ISSUED BY: EMBRAER VEC//GIR/0002

REPORT No.: 190NOY015

PROGRAM: E-Jets

TITLE: Embraer 190 Noise Levels - Technical Substantiation for Bromma Airport Operation

ATA 2200 No.: Not applicable

CLASSIFICATION: Private

1. Scope

The scope of this report is to describe how reduced noise levels have been derived from certificated noise database of Embraer 190 (ERJ 190-100) aircraft in order to comply with noise restrictions established by Bromma Airport. This report is aimed to support a Flight Operations Letter (FOL) to be issued by Embraer to ERJ 190-100 operators interested on having those airliners operating at Bromma airport and complying with its noise rules.

2. Affected aircraft

The ERJ 190-100 is configured as low-wing, conventional tail, twin turbofan airplane. It has a nominal capacity for 100 passengers in 33 in. seat pitch.
The aircraft is presented in STD (Standard), LR (Long Range), IGW (Increased Gross Weight) and SR (maximum pax of 98) versions. ERJ 190-100 is equipped with two General Electric CF34-10E engines, including several variants according take-off ratings available. A three-view of ERJ 190-100 aircraft is shown in Figure 1.

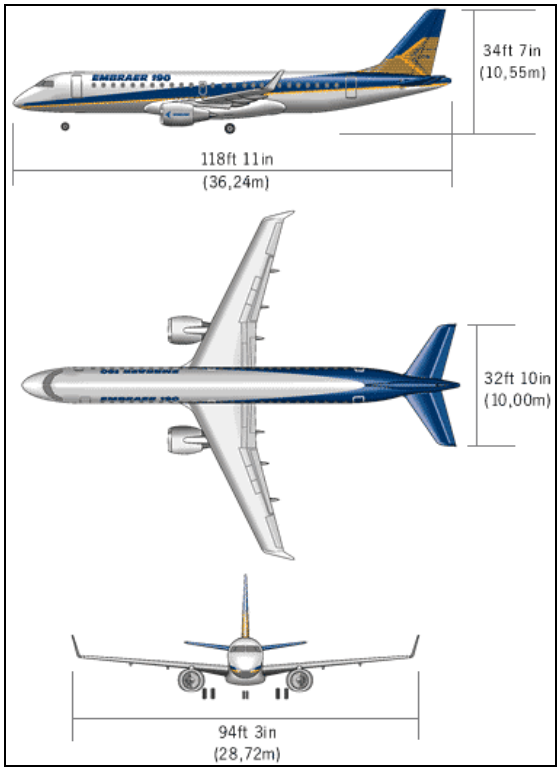


FIGURE 1: ERJ 190-100 THREE VIEW.

Current ERJ 190-100 versions are being delivered featuring CF34-10E Block 2 engines, including noise improvement packages aimed to decrease noise certification levels. Among the noise control measures, Block 2 engines include Improved Acoustic Chevron Nozzles (see Figure 2).

FIGURE 2: IMPROVED ACOUSTIC CHEVRON NOZZLE.

3. Certificated noise levels

3.1. The basics of noise certification

The aircraft noise certification aims at classifying various aircraft within a common background of procedures.
The following section exposes the ICAO Annex 16 Volume 1, which sets the background for aircraft noise certification. This context is introduced in the FAR part 36/RBAC 36, and as such the noise levels identified are part of the approved documentation of the aircraft.

3.1.1. ICAO Annex 16 Chapter 3/FAR 36 Stage III

The ICAO Chapter 3/FAR 36 Stage III is applicable to aircraft for which the application for certificate of airworthiness for the prototype was accepted on or after 6 October 1977 and before 1 January 2006. As a consequence, all relevant aircraft are nicknamed “Chapter 3/Stage III aircraft”. This is the case of most Embraer commercial jet aircraft so far.

3.1.1.1. Noise evaluation measure

The noise evaluation measure is the effective perceived noise level in EPNdB.

3.1.1.2. Noise measurement points

An airplane, when tested in accordance with these Standards, shall not exceed the noise levels specified in Chapter 3 §3.4 at the following points:

- Lateral full-power reference noise measurement point

Generally called sideline, the point on a line parallel to and 1,476 feet (450 m) from the runway centerline, or extended centerline, where the noise level after lift-off is at a maximum during takeoff (see Figure 3).
For a given weight, noise levels strongly affected by normal take-off thrust and engine sound power. Basically, as lower the take-off thrust rating and quieter the engine, the lower the noise levels.

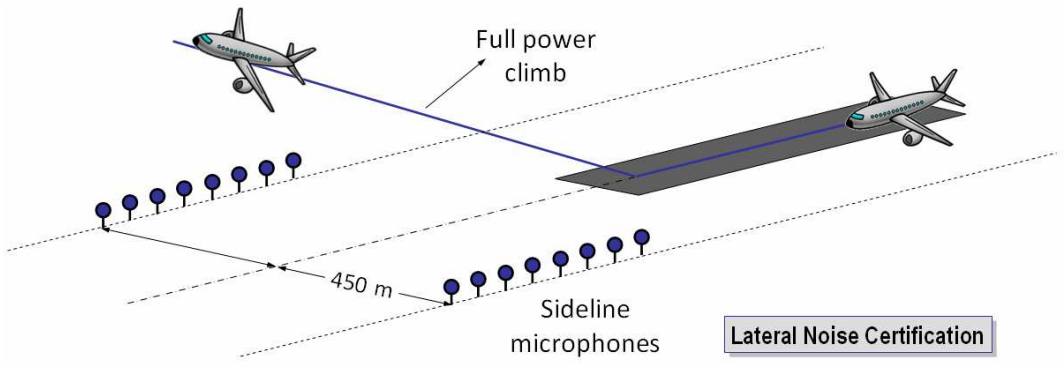


FIGURE 3: SIDELINE NOISE MEASUREMENT POSITION.

- Flyover reference noise measurement point

The point on the extended centerline of the runway that is 21,325 feet (6,500m) from the start of the takeoff roll (see Figure 4).
For e given weight, noise levels affected by aircraft performance (height at 6500 m and cutback thrust – thrust required for 4% climb gradient All Engines Operative (AEO) or leveled flight One Engine Inoperative - OEI) and engine sound power. Generally, as better the aircraft performs, the lower the noise.

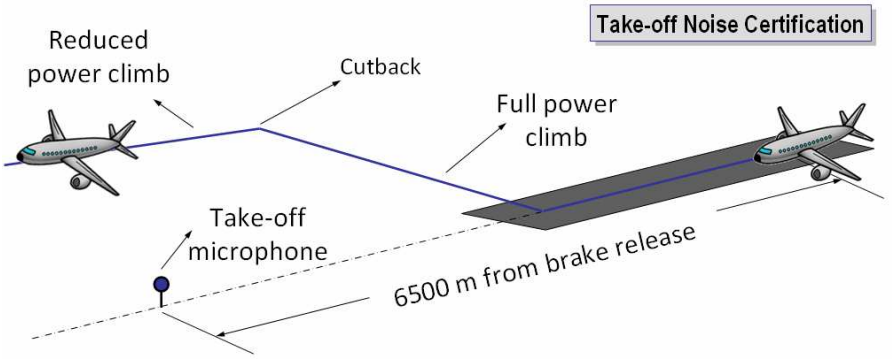


FIGURE 4: FLYOVER NOISE MEASUREMENT POSITION.

- Approach reference noise measurement point

The point on the ground, on the extended centerline of the runway 2 000 m from the threshold. On level ground this corresponds to a position 120 m (394 ft) vertically below the 3° descent path originating from a point 300 m beyond the threshold (see figure 5).

For a given weight, noise levels are strongly affected by thrust required to maintain 3° glide slope at full flaps, engine sound power and airframe sound power. Generally, as cleaner the airframe and quieter the engine, the lower the noise levels.

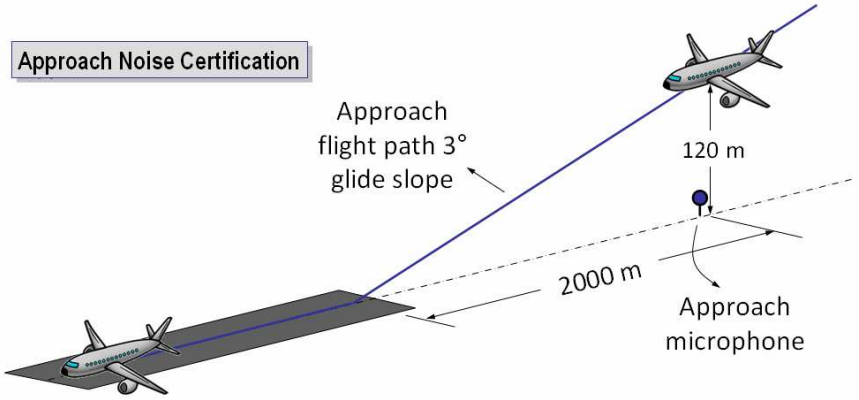


FIGURE 5: APPROACH NOISE MEASUREMENT POSITION.

3.1.1.3. Maximum noise levels

The maximum noise levels, when determined in accordance with the noise evaluation method of Appendix 2 of Annex 16, shall not exceed the following:

- At the lateral full-power reference noise measurement point

103 EPNdB for airplanes with maximum certificated take-off mass, at which the noise certification is requested, of 400 000 kg and over and decreasing linearly with the logarithm of the mass down to 94 EPNdB at 35 000 kg, after which the limit remains constant (see Figure 6).

