The new Stage 4 ruling is lenient compared to Stage 3 noise rules. Besides a requirement for a reduction of 10 EPNdB, only aircraft certified from 2006 are required to comply and there is no phase-out of Stage 3 aircraft. Stage 3 aircraft will be allowed to continue in operation, unaffected.

Stage 4 noise rule fails market for new hushkit programmes

The International Civil Aviation Organisation (ICAO) has now decided that Stage 4/Chapter 4 noise limits should be 10 equivalent perceived noise decibels (EPNdB) lower than Stage 3 limits. Aircraft and engine manufacturers, airlines, and noise modification suppliers have been waiting for several years for ICAO to define the noise reduction standard for Stage 4. Unlike Stage 3, the Stage 4 noise reduction requirement is unlikely to trigger a wave of aircraft modification programmes.

The introduction of Stage 3 noise rules included a phase-out timetable for Stage 2 aircraft, forcing the need for Stage 2 aircraft to be modified to meet Stage 3 levels. The recently defined limits and timetable for Stage 4 noise compliance do not include a phase-out clause for Stage 3 aircraft.

The only timetable requirement for Stage 4 is that only aircraft certified from 1st January 2006 should be Stage 4 compliant. Aircraft already certified and Stage 3 can continue to be manufactured, although manufacturers claim they will be difficult to market if they are not Stage 4 compliant. Stage 3 compliant aircraft will be allowed to continue in operation until the end of their economic life.

Stage 3 definition

Noise emissions of aircraft are determined by noise 'footprints'. An aircraft's footprint is the area around a runway where the noise level falls within an EPNdB contour. The higher the noise emission from the aircraft the larger the allowed area within the contour or footprint.

Aircraft noise levels are also determined by measuring noise emitted at an airport at three measuring points. These are when the aircraft is on approach, at the sideline measurement during take-off and the forward measuring point during take-off.

There are limits of EPNdB emitted for each of the three measuring points for compliance with Stage 2, Stage 3 and Stage 4. The noise limit permitted at each measuring point varies with aircraft size. That is, higher noise emissions are allowed for larger aircraft.

At the take-off and sideline measuring points aircraft size is gauged in terms of the aircraft's certified maximum take-off weight (MTOW) and for the approach measuring point by certified maximum landing weight (MLW). This is because engine thrust, and hence noise, is related to the weight of the aircraft.

In the case of the take-off measurement, a higher noise emission is also permitted for four-engined aircraft compared to three-engined aircraft. Tri-jets in turn are permitted a higher noise emission than twin-jets.

The relationship between aircraft size and take-off, approach and sideline permitted noise emissions is illustrated by the charts *(see page, 11)*. The chart for take-off noise illustrates that these emissions have to remain constant at 89 EPNdB for small aircraft up to a specified MTOW limit. This is up to 44,673lbs for four-engined aircraft, 63,177lbs for tri-jets and 106,250lbs for twin-jets . Noise emissions are then allowed to increase until an MTOW of 850,000lbs is reached.

The 747-400 is the only civil aircraft certified with an MTOW higher than this, although the A380 will also exceed this when it enters service. Take-off noise emissions for aircraft with MTOWs higher than 850,000lbs have to remain constant. These are 106 EPNdB for four-engined aircraft, 104 EPNdB for tri-jets and 101 EPNdB for twin-jets.

The rate of increase between these two constant emission levels increases logarithmically. The implications of the rules are that aircraft with four engines are permitted higher take-off emission levels than tri-jets. Tri-jets in turn are allowed higher emissions than twins. The difference between quads and tri-jets is 2 EPNdB for aircraft with an MTOW higher than 63,000lbs. The difference between tri-jets and twins is 3 EPNdB for aircraft with an MTOW higher than 106,250lbs *(see first chart, page 11)*.

Stage 3 compliance

Stage 3 compliance is determined by the combined, or cumulative, noise emissions of an aircraft at the three measuring points being equal or less than the cumulative allowed noise emissions at the three measuring points as determined by the aircraft's MTOW, MLW and engine numbers.

For example, the A300-600R with an MTOW of 385,500lbs and powered by CF6-80C2 engines has a cumulative noise

emission of 290 EPNdB *(see table, page 14)*. This compares to the limit of 298.8 EPNdB, the combined limits allowed for the aircraft at the three measuring points. The aircraft is thus Stage 3 compliant, with a margin of 8.8 EPNdB.

An example of an aircraft that does not have cumulative noise emissions lower than that allowed by the Stage limits is the JT9D-7F-powered 747-100 with an MTOW of 750,000lbs and MLW of 400,000lbs. The aircraft's cumulative noise emission is 312.1 EPNdB, while the permitted cumulative emission for this aircraft is 310.8 EPBdB. The aircraft's emissions are thus 1.7 EPNdB higher than that allowed by the Stage 3 limits *(see table, page 14)*.

