AIRCRAFT WEIGHTS

1. Introduction

There are many factors that lead to efficient and safe operation of aircraft. Among these vital factors is proper weight and balance control.

The maximum allowable weight for an aircraft is determined by design considerations.
The manufacturer provides the aircraft operator with the empty weight of the aircraft and the location of its empty weight center of gravity (EWCG) at the time the certified aircraft leaves the factory.

However, the maximum operational weight may be less than the maximum allowable weight due to such considerations as high-density altitude or high-drag field conditions caused by wet grass or water on the runway. The maximum operational weight may also be limited by the departure or arrival airport's runway length.

2. Manufacturer's design weight limitation

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The structural weight limits are based on aircraft maximum structural capability and define the envelope for the CG charts. Aircraft structural weight capability is established during aircraft design and certification.

2.1. Maximum design taxi weight (MDTW or MTW)

The maximum design taxi weight or maximum design ramp weight (MDRW) is the maximum certificated design weight for aircraft ground maneuver as limited by aircraft strength and airworthiness requirements.

The difference between the maximum taxi/ramp weight and the maximum take-off weight (maximum taxi fuel allowance) depends on the size of the aircraft, the number of engines, APU operation, and engines/APU fuel consumption, and is typically assumed for 10 to 15 minutes allowance of taxi and run-up operations.

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2.2. Maximum design takeoff weight (MDTOW or MTOW)

The maximum design takeoff weight is the maximum certificated design weight for takeoff run as limited by aircraft strength and airworthiness requirements.

2.3. Maximum design landing weight (MDLW or MLW)

The Maximum design landing weight is the maximum certificated design weight for landing Maximum design landing weight.

It generally depends on the landing gear strength or the landing impact loads on certain parts of the wing structure.

$$MDLW < MDTOW < MDTW$$

2.4. Maximum design zero-fuel weight (MDZFW)

The maximum design zero-fuel weight is the maximum certificated design weight of the aircraft less all usable fuel and other specified usable agents as limited by aircraft strength and airworthiness requirements.

It is the maximum weight permitted before usable fuel and other specified usable fluids are loaded in specified sections of the airplane.

The weight difference between the MDTOW and the MDZFW may be utilized only for the addition of fuel.

$$\text{Maximum payload} = MDZFW - OEW$$

2.5. Minimum flight weight (MFW)

Minimum certificated weight for flight as limited by aircraft strength and airworthiness requirements.

3. Effects of weight

Some of the problems caused by overloading an aircraft are:

- The aircraft will need a higher takeoff speed, which results in a longer takeoff run.
- Both the rate and angle of climb will be reduced.
- The service ceiling will be lowered.
- The cruising speed will be reduced.
- The cruising range will be shortened.
- Maneuverability will be decreased.
- A longer landing roll will be required because the landing speed will be higher.
- Excessive loads will be imposed on the structure, especially the landing gear.

4. Definition

4.1. Aircraft gross weight

The aircraft gross weight is the total aircraft weight at any moment during the flight or ground operation.

The aircraft gross weight decreases during flight due to fuel and oil consumption. The aircraft gross weight may also vary during flight due to payload dropping or in-flight refueling.

4.2. Manufacturer's empty weight (MEW)

Let's start with the aircraft itself. An aircraft "as is" includes:

- Airframe structure with all moving mechanical parts (fuselage, wings, flaps, gear, rudder, nacelle …)
- Power generation system (APU, main engines, power plant…)
- Systems (electrical, hydraulics, pneumatic, fuel flow system, instrument, navigation, air conditioning, anti-ice, fixed furnishing)
- Fixed equipment and services considered an integral part of the aircraft
- Fixed ballast
- Closed system fluids
- Unused fuel only for small aircraft

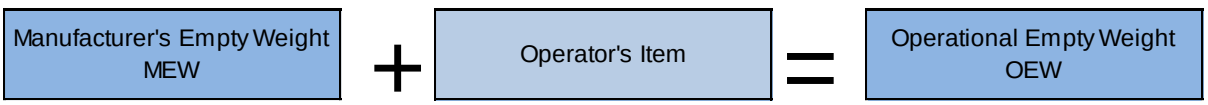
All these items above form the Manufacturer's Empty Weight (MEW).