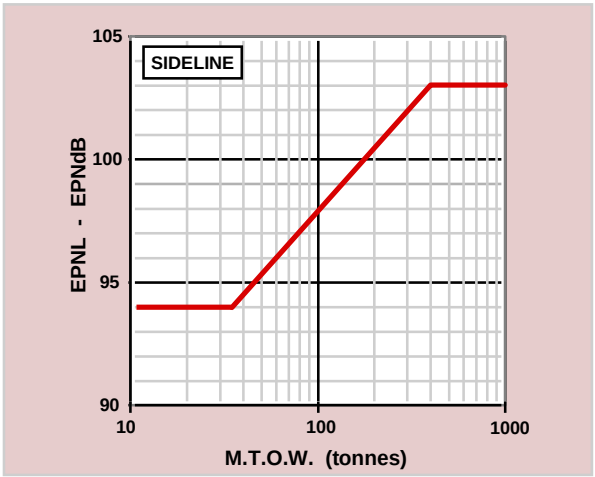


FIGURE 6: CHAPTER 3/STAGE III LATERAL NOISE LIMITS.

- At flyover reference noise measurement point

a) Airplanes with two engines or less:
101 EPNdB for airplanes with maximum certificated take-off mass, at which the noise certification is requested, of 385000 kg and over and decreasing linearly with the logarithm of the airplane mass at the rate of 4 EPNdB per halving of mass down to 89 EPNdB, after which the limit is constant.
b) Airplanes with three engines:
As a) but with 104 EPNdB for airplanes with maximum certificated take-off mass of 385000 kg and over.
c) Airplanes with four engines or more:
As a) but with 106 EPNdB for airplanes with maximum certificated take-off mass of 385000 kg and over.
Figure 7 shows a plot describing the flyover limits.

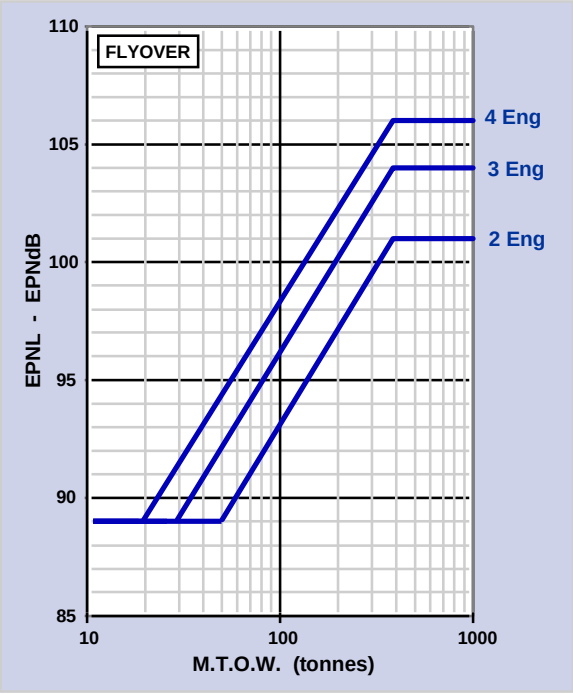


FIGURE 7: CHAPTER 3/STAGE III FLYOVER NOISE LIMITS.

- At approach reference noise measurement point

105 EPNdB for airplanes with maximum certificated take-off mass, at which the noise certification is requested, of 280000 kg or over, and decreasing linearly with the logarithm of the mass down to 98 EPNdB at 35000 kg, after which the limit remains constant (see Figure 8).

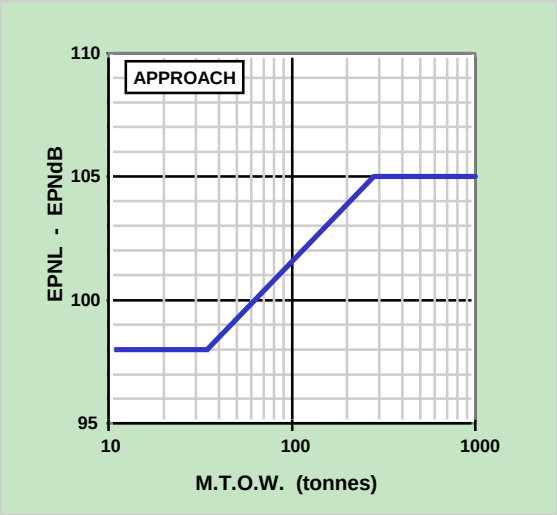


FIGURE 8: CHAPTER 3/STAGE III APPROACH NOISE LIMITS.

3.1.2. ICAO Annex 16 Volume I, Chapter 4/FAR 36 Stage IV

The ICAO Chapter 4/FAR 36 Stage IV is applicable to aircraft for which the application for certificate of airworthiness for the prototype was accepted on or after 1 January 2006. As a consequence, all relevant aircraft will be nicknamed “Chapter 4/Stage IV aircraft”. This will be the case of the Embraer Phenom (100 and 300), Legacy 650 e ERJ 170-100/200 equipped with SILENT KIT. However, despite of data of application, most current Embraer aircraft are eligible to re-certification in this new category.

3.1.2.1. Noise measurement points

An airplane, when tested in accordance with these Standards, shall not exceed the maximum noise level specified in the Section 1.3.2.2 at the same measurement points described for Chapter 3/Stage III (see Sections 1.3.1.3).

3.1.2.2. Maximum noise levels

The maximum permitted noise levels are defined in ICAO Annex 16 Volume 1 Chapter 3/FAR 36 Stage III and shall not be exceeded at any of the measurement points specified in the Section 1.3.2.2.

- The sum of the differences at all three measurement points between the maximum noise levels and the maximum permitted noise levels specified in Chapter 3/Stage III, (see Section 1.3.1.3) shall not be less than 10 EPNdB.
- The sum of the differences at any two measurement points between the maximum noise levels and the corresponding maximum permitted noise levels specified in Section 1.3.1.3 shall not be less than 2 EPNdB.

Figure 9 shows a summary of the Chapter 4/Stage IV rule.

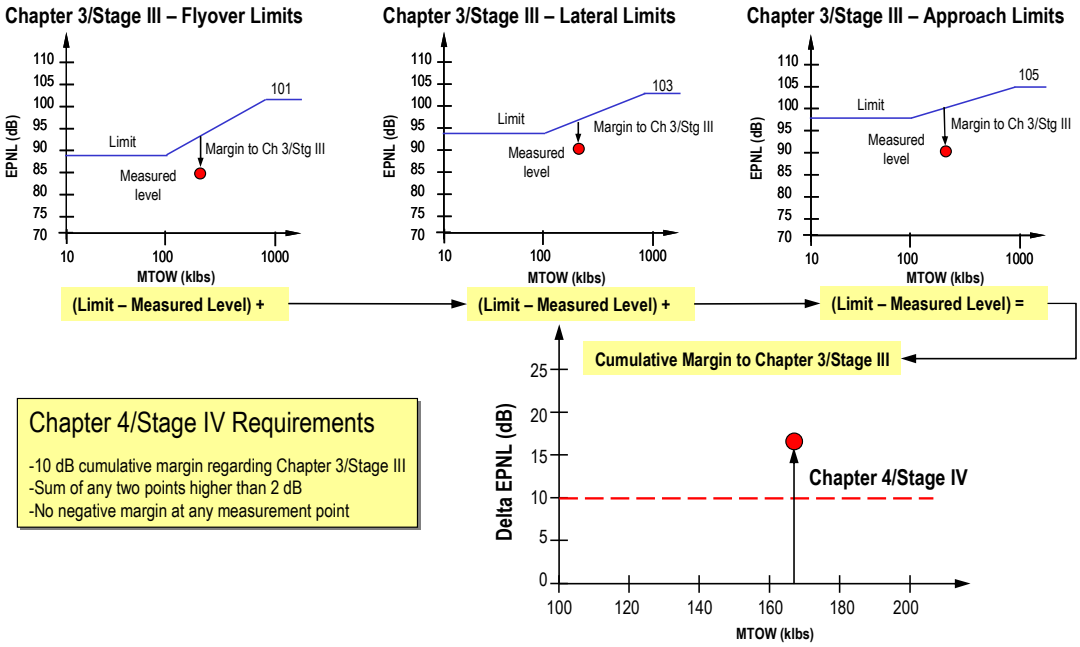


FIGURE 9: CHAPTER 4/STAGE IV NOISE RULE SUMMARY.

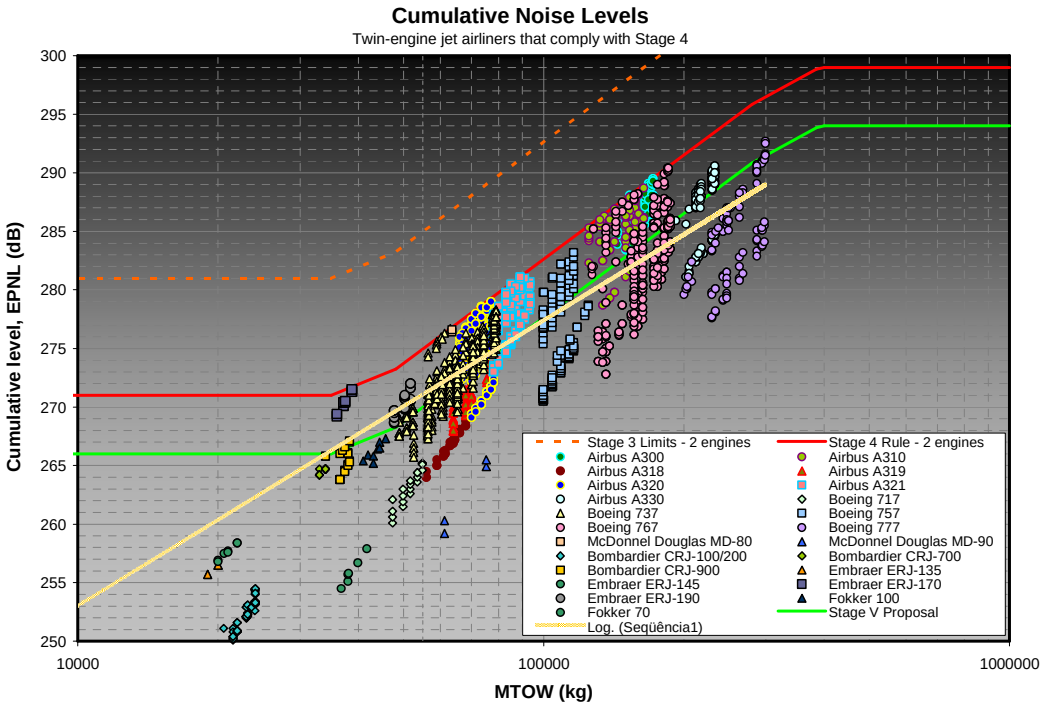


FIGURE 10: CUMULATIVE CERTIFICATED NOISE LEVELS FOR MOST IN SERVICE JET COMMERCIAL AIRCRAFT.