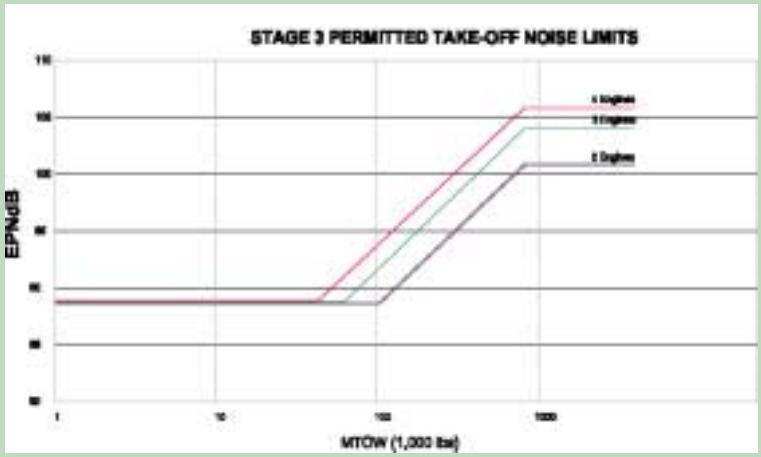
The cumulative Stage 3 margins of common aircraft types are listed *(see table, page 14)*. Some of these are types, such as the 747-100 and 737 classics are no longer in production. With the exception of the 747-100 at it originally specified weights, all are Stage 3 compliant. All other aircraft in current production are naturally Stage 3 compliant. These include the A321, A330-200, A340-500/-600, 737NG family and 757-300.

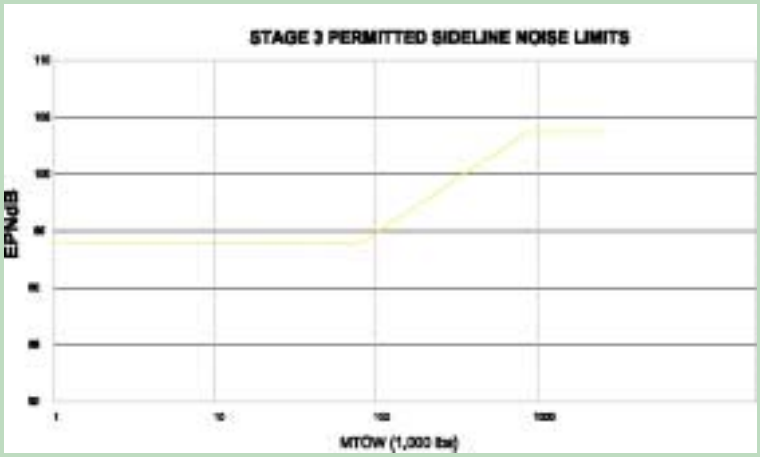
Trade-off

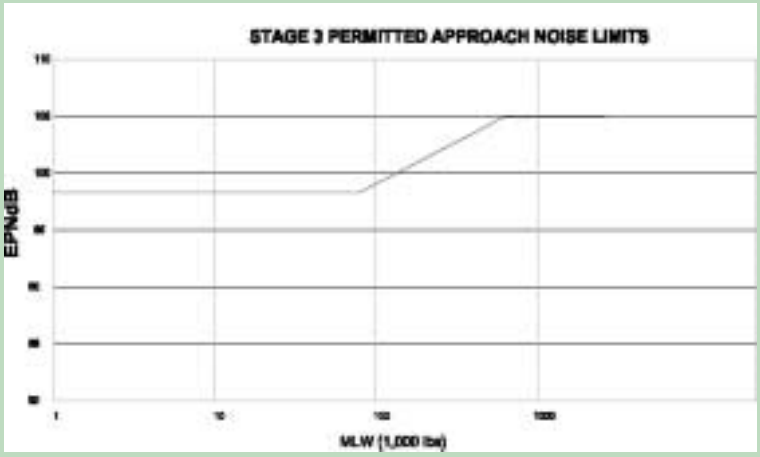
While the charts illustrate Stage 3 noise compliance limits, the Stage 3 noise rules allow a 'trade-off' of noise emissions for aircraft to be compliant. Trade-off is the process whereby the aircraft is deemed to be Stage 3 compliant provided its cumulative noise emissions are lower than the cumulative permitted emissions. This is despite the noise emitted at one or two of the measuring points being higher than that allowed by the rules.