This weight shall not include:

- Fuel
- Oil, potable water
- Payload (Cargo, passenger, luggage)
- Removable equipment
- Customer specific installation or operator items

4.3. Operational Empty Weight (OEW)

The MEW and the operator's items are summed up to the ***Operational Empty Weight (OEW).*** The OEW is usually fixed for a specific aircraft and only gets changed during maintenance or operational changes.



OEW is the empty weight that's used in the flight simulator or the usual planning software.

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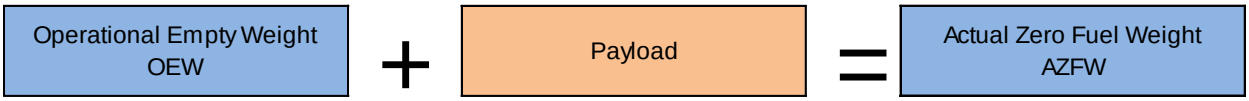
The operator's items are:

- fluids necessary for aircraft operation (engine oil and coolant, water, unusable fuel)
- the water for galleys and lavatories
- aircraft documentation
- passenger seats (and the life vests)
- galley structure
- catering emergency equipment
- aircraft crew and their luggage.
- standard items necessary for full operation

4.4. Actual Zero Fuel Weight (AZFW)

If we add the payload to the empty plane weight, we get the ***Actual Zero Fuel Weight (AZFW)***.



The payload includes:

- the passenger's weight (the standard weights used defined by ICAO respectively)
- the passenger luggage's weight
- the cargo weight

The assumed weights vary around some kg / lbs. pending on the number of seats available on the aircraft.

- a male passenger (incl. cabin luggage) weighs around 82kg (181 lbs.)
- a female passenger around 67kg (148 lbs.)
- a child around 50kg (110lbs.)
- an infant 16kg (35 lbs.).

These are statistical values but otherwise one would need to weigh every single passenger during check in to get his exact weight. Additional payload consists of baggage and cargo (such as mail or goods).

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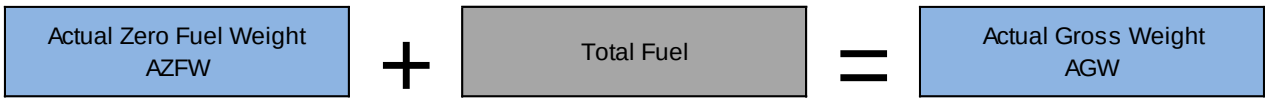
4.5. Actual Gross Weight (AGW)

In addition the actual zero fuel weight, we add the fuel required for the flight and we get the ***Actual Gross Weight (AGW)***.



At that time, you should have calculated your total fuel for this flight.
The actual gross weight is the weight of aircraft ready for departure at the gate before push-back and start-up.

type	1 Litre	1 U.S. Gallon	1 Imp. Gallon
Aviation Gas	1.58 lb.	6.0 lb.	7.20 lb.
JP-4	1.76 lb.	6.6 lb.	8.01 lb.
Kerosene	1.85 lb.	7.0 lb.	8.39 lb.
Oil	1.95 lb.	7.5 lb.	8.5 lb.

Note: 1kg = 2.20462262185 lb(s)

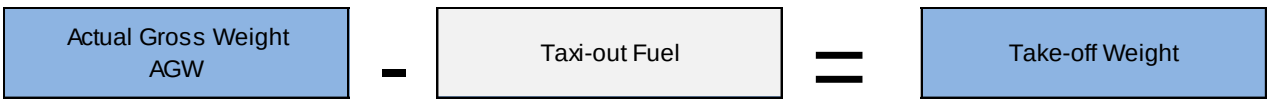
The total fuel shall include:

- Taxi-out fuel (at departure airfield)
- Trip fuel
- Holding
- Re-routing expectation
- regulation needs depending your route arrival airfield
- fuel to join alternate airfield
- taxi-in fuel at destination,
- final reserve

4.6. Take-off weight

Fuel burn during taxi operation to the departure runway reduces the gross weight. At the holding point, we have the ***Actual Take-off Weight (ATOW)*** which is used for take-off performance calculation.

The gross weight varies during flight. Fuel and oil consumption reduces the gross weight. Additionally it may vary during flight due to inflight refuelling or payload dropping.



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4.7. Maximum design takeoff weight (MDTOW)

The maximum takeoff weight (also known as the maximum brake-release weight) is the maximum weight authorized at brake release for takeoff, or at the start of the takeoff roll.