Although not all of them are Chapter 4/Stage IV compliant aircraft, due to the application date, most of the jet commercial fleet complies with the more stringent rule, as seen in Figure 10.

3.2. ERJ 190-100 noise certificated levels

Embraer 190 is currently certificated for noise following the versions (combinations of MTOW/MLW and engine take-off rating) described in Table 1.

Table 1: Currently certificated noise levels for Embraer 190 versions.

					Noise Levels EPNdB			ICAO Limits EPNdB			Margins (ICAO) EPNdB			EPNdB	
Aircraft	Version	Engine	MTOW [kg]	MLW [kg]	TAKEOFF	LATERAL	APPROACH [Flap 06]	TAKEOFF	LATERAL	APPROACH	TAKEOFF	LATERAL	APPROACH [Flap 06]	Cumulative [Flap 06]	Bromma Noise Metric
EMBRAER 190	STD	CF34-10E5G07	43740	43000	81.1	91.7	92.5	89.0	94.8	98.7	7.9	3.1	6.3	17.3	88.4
EMBRAER 190	LR / STD	CF34-10E5	44000	43000	81.3	91.7	92.5	89.0	94.9	98.8	7.7	3.1	6.3	17.1	88.5
EMBRAER 190	LR / STD	CF34-10E5	44600	43000	81.7	91.7	92.5	89.0	94.9	98.8	7.3	3.2	6.4	16.9	88.6
EMBRAER 190	LR	CF34-10E5G07	44900	43000	81.7	91.7	92.5	89.0	94.9	98.8	7.3	3.2	6.4	16.9	88.6
EMBRAER 190	LR / STD	CF34-10E5	45000	43000	81.9	91.7	92.5	89.0	94.9	98.8	7.1	3.2	6.4	16.7	88.7
EMBRAER 190	LR / STD	CF34-10E5	46000	43000	82.4	91.6	92.5	89.0	95	98.9	6.6	3.4	6.5	16.4	88.8
EMBRAER 190	IGW	CF34-10E5A1G07	46000	44000	81.5	92.8	92.5	89.0	95.0	98.9	7.5	2.2	6.4	16.1	88.9
EMBRAER 190	SR	CF34-10E5A1G07	45990	43000	81.4	93.0	92.5	89.0	95.0	98.9	7.7	2.1	6.5	16.2	89.0
EMBRAER 190	SR	CF34-10E7G07	45990	43000	81.5	93.0	92.5	89.0	95.0	98.9	7.5	2.1	6.5	16.1	89.0
EMBRAER 190	STD	CF34-10E5G07	47790	43000	83.4	91.6	92.5	89.0	95.2	99.0	5.6	3.6	6.6	15.8	89.2
EMBRAER 190	STD	CF34-10E6G07	47790	43000	83.4	91.6	92.5	89.0	95.2	99.0	5.6	3.6	6.6	15.8	89.2
EMBRAER 190	STD	CF34-10E5A1G07	47790	43000	82.5	92.8	92.5	89.0	95.2	99.0	6.5	2.4	6.6	15.5	89.3
EMBRAER 190	STD	CF34-10E6A1G07	47790	43000	82.5	92.8	92.5	89.0	95.2	99.0	6.5	2.4	6.6	15.5	89.3
EMBRAER 190	STD	CF34-10E7G07	47790	43000	82.5	92.8	92.5	89.0	95.2	99.0	6.5	2.4	6.6	15.5	89.3
EMBRAER 190	LR/IGW	CF34-10E5G07	47790	43000	83.4	91.6	92.5	89.0	95.2	99.0	5.6	3.6	6.6	15.8	89.2
EMBRAER 190	LR	CF34-10E6G07	47790	43000	83.4	91.6	92.5	89.0	95.2	99.0	5.6	3.6	6.6	15.8	89.2
EMBRAER 190	LR	CF34-10E5A1G07	47790	43000	82.5	92.8	92.5	89.0	95.2	99.0	6.5	2.4	6.6	15.5	89.3
EMBRAER 190	LR	CF34-10E6A1G07	47790	43000	82.5	92.8	92.5	89.0	95.2	99.0	6.5	2.4	6.6	15.5	89.3
EMBRAER 190	LR	CF34-10E7G07	47790	43000	82.5	92.8	92.5	89.0	95.2	99.0	6.5	2.4	6.6	15.5	89.3
EMBRAER 190	LR	CF34-10E5G07	49990	43000	84.7	91.4	92.5	89.2	95.3	99.2	4.5	3.9	6.7	15.2	89.5
EMBRAER 190	LR	CF34-10E5G07	50000	43000	84.8	91.4	92.5	89.2	95.3	99.2	4.4	3.9	6.8	15.1	89.6
EMBRAER 190	LR	CF34-10E6A1G07	50000	43000	83.6	92.6	92.5	89.2	95.3	99.2	5.6	2.7	6.8	15.1	89.6
EMBRAER 190	IGW	CF34-10E5G07	50000	44000	84.8	91.4	92.5	89.2	95.3	99.2	4.4	3.9	6.7	15.0	89.6
EMBRAER 190	IGW	CF34-10E6A1G07	50000	44000	83.6	92.6	92.5	89.2	95.3	99.2	5.6	2.7	6.7	15.0	89.6
EMBRAER 190	LR	CF34-10E5G07	50300	43000	84.9	91.4	92.5	89.3	95.4	99.2	4.4	3.9	6.8	15.1	89.6
EMBRAER 190	LR	CF34-10E6G07	50300	43000	84.8	91.5	92.5	89.3	95.4	99.2	4.5	3.9	6.8	15.1	89.6
EMBRAER 190	LR	CF34-10E5A1G07	50300	43000	83.6	92.6	92.5	89.3	95.4	99.2	5.6	2.7	6.8	15.1	89.6
EMBRAER 190	LR	CF34-10E6A1G07	50300	43000	83.6	92.6	92.5	89.3	95.4	99.2	5.6	2.7	6.8	15.1	89.6
EMBRAER 190	LR	CF34-10E7G07	50300	43000	83.7	92.6	92.5	89.3	95.4	99.2	5.5	2.7	6.8	15.0	89.6
EMBRAER 190	IGW	CF34-10E5G07	51800	44000	85.8	91.4	92.5	89.4	95.5	99.3	3.7	4.1	6.8	14.6	89.9
EMBRAER 190	IGW	CF34-10E6G07	51800	44000	85.7	91.4	92.5	89.4	95.5	99.3	3.7	4.1	6.8	14.6	89.9
EMBRAER 190	IGW	CF34-10E5A1G07	51800	44000	84.5	92.6	92.5	89.4	95.5	99.3	4.9	2.9	6.8	14.6	89.9
EMBRAER 190	IGW	CF34-10E6A1G07	51800	44000	84.5	92.6	92.5	89.4	95.5	99.3	4.9	2.9	6.8	14.6	89.9
EMBRAER 190	IGW	CF34-10E7G07	51800	44000	84.6	92.6	92.5	89.4	95.5	99.3	4.9	2.9	6.8	14.6	89.9

All certificated noise levels for Embraer 190 are derived from approved Noise-Power-Distance (NPD) databases, since noise certification test were carried out following equivalent procedures. Such equivalent procedures allow certification of derivative versions of an aircraft family provided that noise sources are the same among the members. Application of equivalent procedures are detailed on noise certification guidance material, notably AC-364C from FAA and ICAO ETM Doc 9501/29.

As highlighted in Table 1, Embraer 190 has nine certificated versions compliant with Bromma Airport Noise Metric of 89 dB (average of the noise levels from the three noise certification points - flyover, lateral and approach. See Section 7 for further details).

4. Effect of design weight changes (MTOW and MLW)

When approved NPD database is available, noise certification levels at the three prescribed reference points (flyover, lateral and approach) can be calculated using reference performance profiles for take-off and landing.
Reference noise profiles represent the flight path described by the aircraft when following the conditions established by noise certification rules:

- Take-off (Flyover) and Sideline – MTOW, All Engines Operating, Configuration (including flap position) selected by Applicant, V2+10 to 20 knots, Normal Take-off Power, power cutback allowed;
- Approach – MLW, Landing Gear Extended, Configuration Most Critical for Noise (including flap position), 1.3Vs1g+10 knots, 3° Slope;
- ISA + 10°C (25°C), Sea Level Runway, No Gradient, Hard Surface, Zero Wind, 70% RH.