One example of an aircraft which uses the trade-off rule to achieve Stage 3 compliance is the 747-200 with an MTOW of 833,000lbs and MLW of 600,000lbs powered by JT9D-7Q engines. The aircraft's sideline and approach emissions are higher than those permitted by the limits by 0.8 and 1.7 EPNdB, while its take-off emissions are within Stage 3 limits. The aircraft's cumulative emissions are 313.3 EPNdB, while the permitted cumulative emission is 313.5 EPNdB based on the MTOW and MLW *(see table, page 14)*. The aircraft thus has a cumulative margin of 0.2 EPNdB, despite its sideline and approach emissions being higher than limits. The aircraft has thus used the trade-off rule to achieve Stage 3 compliance. Trade-off is also used by the same aircraft powered by RB211-524C2 engines.

Use of the trade-off rule is more commonly used by older aircraft no longer being manufactured. These also







The GE90-powered 777-200 with a gross weight of 632,500lbs has one of the highest Stage 4 margins of aircraft currently in production. Virtually all aircraft being manufactured meet Stage 4 requirements, even though they are not legally required to do so.

tend to have lower cumulative Stage margins, which is the main reason for these types using the trade-off rule, than modern aircraft still in production. Examples of older aircraft types using trade-off to comply with Stage 3 are the A300B2, A300B4-100, various 727 variants hushkitted with the FedEx hushkit, some variants of the 727 re-engined with the Goodrich Super 27 program, several variants of the 737-200 hushkitted with the Av Aero and Nordam hushkits, high landing weight variants of the 737-300/-400/-500 family, JT9D-7R4E-powered versions of the 767-200/-300, and most versions of the hushkitted DC-8-60 series and DC-9, DC-10, MD-11 and MD-80.

All aircraft types currently being manufactured have high cumulative Stage 3 margins, and so do not rely on the trade-off rule to achieve Stage 3 compliance.

Stage 3 margins of most aircraft currently in production exceed 10 EPNdB. Different A319 variants have Stage 3 margins in the range of 12.4-20.6, depending on MTOW, MLW and engine type *(see table, page 14)*. The A319 powered by the CFM56-5B6 has one of the highest margins of all aircraft currently in production.

The A340-200/-300 with an MTOW of 595,000lbs has a cumulative margin of 19.8 EPNdB, while the GE90-powered 777-200 with an MTOW of 632,500lbs has a cumulative margin of 21.4 EPNdB (see table, page 14). This compares to a Stage 3 margin of 14.2 EPNdB for the same aircraft powered by the Rolls-Royce Trent 894 *(see table, page 14)*.

Stage 4 definition

The recently defined Stage 4 noise limits are based on two main conditions. The first of these is that the cumulative permitted noise emission for an aircraft is at least 10 EPNdB lower than the permitted cumulative Stage 3 emission level in accordance with its MTOW, MLW and engine numbers *(see table page 14)*. That is, the CF6-80C2-powered A300-600R with an MTOW of 385,500lbs has a cumulative Stage 3 noise limit of 298.8 EPNdB, and thus its cumulative Stage 4 noise emissions must be 288.8 EPNdB, or lower *(see table, page 14)*. The aircraft's cumulative noise emissions are actually 290 EPNdB, and so 1.2 EPNdB less than required by Stage 4 rules *(see table, page 14)*.

The second main part of the Stage 4 noise limits ruling is that trade-off is not allowed. That is, the emission at each of the measuring points has to be at least the level required by Stage 3, or lower. The second half of this point is that the sum of the margins at the worst two points must be at least 2EPNdB relative to Stage 3.

The Stage 4 limit for each aircraft is shown *(see table, page 14)*. These limits are simply the Stage 3 limit, as determined by the aircraft's MTOW, MLW and engine numbers, less 10 EPNdB.

The third main part of Stage 4 definition is that, unlike the Stage 3 ruling, there is no phase-out time limit set for Stage 3 aircraft. That is, when Stage 3 noise limits were defined a timetable was also set out for the retirement or modification compliance of Stage 2 aircraft to Stage 3 compliance in North America and West Europe. All aircraft operating in north American airspace after 1st January 2000 had to be Stage 3 compliant, and aircraft operating in west European airspace had one additional year to comply.

This phase-out clause of Stage 2 aircraft in the definition of Stage 3 triggered a wave of programmes to modify aircraft to comply with Stage 3 noise regulations, since the date for full Stage 3 compliance would come several years before the end of their economically useful life.

The absence of a phase-out timetable for Stage 3 aircraft means that Stage 3 aircraft in operation do not have to be modified to be Stage 4 compliant, and can continue operating until they reach the end of their economically useful life. The definition of Stage 4 noise limits only requires aircraft certified from 1st January 2006 to be Stage 4 compliant. This includes aircraft that are re-engined. The only planned certifications after 1st January 2006 are the A380, Boeing's Sonic Cruiser and the 707 re-engined with the PW6000.