The maximum takeoff weight is always less than the maximum taxi/ramp weight to allow for fuel burned during taxi by the engines and the APU.

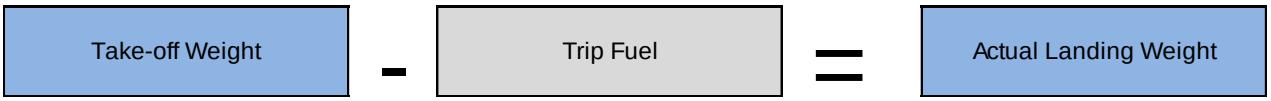
In operation, the maximum weight for takeoff may be limited to values less than the maximum takeoff weight due to aircraft performance, environmental conditions, airfield characteristics (takeoff field length, altitude), maximum tire speed and brake

At this weight, the subsequent addition of fuel will not result in the aircraft design strength being exceeded. The weight difference between the MTOW and the MZFW may be utilized only for the addition of fuel.

4.8. Landing weight

With the calculation of fuel consumption during flight, we can calculate the ***Estimated Landing Weight (ELW)*** which is used for landing performance calculation at the destination.

Approaching your destination you use your current gross weight to determine the final approach speed. The gross weight now is the ***Actual Landing Weight (ALW).***



Of course before landing, you never land without any fuel in reserve. The regulation is strict about fuel calculation for commercial air transportation including reserve fuel.
Except on specific situation like re-routing, multiple holding, landing at alternate or technical problems, at landing, and the aircraft shall still have the expected reserve fuel if there was no extra consumption.

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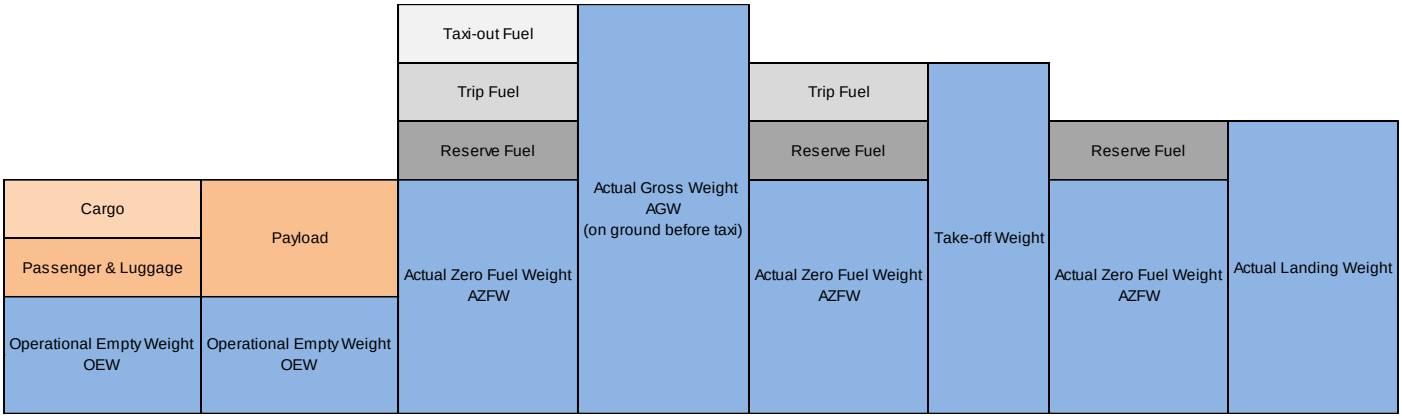
4.9. Graphical summary of operational weight



4.10. Example

Now we will get started and calculate an example (we operate an Airbus A319):

Manufacturer's Empty Weight (MEW)	36,779 kg
+ Operator's Items	+ 5,205 kg
= Operational Empty Weight (OEW)	= 41,981 kg
+ Payload	+ 13,529 kg
= Actual Zero Fuel Weight (AZFW)	= 55,510 kg
+ Fuel	+ 13,239 kg
= Actual Gross Weight (AGW)	= 68,749 kg
- Taxi Fuel	- 100 kg
= Actual Take-Off Weight (ATOW)	= 68,649 kg
- Fuel consumption	-10,900 kg
= Actual Landing Weight (ALW)	= 57,749 kg