The approved NPD database makes possible the calculation of design weights derivatives of the base aircraft.

4.1. Effect of MTOW

Reference take-off trajectories for noise certification are directly affected by maximum take-off weight (MTOW). Figure 11 shows a schematic of a typical reference take-off noise profile. As explained in Section 3.1.1.2, a power cutback is acceptable at a certain height above ground level, resulting on reduced take-off noise levels.
When the noise certification test is carried out following equivalent procedures, which is the case of ERJ 190-100, noise certification levels for different reference take-off performances can be calculated using an approved noise database. As a consequence, noise reference take-off performances are calculated for each desired aircraft configuration, including take-off weight, flap position, take-off speeds etc. The profiles are provided in a tabular form, prescribing flight and geometrical parameters at each 0.5 second throughout the take-off flight path.
This process makes easier the calculation of noise certification levels of weight and engine derivatives of a particular aircraft.
In the case of MTOW changes, Figure 12 details the change over the reference profile. It can noticed that as the take-off weight goes up, the described flight path goes down in height and climb angle, as well as the required engine thrust after cutback increases. The result is a lower height when crossing the vertical of the fixed noise certification monitor and the high engine noise associated with the higher thrust, both effects contributing to generate higher noise levels.

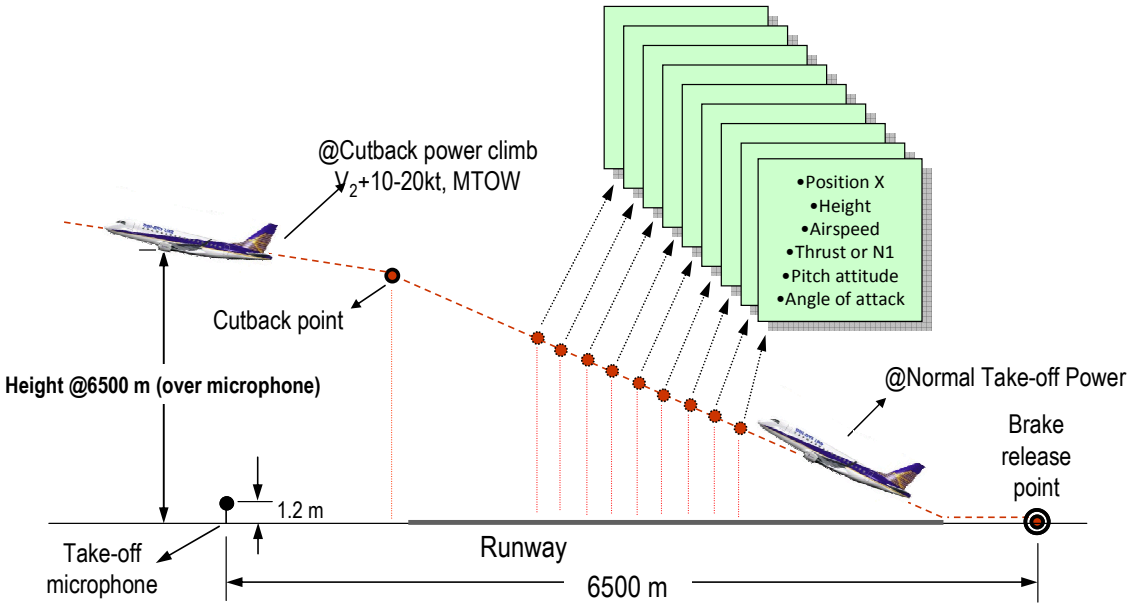


FIGURE 11: REFERENCE TAKE-OFF PERFORMANCE FOR NOISE CERTIFICATION.

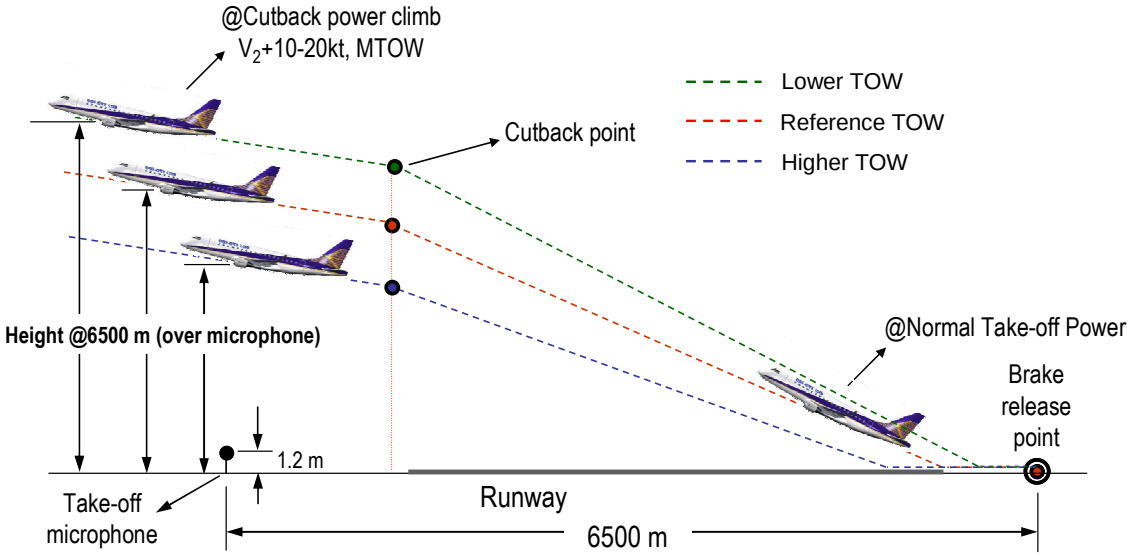


FIGURE 12: EFFECT OF TAKE-OFF WEIGHT CHANGES ON NOISE REFERENCE TAKE-OFF PROFILES.

In a similar fashion, when the take-off weight goes down, the described flight path during a reference noise take-off procedure yields to an increase in height over the reference take-off noise monitor and also to a reduced thrust after power cutback, contributing to achieve lower take-off noise certification levels.

4.2. Effect of MLW

Noise certification at approach condition specifies the glide slope, airspeed and the height over the fixed noise monitor. As a consequence, for a given aerodynamic configuration (flap/slat position), approach noise certification levels at dictated by airframe and engine noise, being the last one associated with required thrust to comply with the prescribed glide slope.

Again, for those aircraft certificated following equivalent procedures, approach noise levels can be calculated for weight derivatives using approach reference noise profiles, as shown in Figure 13.

As for the approach noise reference performance the flight path is established by the regulations, the effect of landing weight changes are only noticed by changes on the engine required thrust to maintain the 3° glide slope, since the aircraft will fly over the fixed monitor always at the same height (394 ft). As a consequence, when the landing weight goes up, the required thrust to maintain the 3° glide slope goes up as well, resulting in higher approach certificated noise levels. On the other hand, for lower landing weights, the required thrust is also lower and the results is a reduction on the approach noise certificated levels.

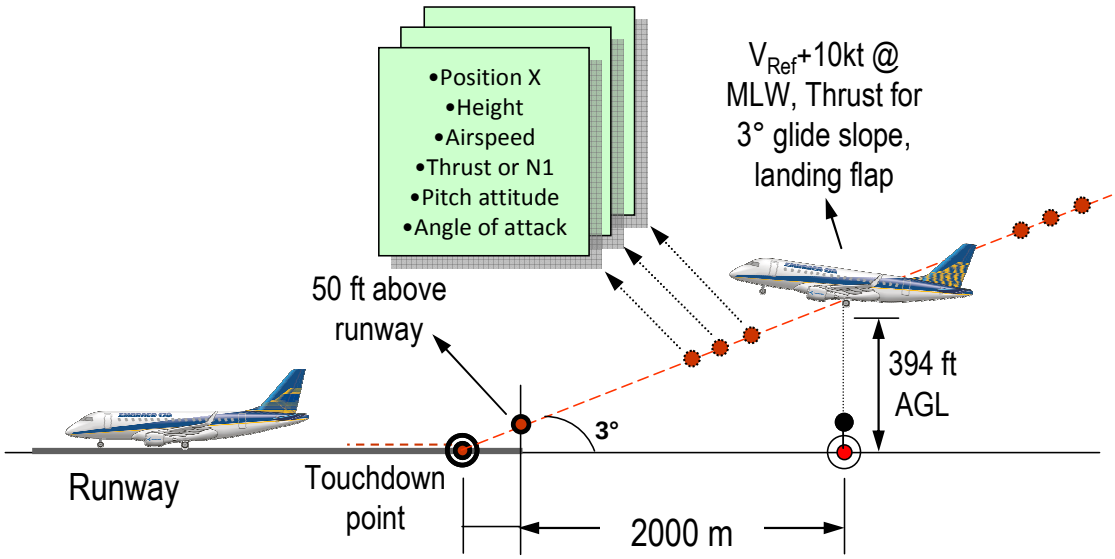
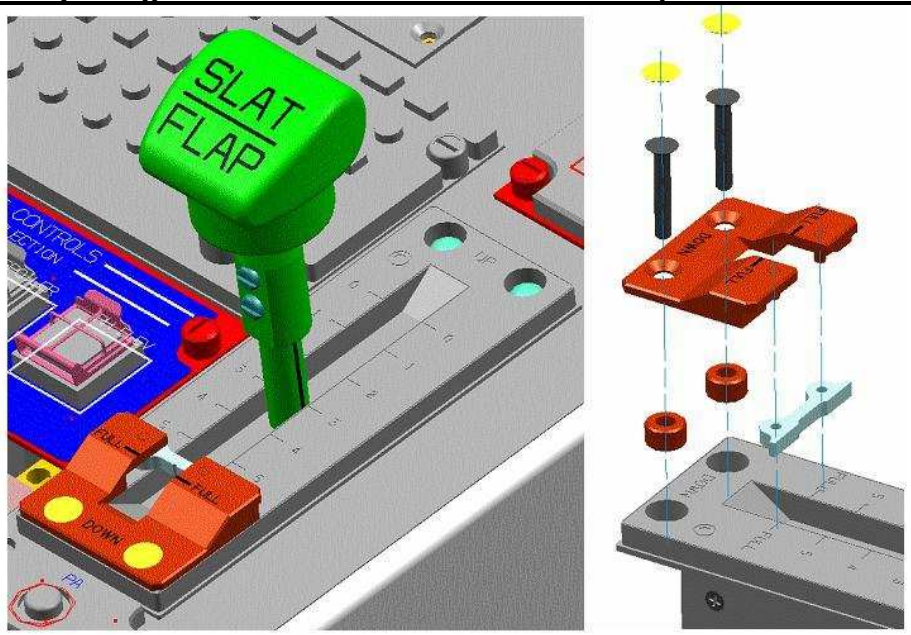


FIGURE 13: REFERENCE APPROACH PERFORMANCE FOR NOISE CERTIFICATION.

