
MAX 79015	=	6	5	4	6	3	+	39	.	4
Trip Fuel	-		4	1	6	0				
EST. LANDING WEIGHT /INDEX		6	1	3	0	3	N/A			
LMC	±									
MAX 66360	=	6	1	3	0	3				

w) Last Minute Changes (LMC) In the event of any last-minute changes to the load and trim sheet enter the details in the second build-up table (adjust LMC according to company limits stated in flight operations manual). Enter information into the LMC box: the specification,

Compartment or Pallet Position of the LMC and if it is being removed or added. The weight and index of the LMC should be entered into the box. Should the LMC adjustment be according to company requirements (and there is no change to the fuel load), additionally check that none of the limiting weights are exceeded then no action is required to recalculate the actual ZFW, TOW and LDW.

NOTE: Assumed that when cargo or mail are added or deleted as part of the LMC, that the load is distributed evenly between the bays and upper/lower deck cargo bays respectively and LMC is adjusted to maximums according to company operations manual

NOTE: Consideration must be given to the change in C.G. of this LMC. If the original C.G. is within 4 index units of the fwd limit or 4 index units from the aft limit then a new balance calculation must be completed, unless the change takes the C.G. to the centre of the

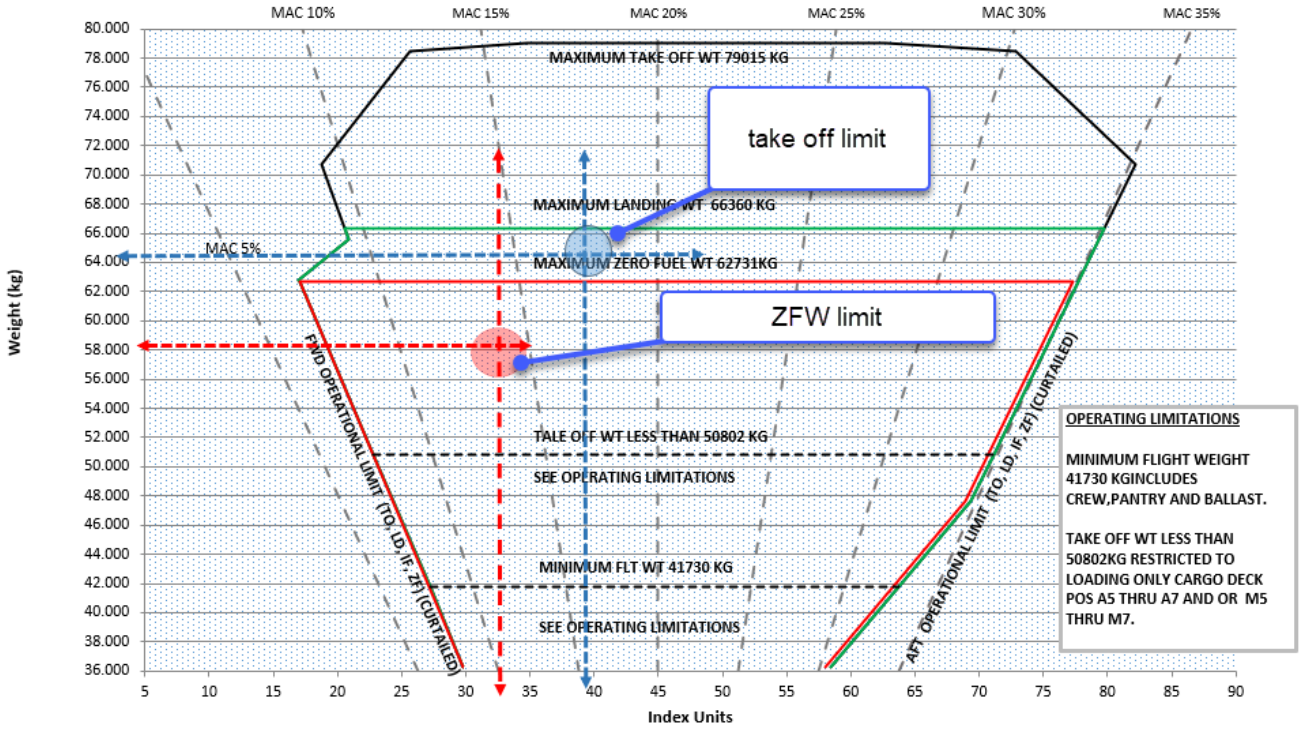
LAST MINUTE CHANGE			Weight					±	Index		
Item	Location	±								.	
										.	
	None									.	
										.	
		=								.	