5. Effect of landing flap on approach noise certification levels

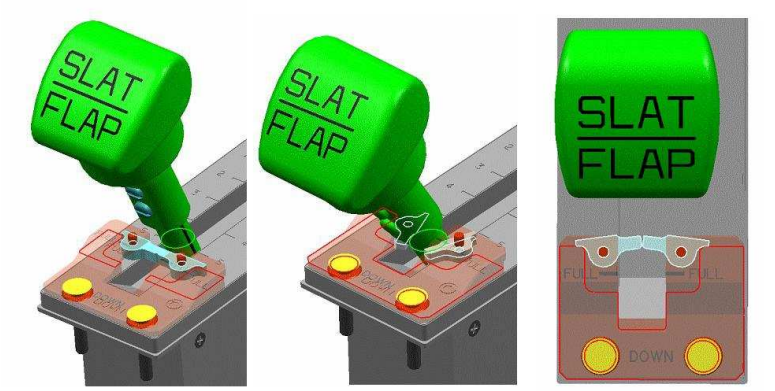
Noise certification rules establish that approach noise be certificated based on the noisiest aircraft configuration for a landing procedure, which requires landing gear down, full/slat flap approved deflection, APU and environmental control system set to ON.

It is a common procedure to measure approach noise during noise certification tests at all available landing flap/slat configurations, in order to assure that full position is the noisiest one. Hence, certification data for alternative landing flaps are usually available for most of certificated aircraft.
ERJ 190-100 has two landing flap/slat positions available: 5 and 6 (full). Noise certification data is available for both, being the position 6 (full) submitted for basic type certificate approval. Noise data included in Table 1 (see Section 3.2) refers to landing flap/slat full.
For ERJ 190-100, in case an operator needs improved (better) noise levels in order to comply with a particular airport noise requirement, Embraer offers a frangible device to inhibit the Flap Setting 6 (Flap 06 Inhibitor (per EMBRAER DWG 171-12124-801 – Flap 06 Inhibitor, Inst)) must be incorporated. With this device, the certified noise level valid is with Flap Setting 05 instead Flap Setting 06. See Figure 14FIGURE and Figure 15FIGURE for more details. This is a certification artifact required to comply with an specific noise certification rule, which demands that the aircraft be certificated with the noisiest flap/slat position available. For ERJ 190-100, landing flap/slat 5 provides approach noise levels 0.7 EPNdB quieter than landing flap/slat position 6 (full). **From the operational point of view however, provided that the operator follows landing procedures with flap/slat 5 instead of full, noise levels will be consequently lower, despite any frangible device installed to inhibit full position to be set.**



Device Installed Exploded View

FIGURE 14: FRANGIBLE DEVICE INSTALLED.



Flap 5 position "before device violation" | Full Flap position "after device violation" | Out of Full Flap position "after device violation"

FIGURE 15: VIOLATION OF THE FRANGIBLE DEVICE.

Lower noise levels obtained with flap/slat position 5 are associated with the lower approach drag of this configuration, which requires less engine thrust in order to maintain the 3° glide slope specified by noise certification regulations. Moreover, with a lower deflection flap, airframe noise generated during landing is substantially lower, also contributing to decrease certificated noise levels.

Table 2 shows approach noise levels obtained during noise certification flight tests for ERJ 190-100 considering flap/slat position 5. When using the flap full inhibitor, compliance with Bromma Airport Noise Rules are possible with 14 certificated versions of Embraer 190.

Table 2: Approach noise certification levels for ERJ 190-100 considering flap/slat 5 as the landing flap.

					Noise Levels EPNdB			ICAO Limits EPNdB			Margins (ICAO) EPNdB			EPNdB	
Aircraft	Version	Engine	MTOW [kg]	MLW [kg]	TAKEOFF	LATERAL	APPROACH [Flap 05]	TAKEOFF	LATERAL	APPROACH	TAKEOFF	LATERAL	APPROACH [Flap 05]	Cumulative [Flap 05]	Bromma Noise Metric
EMBRAER 190	STD	CF34-10E5G07	43740	43000	81.1	91.7	91.8	89.0	94.8	98.7	7.9	3.1	7.0	17.9	88.2
EMBRAER 190	LR / STD	CF34-10E5	44000	43000	81.3	91.7	91.8	89.0	94.9	98.8	7.7	3.1	7.0	17.8	88.3
EMBRAER 190	LR / STD	CF34-10E5	44600	43000	81.7	91.7	91.8	89.0	94.9	98.8	7.3	3.2	7.0	17.6	88.4
EMBRAER 190	LR	CF34-10E5G07	44900	43000	81.7	91.7	91.8	89.0	94.9	98.8	7.3	3.2	7.0	17.5	88.4
EMBRAER 190	LR / STD	CF34-10E5	45000	43000	81.9	91.7	91.8	89.0	94.9	98.8	7.1	3.2	7.0	17.4	88.5
EMBRAER 190	LR / STD	CF34-10E5	46000	43000	82.4	91.6	91.8	89.0	95	98.9	6.6	3.4	7.1	17.1	88.6
EMBRAER 190	IGW	CF34-10E5A1G07	46000	44000	81.5	92.8	91.8	89.0	95.0	98.9	7.5	2.2	7.1	16.8	88.7
EMBRAER 190	SR	CF34-10E5A1G07	45990	43000	81.4	93.0	91.8	89.0	95.0	98.9	7.7	2.1	7.1	16.8	88.7
EMBRAER 190	SR	CF34-10E7G07	45990	43000	81.5	93.0	91.8	89.0	95.0	98.9	7.5	2.1	7.1	16.7	88.8
EMBRAER 190	STD	CF34-10E5G07	47790	43000	83.4	91.6	91.8	89.0	95.2	99.0	5.6	3.6	7.2	16.4	88.9
EMBRAER 190	STD	CF34-10E6G07	47790	43000	83.4	91.6	91.8	89.0	95.2	99.0	5.6	3.6	7.2	16.4	88.9
EMBRAER 190	STD	CF34-10E5A1G07	47790	43000	82.5	92.8	91.8	89.0	95.2	99.0	6.5	2.4	7.2	16.1	89.0
EMBRAER 190	STD	CF34-10E6A1G07	47790	43000	82.5	92.8	91.8	89.0	95.2	99.0	6.5	2.4	7.2	16.1	89.0
EMBRAER 190	STD	CF34-10E7G07	47790	43000	82.5	92.8	91.8	89.0	95.2	99.0	6.5	2.4	7.2	16.2	89.0
EMBRAER 190	LR/IGW	CF34-10E5G07	47790	43000	83.4	91.6	91.8	89.0	95.2	99.0	5.6	3.6	7.2	16.4	88.9
EMBRAER 190	LR	CF34-10E6G07	47790	43000	83.4	91.6	91.8	89.0	95.2	99.0	5.6	3.6	7.2	16.4	88.9
EMBRAER 190	LR	CF34-10E5A1G07	47790	43000	82.5	92.8	91.8	89.0	95.2	99.0	6.5	2.4	7.2	16.1	89.0
EMBRAER 190	LR	CF34-10E6A1G07	47790	43000	82.5	92.8	91.8	89.0	95.2	99.0	6.5	2.4	7.2	16.1	89.0
EMBRAER 190	LR	CF34-10E7G07	47790	43000	82.5	92.8	91.8	89.0	95.2	99.0	6.5	2.4	7.2	16.2	89.0
EMBRAER 190	LR	CF34-10E5G07	49990	43000	84.7	91.4	91.8	89.2	95.3	99.2	4.5	3.9	7.4	15.8	89.3
EMBRAER 190	LR	CF34-10E5G07	50000	43000	84.8	91.4	91.8	89.2	95.3	99.2	4.4	3.9	7.4	15.7	89.3
EMBRAER 190	LR	CF34-10E6A1G07	50000	43000	83.6	92.6	91.8	89.2	95.3	99.2	5.6	2.7	7.4	15.7	89.3
EMBRAER 190	IGW	CF34-10E5G07	50000	44000	84.8	91.4	91.8	89.2	95.3	99.2	4.4	3.9	7.3	15.7	89.3
EMBRAER 190	IGW	CF34-10E6A1G07	50000	44000	83.6	92.6	91.8	89.2	95.3	99.2	5.6	2.7	7.4	15.7	89.3
EMBRAER 190	LR	CF34-10E5G07	50300	43000	84.9	91.4	91.8	89.3	95.4	99.2	4.4	3.9	7.4	15.7	89.4
EMBRAER 190	LR	CF34-10E6G07	50300	43000	84.8	91.5	91.8	89.3	95.4	99.2	4.5	3.9	7.4	15.8	89.4
EMBRAER 190	LR	CF34-10E5A1G07	50300	43000	83.6	92.6	91.8	89.3	95.4	99.2	5.6	2.7	7.4	15.8	89.3
EMBRAER 190	LR	CF34-10E6A1G07	50300	43000	83.6	92.6	91.8	89.3	95.4	99.2	5.6	2.7	7.4	15.8	89.3
EMBRAER 190	LR	CF34-10E7G07	50300	43000	83.7	92.6	91.8	89.3	95.4	99.2	5.5	2.7	7.4	15.7	89.4
EMBRAER 190	IGW	CF34-10E5G07	51800	44000	85.8	91.4	91.8	89.4	95.5	99.3	3.7	4.1	7.5	15.3	89.7
EMBRAER 190	IGW	CF34-10E6G07	51800	44000	85.7	91.4	91.8	89.4	95.5	99.3	3.7	4.1	7.5	15.3	89.6
EMBRAER 190	IGW	CF34-10E5A1G07	51800	44000	84.5	92.6	91.8	89.4	95.5	99.3	4.9	2.9	7.5	15.3	89.6
EMBRAER 190	IGW	CF34-10E6A1G07	51800	44000	84.5	92.6	91.8	89.4	95.5	99.3	4.9	2.9	7.5	15.3	89.6
EMBRAER 190	IGW	CF34-10E7G07	51800	44000	84.6	92.6	91.8	89.4	95.5	99.3	4.9	2.9	7.5	15.2	89.7

6. Effect of 3.5° glide slope on approach noise certification levels

All approach noise data provided herein for ERJ 190-100 are based on noise certification procedures, as Bromma Airport noise requirement essentially takes the average of all three noise certification points as the main metric. Approach noise certification data, as explained before, is based on 3° glide slope descent flight paths, with steep approaches not acceptable on getting potential noise benefits over certificated noise levels.

In order to demonstrate the effect of 3.5° glide slope on approach certification noise levels, Embraer proposes the use of FAA INM - Integrated Noise Model. INM is a computer program used by over 1000 organizations in over 65 countries, with the user base increasing every year. The program can be used directly to assess noise impact with different metrics for various scenarios such as: (1) new or extended runways or runway configurations; (2) new traffic demand and fleet mix; (3) revised routings and local airspace structures; (4) alternative flight profiles; and (5) modifications to other operational procedures.

6.1. Methodology of noise assessment

The effect of a 3.5° approach glide slope has been simulated assuming a "customized" approach noise certification profile updated from 3 to 3.5° descent path, keeping the

basic geometry of the certification scheme. So, instead of a 394 ft over the fixed noise monitor on ground as prescribed by the noise regulations, aircraft will fly over the microphone at 459 ft, which represents a height increment of 65 ft (see Figure 16).
As the noise propagating from the aircraft to the reference approach noise certification microphone on the ground is affected by spherical divergence and atmospheric absorption, the gain in height due to the steeper glide slope results in lower noise levels. Since ERJ 190-100 is a steep approach certificated aircraft, Embraer took advantage of previous evaluations regarding benefits of 5.5° glide slope descent paths in order to assess the impact of a less steeper descent (3.5°). This procedure has been chosen since calculation of a specific 3.5° approach noise reference profiles is not straightforward, demanding some customization on existing engineering tools.
INM has been fed with two landing profiles: the normal 3° and the steeper 5.5° glide slope. Figure 17 shows the effect on EPNL associated with the steeper 5.5° landing profile.

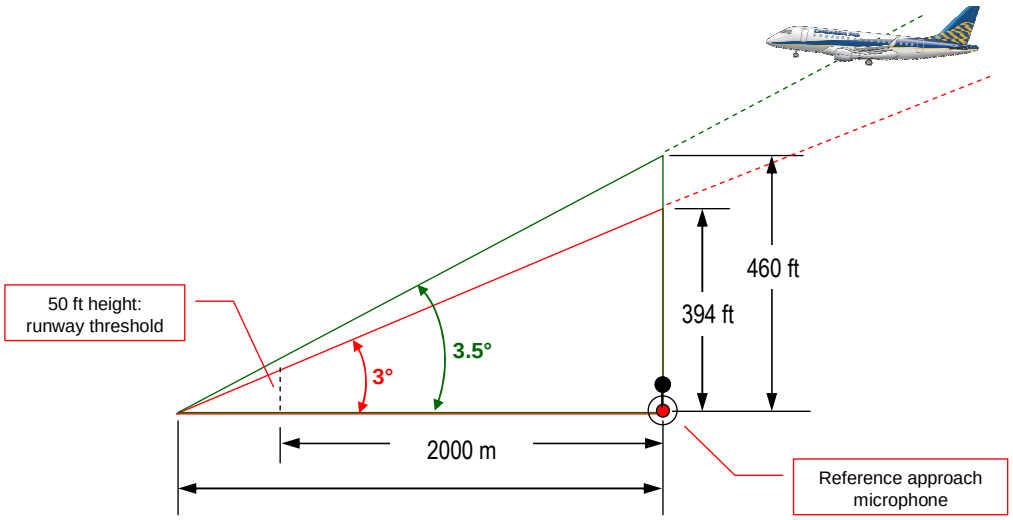


FIGURE 16: HEIGHT CHANGES OVER THE APPROACH NOISE CERTIFICATION MICROPHONE ASSOCIATED WITH 3.5° GLIDE SLOPE.

Assuming that the effect of steeper glide slopes is linear between 3° and 5.5°, the 5.3 EPNdB benefit at the noise certification microphone position associated with the 5.5° glide slide profile is reduced to around 1.1 dB with the 3.5°. This is consistent with the standard practice of correcting EPNL curves as a function of distance from the aircraft to the microphone by a factor of 18*log(H/Href), where Href is the reference height (in this case the 394 ft prescribed by the noise rules) and H is the updated height (in this case 459 ft resulting from the 3.5° glide slope).
Based on the exposed above, considering the standard 3° glide slope from approach noise certification on evaluating capability of ERJ 190-100 to comply with Bromma Airport noise requirements is conservative when compared with the steeper 3.5° glide slope.

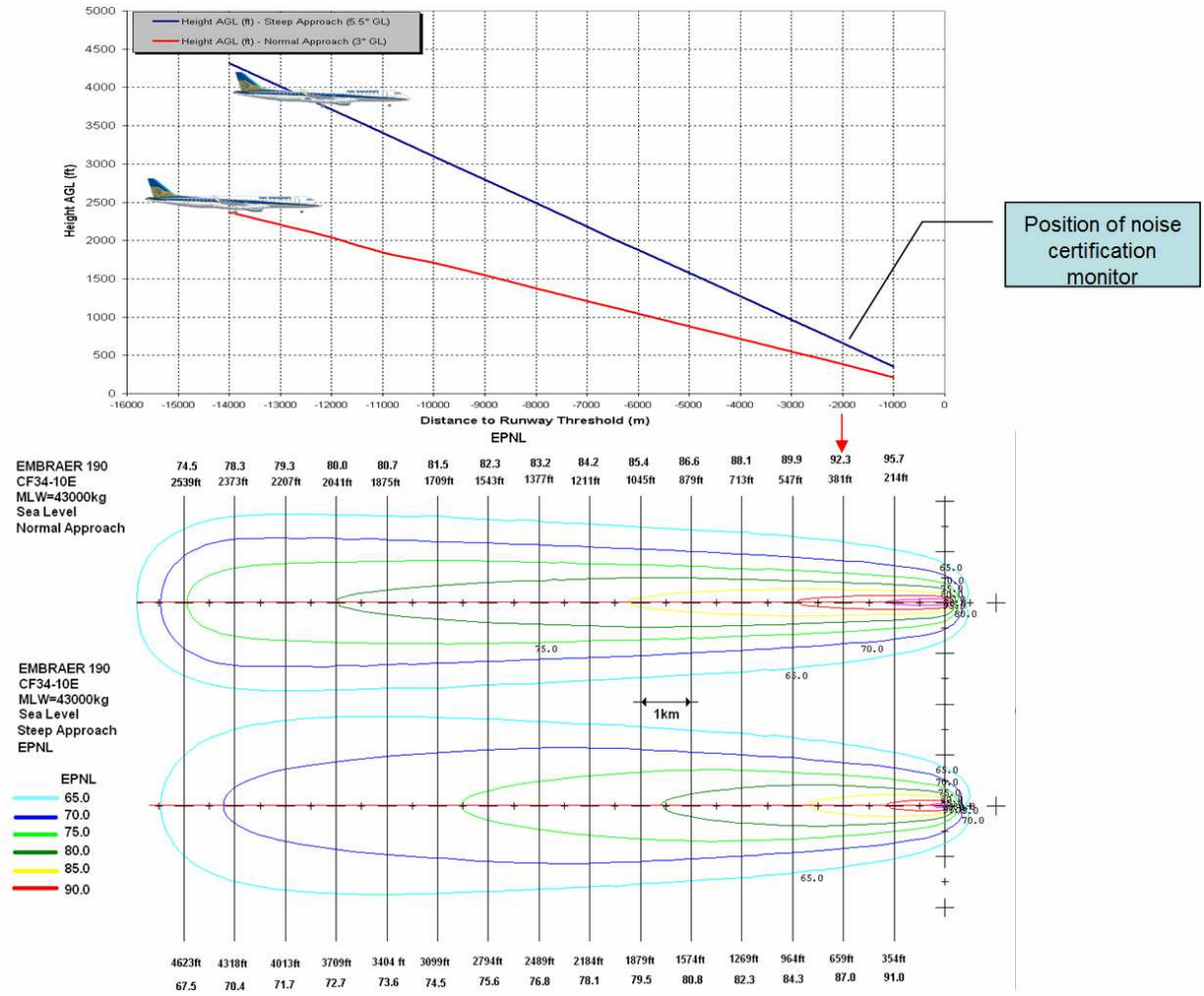


FIGURE 16: APPROACH EPNL BENEFITS DUE TO THE STEEPER 5.5° LANDING PROFILE.