7.2 User Instruction Drawing balance chart limits

a) Draw a cross where the Zero Fuel index value intersects a horizontal line drawn on the balance chart at actual Zero Fuel weight. This point shows the aircraft center of gravity at Zero Fuel condition.

NOTE: ZFW point MUST fall within the forward and aft Zero Fuel operational limit boundary to give a safe loading. This is the ONLY criterion for determining that the aircraft will remain within the certificated limits throughout the flight.

b) Draw a cross where the Take-Off index value intersects a horizontal line drawn on the balance chart at actual Take-Off weight. This point will show the aircraft center of gravity at Take-Off condition.



c) Observe the position of the TOW in relation to the %MAC lines on the chart.

d) Reference the C.G. %MAC on the trim setting tables and enter the applicable elevator trim setting (STAB TRIM), for relevant Flap settings, in the lower center of the loadsheet.

	%MAC (Flaps 1 & 5)										
Weights	6	8,5	9	11	16	20	24	26	32,5	34,4	36
36287 > 45359	6,20	5,87	5,80	5,53	4,86	4,32	3,79	3,52	2,65	2,65	2,65
45359 > 50000	6,61	6,26	6,19	5,91	5,22	4,66	4,10	3,82	2,91	2,65	2,65
50001 > 60000	7,49	7,11	7,03	6,73	5,97	5,36	4,75	4,45	3,46	3,17	2,93
60001 > 70000	8,30	7,89	7,81	7,48	6,66	6,01	5,35	5,03	3,96	3,65	3,39
70001 > MRW	8,50	8,50	8,42	8,08	7,23	6,55	5,87	5,53	4,42	4,10	3,83
	%MAC (Flaps 10, 15 & 25)										
Weights	6	8	10,7	11	16	24	26,5	30,4	33	35,6	36
36287 > 45359	5,30	5,01	4,61	4,56	3,83	2,65	2,65	2,65	2,65	2,65	2,65
45359 > 50000	6,17	5,81	5,33	5,28	4,38	3,06	2,65	2,65	2,65	2,65	2,65
50001 > 60000	7,68	7,21	6,58	6,51	5,33	3,84	3,38	2,65	2,65	2,65	2,65
60001 > 70000	8,50	8,50	7,64	7,55	5,96	4,40	3,92	3,16	2,65	2,65	2,65

Total Persons On Board	%MAC -Take-Off	Prepared by
2	17%	CCCC
Notes	Stab Trim Setting	PIC Signature
NIL	6,49	AAAA

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e) Enter the total persons on board the aircraft.

f) Enter any notes if necessary.

Total Persons On Board	%MAC -Take-Off	Prepared by
2	17%	CCCC
Notes	**Stab Trim Setting**	**PIC Signature**
NIL	6,49	AAAA

7.3 Loadsheet Signatures

The person preparing the loadsheet must sign against 'Prepared by' and the captain must sign the 'PIC Signature' box appropriately. If a flight crew member has prepared the loadsheet, this persons signature should certify additionally that the aircraft has been loaded in accordance with the current loading specified on the LoadSheet.

Total Persons On Board	%MAC -Take-Off	Prepared by
2	17%	CCCC
Notes	**Stab Trim Setting**	**PIC Signature**
NIL	6,49	AAAA