7. Proposed reduced noise levels of ERJ 190-100 for Bromma operation

7.1. Bromma airport noise requirements

The noise emission must not exceed 89 EPNdB, an average for the three points of measurement in accordance with ICAO Annex 16 Vol I Chapter 3.

Operators wanting to apply for special procedure to lower their noise emissions in order to operate within the limits above must seek permission addressed to the aerodrome manager in writing or in special cases by phone. The request shall include relevant information on type and model of the aircraft and engines, MTOW and an exact description of the suggested procedure.

Note 1: Detailed provisions for the use of Bromma aerodrome are published in Regulations to Civil Aviation BCL A 5.

Aircraft used for scheduled service shall,

- either be certified for noise emission which does not exceed 86 EPNdB as an average for the three measuring points in accordance with ICAO Annex 16 Volume I, Part 2, Chapter 3,
- or be able to operate at the airport not exceeding 86 EPNdB for the three measuring points in accordance with ICAO Annex 16, Volume I, Part 2, Chapter 3.
- however 20,000 annual movements are permitted to be operated by subsonic jet aircraft with a seating capacity exceeding 60 seats with a noise emission which exceeds 86 by not 89 EPNdB as an average for the three measuring points in accordance with ICAO Annex 16, Volume I, Part 2, Chapter 3. The number of such operations on Saturdays and Sundays may not exceed the number of such operations during 2001.

7.2. Proposed action plan for ERJ 190-100

Embraer is proposing to release a Flight Operations Letter (FOL) in order to demonstrate that ERJ 190-100 is able to comply with Bromma airport noise requirements, based on the following configuration and operational conditions:

- Operational take-off weight not exceeding 47,790 kg;
- Operational landing weight not exceeding 43,000 kg;
- Landing procedure with flap/slat 5;
- Engine CF34-10E5A1G07

In the engine nomenclature, G07 refers to the hardware evolution (latest update), while E5A1 refers to the maximum normal take-off rating available.

Based on the conditions above, noise levels obtained following certification procedures are outlined in Table 3.

Table 3: ERJ 190-100 noise certification levels complying with Bromma airport noise rules.

					Noise Levels EPNdB			ICAO Limits EPNdB			Margins (ICAO) EPNdB			EPNdB	
Aircraft	Version	Engine	MTOW [kg]	MLW [kg]	TAKEOFF	LATERAL	APPROACH [Flap 05]	TAKEOFF	LATERAL	APPROACH	TAKEOFF	LATERAL	APPROACH [Flap 05]	Cumulative [Flap 05]	Bromma Noise Metric
EMBRAER 190	LR	CF34-10E5A1G07	47790	43000	82.5	92.8	91.8	89.0	95.2	99.0	6.5	2.4	7.2	16.1	89.0

An alternative for the configuration above is the ERJ 190-100 based on the following configuration and operational conditions:

- Operational take-off weight not exceeding 45,990 kg;
- Operational landing weight not exceeding 44,000 kg;

- Landing procedure with flap/slat 6 (full);
- Engine CF34-10E5A1G07

Based on the conditions above, noise levels obtained following certification procedures are outlined in Table 3.

Table 4: Alternative ERJ 190-100 noise certification levels complying with Bromma airport noise rules.

					Noise Levels EPNdB			ICAO Limits EPNdB			Margins (ICAO) EPNdB			EPNdB	
Aircraft	Version	Engine	MTOW [kg]	MLW [kg]	TAKEOFF	LATERAL	APPROACH [Flap 06]	TAKEOFF	LATERAL	APPROACH	TAKEOFF	LATERAL	APPROACH [Flap 06]	Cumulative [Flap 06]	Bromma Noise Metric
EMBRAER 190	SR	CF34-10E5A1G07	45990	43000	81.4	93.0	92.5	89.0	95.0	98.9	7.7	2.1	6.5	16.2	89.0

8. Conclusions

This report demonstrates that ERJ 190-100 is able to comply with Bromma airport noise rules of 89 EPNdB (average of three noise certification points) based on a specific configuration of take-off weight, engine rating and landing flap.
Although a specific serial number of ERJ 190-100 may hold a noise certificate with different numbers, noise certification levels described in Tables 3 and 4 can be associated with it provided that the configuration described in Section 7.2 is pursued during operation.

9. Appendix A: Noise FOL (Flight Operational Letter) for ERJ-145

EMBRAER
CUSTOMER SUPPORT

Flight Operations Support

TO: Eng. Daniel Rodríguez
COMPANY: SATENA
FROM: EMBRAER – FLIGHT OPERATIONS SUPPORT
SUBJECT: Compliance with 14 CFR PART 36 - Stage 4
APPLICABILITY: ERJ 145
DUE TO: February 26, 2014

February 26, 2013 FOL 145-2013-005

Dear Operator,

From an airworthiness certification point of view, the airplane must comply with the requirements from the date of Type Certificate application, known as certification basis. The certification basis is specified in the Type Certification Data Sheet (TCDS).

Concerning aircraft noise, the certification basis for the ERJ 145 family is 14 CFR Part 36 Incorporating Amendments 1 through 23, which, at the time of the type certification application, required compliance with Stage 3 standard. That's why AFM–145/1153 only mentions Stage 3 noise limits and levels.

Later on, in January 2006, based on the recommendations of CAEP (Committee on Aviation Environment Protection) ,the Council of ICAO introduced a new Chapter 4 / Stage 3 noise standard, more stringent than that contained in Chapter 3 / Stage 3.

Nevertheless, 14 CFR Part 36 - Stage 4 compliance is demonstrated according the conditions below:

- No exceedance of the Stage 3 noise limits at any certification condition.

- Sum of Margins to Stage 3 requirements ≥ 10.0 EPNdB

- A minimum sum of the margins at two any conditions ≥ 2.0 EPNdB

The AFM–145/1153 Effective Perceived Noise Levels (EPNL's) that comply with 14 CFR Part 36 Stage 3 noise limits were obtained by analysis of approved data from noise tests conducted under the provisions of 14 CFR Part 36.

The following Actual Noise Levels and Stage 3 limits were extracted from AFM–145/1153. The margins shown in the table are merely the difference between Stage 3 limit and Actual Noise Level.

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EMBRAER
CUSTOMER SUPPORT

TO: Eng. Daniel Rodríguez
COMPANY: SATENA
FROM: EMBRAER – FLIGHT OPERATIONS SUPPORT
SUBJECT: Compliance with 14 CFR PART 36 - Stage 4
APPLICABILITY: ERJ 145
DUE TO: February 26, 2014

February 26, 2013 FOL 145-2013-005

Flight Operations Support

Airplane Model	Condition	Actual Noise Level (EPNdB)	Stage 3 Limit (EPNdB)	Margin (EPNdB)
ERJ-145 LR	Takeoff	81.6	89.0	7.4
	Lateral	84.9	94.2	9.3
	Approach	92.5	98.2	5.7

Below a summary table of Stage 4 Noise level requirements compliance.

Stage 4 Condition	ERJ-145 LR
Exceeds Stage 3 noise limits at any condition?	No
Sum of Margins to Stage 3 requirements is higher than 10.0 EPNdB?	Yes (22.4 EPNdB)
Minimum sum of the margins at two any conditions is higher than 2.0 EPNdB?	Yes (13.1 EPNdB)

Therefore, even though it is not stated in AFM that those airplanes are compliant with Stage 4 noise standard, it can be demonstrated that they comply with the rules associated with Stage 4 requirement.

This document does not constitute an operational approval. If Local Regulatory Authority approval is required, it should be obtained by the Operator.

In case of any conflict between this FOL and any mandatory requirements issued by the Local Regulatory Authority, including but not limited to Airworthiness Directives, the Local Regulatory Authority document/orientation shall prevail.

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TO: Eng. Daniel Rodríguez
COMPANY: SATENA
FROM: EMBRAER – FLIGHT OPERATIONS SUPPORT
SUBJECT: Compliance with 14 CFR PART 36 - Stage 4
APPLICABILITY: ERJ 145
DUE TO: February 26, 2014

February 26, 2013 FOL 145-2013-005

This NTO/FOL remains valid until February 26, 2014.

If you have any question, please do not hesitate to contact us.

Best regards,

Danilo Mayer Oliveira
EMBRAER – Flight Operations Support

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10. Appendix B: Noise FOLs (Flight Operational Letters) for ERJ-190

EMBRAER
CUSTOMER SUPPORT

Flight Operations Support

COMPANY: FINNAIR
FROM: EMBRAER FLIGHT OPERATIONS SUPPORT
SUBJECT: Operation at Stockholm/Bromma Airport (ESSB)
APPLICABILITY: EMBRAER 170 LR and EMBRAER 190 LR models

June 17th, 2010 FOL 170-2010-027 Rev1

Dear Sirs,

The regulatory document LFS 2004:01 item 3.1.2 applies Environmental Provisions for any aircraft operating at Bromma Airport as follows:

"According to an agreement between the Swedish National Environmental Protection Agency and the Swedish CAA, the above mentioned provision concerning permissible noise emissions from aircraft using STOCKHOLM/Bromma aerodrome shall be constructed to mean that noise emissions may not exceed an average of 89 EPNdB for the three measuring points in accordance with ICAO, Annex 16, Volume 1, Part 2, chapter 3."

Based that Embraer has demonstrated that the EMBRAER 170-100 LR model equipped with CF34-8E5 engines complies with the above requirements provided:

- The airplane is equipped with the following components: Inlet Assembly P/N 15C0003007 and on (excluded the P/N 15C0003301); Thrust Reverser LH assemblies P/N 15G0002-013 and on; Thrust Reverser RH assemblies P/N 15G0003-013 and on;
- MTOW is limited to 34473kg and MLW to 32800kg
- flap/slat 5 is used for landing.

In this case, the three ICAO measuring points will be:

- Flyover: 81,0 EPNdB
- Lateral: 92,2 EPNdB
- Approach: 93,6 EPNdB

Thus producing an average noise emission of 88,9 EPNdB.

Similarly, Embraer has demonstrated that the EMBRAER 190-100 LR model equipped with CF34-10E5 engines also complies with Bromma noise requirements provided:

- The airplane is equipped with both left and right engines with reference EBUCF34-10E5G07;
- MTOW is limited to 47990 kg and MLW to 43000kg
- flap/slat 5 is used for landing.

In this case, the three ICAO measuring points will be:

- Flyover: 83,4 EPNdB
- Lateral: 91,6 EPNdB

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EMBRAER
CUSTOMER SUPPORT

Flight Operations Support

COMPANY: FINNAIR
FROM: EMBRAER FLIGHT OPERATIONS SUPPORT
SUBJECT: Operation at Stockholm/Bromma Airport (ESSB)
APPLICABILITY: EMBRAER 170 LR and EMBRAER 190 LR models

June 17th, 2010 **FOL 170-2010-027 Rev1**

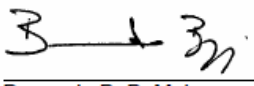
- Approach: 91,8 EPNdB

Thus also producing an average noise emission of 88,9 EPNdB.

NOTE: For both EMBRAER 170-100 and EMBRAER 190-100 the use of flap/slat full at Bromma Airport should be limited to emergency or abnormal situations.

The information of the FOL remains valid until December 2011.

Best regards,



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COMPANY: Royal Air Maroc
FROM: EMBRAER – Flight Operations Engineering & Support
SUBJECT: Compliance with ICAO Annex 16 Chapter 4 / 14 CFR Part 36 Stage IV
APPLICABILITY: EMBRAER 190 AR
EXPIRY DATE: October 15th, 2016

October 15th, 2015 FOL170-2015-050

Dear Operator,

From an airworthiness certification point of view, the airplane must comply with the requirements from the date of Type Certificate application, known as certification basis. The certification basis is specified in the Type Certification Data Sheet (TCDS).

Concerning aircraft noise, the certification basis for the E-Jets family is ICAO's Annex 16 Volume I, harmonized with US 14 CFR Part 36 Amendment 25, which, at the time of the type certification application, required compliance with Chapter 3/Stage III standards. That's why AFM-1912-034 (EMBRAER 190) only mentions Chapter 3/Stage III noise levels.

Later on, in January 2006, based on the recommendations of CAEP (Committee on Aviation Environment Protection), the Council of ICAO introduced a new Chapter 4 noise standard, more stringent than that contained in Chapter 3.

Nevertheless, by ICAO Annex 16 Chapter 4 §4.4 and 14 CFR Part 36 Appendix B Section 36.5 Stage IV/Chapter 4 compliance is demonstrated according the conditions below:

- No exceedance of the Stage III/Chapter 3 noise limits at any certification condition (using average engine maximum available takeoff thrust for normal operations).

- Sum of Margins to Stage III/Chapter 3 requirements ≥ 10.0 EPNdB

- A minimum sum of the margins at two any conditions ≥ 2.0 EPNdB

From AFM-1912-034, the Effective Perceived Noise Levels (EPNL's) comply with 14 CFR Part 36 Stage III noise limits and was obtained by analysis of approved data from noise tests conducted under the provisions of ICAO Annex 16, Volume 1 - Chapter 3 (harmonized with 14 CFR Part 36 Amendment 25).

The following Actual Noise Levels are presented AFM-1912-034. Stage III noise limits were extracted from 14 CFR Part 36. The margins are merely the difference between Stage III limit and Actual Noise Level.

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COMPANY: Royal Air Maroc
FROM: EMBRAER – Flight Operations Engineering & Support
SUBJECT: Compliance with ICAO Annex 16 Chapter 4 / 14 CFR Part 36 Stage IV
APPLICABILITY: EMBRAER 190 AR
EXPIRY DATE: October 15th, 2016

October 15th, 2015 FOL170-2015-050

For airplanes equipped with CF34-10E6 engines with both right and left hand side engines with the reference EBUCF34-10E6G07, the noise levels and margins are:

Airplane Model	Condition	Actual Noise Level (EPNdB)	Stage III Limit (EPNdB)	Margin (EPNdB)
EMBRAER 190 AR (CF34-10E6, MTOW 51800 kg and MLW 44000 kg)	Flyover	85.7	89.4	3.7
	Lateral	91.4	95.4	4.0
	Approach	92.5	99.3	6.8

Otherwise, the noise levels and margins are:

Airplane Model	Condition	Actual Noise Level (EPNdB)	Stage III Limit (EPNdB)	Margin (EPNdB)
EMBRAER 190 AR (CF34-10E6, MTOW 51800 kg and MLW 44000 kg)	Flyover	86.9	89.4	2.5
	Lateral	91.9	95.4	3.6
	Approach	92.8	99.3	6.5

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COMPANY: Royal Air Maroc
FROM: EMBRAER – Flight Operations Engineering & Support
SUBJECT: Compliance with ICAO Annex 16 Chapter 4 / 14 CFR Part 36 Stage IV
APPLICABILITY: EMBRAER 190 AR
EXPIRY DATE: October 15th, 2016

October 15th, 2015 FOL170-2015-050

Below a summary table of Stage IV/Chapter 4 Noise level requirements compliance.

Stage IV/Chapter 4 Condition	EMBRAER 190 AR EBUCF34-10E6G07	EMBRAER 190 AR Otherwise
Exceeds Stage III/Chapter 3 noise limits at any condition?	No	No
Sum of Margins to Stage III/Chapter 3 requirements is higher than 10.0 EPNdB?	Yes (14.5 EPNdB)	Yes (14.6 EPNdB)
Minimum sum of the margins at two any conditions is higher than 2.0 EPNdB?	Yes (7.7 EPNdB)	Yes (6.1 EPNdB)

Therefore, even though it is not stated in AFM that those airplane models are compliant with Stage IV Noise Standard, it is demonstrated herein that they comply with the technical rules associated with Stage IV requirement.

The EMBRAER 190 meets all the recertification criteria from ICAO Annex 16 Vol. 1 Chapter 3 to Chapter 4 as listed in Chapter 9.2 of ICAO Environmental Technical Manual Doc. 9501.

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COMPANY: Royal Air Maroc
FROM: EMBRAER – Flight Operations Engineering & Support
SUBJECT: Compliance with ICAO Annex 16 Chapter 4 / 14 CFR Part 36 Stage IV
APPLICABILITY: EMBRAER 190 AR
EXPIRY DATE: October 15th, 2016

October 15th, 2015 FOL170-2015-050

This document does not constitute an operational approval. If Local Regulatory Authority approval is required, it should be obtained by the Operator.

In case of any conflict between this FOL and any mandatory requirements issued by the Local Regulatory Authority, including but not limited to Airworthiness Directives, the Local Regulatory Authority document/orientation shall prevail. This FOL is not valid if any modification incorporated to the airplane affects the noise levels published in the AFM-1912-034 for the airplanes models and engines presented herein.

This FOL remains valid until October 15th, 2016.

If you have any question, please do not hesitate to contact us.

Best regards,

Fábio Corrêa Simões
EMBRAER – Flight Operations Engineering & Support

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11. Appendix C: Noise Certificate for ERJ 190-100 complying with Bromma Airport Noise Restrictions

Type Certificate Holder[1] **Embraer** Aircraft Type Designation[1] **ERJ 190-100**

Engine Manufacturer[1] **General Electric** Engine Type Designation[1] **CF34-10E5A1 G07**

Additional modifications essential to meet the requirements or needed to attain the certificated noise levels[1] **Block 2, P/N 341-3001-501 (Improved acoustic chevron nozzle (IACN))**

Noise Certification Basis **ICAO Annex 16, Volume I** Edition / Amendment **Edition 3 / Amendment 7** Chapter[1] **3**

EASA Record No.	Variant	Maximum Mass		Lateral EPNL		Flyover EPNL		Approach EPNL		See Note
		Take-off[1] (kg)	Landing[1] (kg)	Level[1]	Limit	Level[1]	Limit	Level[1]	Limit	
A8511	IGW	51,800	44,000	92.6	95.5	84.5	89.4	92.5	99.3	-
A8510	LR	50,300	43,000	92.6	95.4	83.6	89.3	92.5	99.2	-
A10640	LR	47,790	43,000	92.8	95.2	82.5	89.0	92.5	99.0	-
A8509	STD	47,790	43,000	92.8	95.2	82.5	89.0	92.5	99.0	-
A13627	SR	45,990	43,000	93.0	95.0	81.4	89.0	92.5	98.9	-

[1] See Note 1.