The further implications of this are that aircraft which meet Stage 3 compliance currently in production do not have to meet Stage 4 noise limits.

Stage 4 compliance

Two factors will thus determine if an aircraft meets Stage 4 noise limits. The first is if it has a cumulative reduction of at least 10 EPNdB compared to the

The CFM56-powered low gross weight A319 has a Stage 4 margin of more than 10EPNdB. In comparison, the highest gross weight, CFM56-powered A321-200 is not Stage 4 compliant. CFMI is developing a modification to bring into Stage compliance.

emissions permitted by Stage 3 regulations.

The second is that each of the three emissions at each of the three measuring points are at least the same level as Stage 3 requirements, and the sum of the margins at the worst two points is at least 2 EPNdB. For example, while an aircraft may have a cumulative limit of at least 10 EPNdB less than its Stage 3 noise limits, its margins at two of the measuring points may only 1.6 EPNdB less than Stage 3 limits, making it non-compliant with Stage 4.

This, of course, only applies to aircraft that will be certified after 1st January 2006. Thus any aircraft currently in production that has noise margins which do not allow it to meet Stage 4 for one or more reasons will still not be legally affected.

The Stage 4 compliance margins of some of the aircraft in production are shown *(see table, page 14)*. These are just for illustrative purposes, since Stage 4 compliance only has to be met by aircraft that are yet to be certified.

There are, however, variants of each aircraft type which do not meet Stage 4 compliance. Some versions of the A300-600R are Stage 4 compliant, because they do not have a cumulative reduction of at least 10 EPNdB. One variant also has less than a combined cumulative reduction of

AIRCRAFT NOISE LIMITS, ALLOWABLE STAGE 3& 4 NOISE LIMITS, STAGE 3 & 4 MARGINS AND STAGE 3 & 4 COMPLIANCE

Aircraft type	MTOW K lbs	Engine	Noise emissions (EPNdB)	Stage 3 limit (EPNdB)	Stage 3 margin (EPNdB)	Stage 4 limit (EPNdB)	Stage 4 margin (EPNdB)	Two points less than 2 EPNdB?	Stage 4 compliant?
A300-600R	330	CF6-80C2A5F	285.7	296.7	11.0	286.7	1.0	No	Yes
A300-600R	330	PW4158	287.6	296.7	9.3	286.9	-0.7	No	No
A3000-600R	385.5	CF6-80C2A5F	290.0	298.8	8.8	288.8	-1.2	No	No
A310-324	330.7	PW4152	288.0	296.9	8.9	286.9	-1.1	No	No
A319-112	123.5	CFM56-5B6	264.3	284.9	20.6	274.9	10.6	No	Yes
A320-231	149.9	V.200A1	273.6	286.8	13.2	276.8	3.2	No	Yes
A330-301	507.1	CF6-80E1	290.1	302.1	12.0	292.1	2.0	No	Yes
A330-322	507.1	PW4168	290.6	302.1	11.5	292.1	1.5	No	Yes
A340-312	595.2	CFM56-5C3	288.7	308.5	19.8	298.5	9.8	No	Yes
727-200RE	203.1	JT8D-17A/217C	292.3	293.4	1.1	283.4	-8.9	Yes	No
737-300	139.5	CFM56-3 HWFA	273.0	285.7	12.7	275.7	2.7	No	Yes
737-300	139.5	CFM56-3B2	277.7	285.7	8.0	275.5	-2.0	No	No
737-400	150.0	CFM56-3 HWFAP	275.4	286.3	10.9	276.3	0.9	No	Yes
737-400	150.0	CFM56--3C1	280.4	286.3	5.9	276.3	-4.1	No	No
737-500	132.8	CFM56-3 HWFAP	272.3	285.0	12.7	275.0	2.7	No	Yes
737-500	132.8	CFM56-3B1	276.6	285.0	8.4	275.0	-1.6	Yes	No
747-100	750.0	JT9D-7F	312.1	310.8	-1.3	300.8	-11.3	Yes	No
747-200	833.0	JT9D-7Q	313.3	313.5	0.2	303.5	-9.8	Yes	No
747-400	875.0	CF6-80C2B1F	301.8	313.9	12.1	303.9	2.1	No	Yes
747-400	875.0	PW4056 Phase 1	301.2	313.9	12.7	303.9	2.7	No	Yes
747-400	875.0	RB211-524H2	300.6	313.9	13.3	303.9	3.3	No	Yes
757-200	220.0	PW2040	276.8	292.1	15.3	282.1	5.3	No	Yes
757-200	255.5	PW2040	282.0	293.4	11.4	283.4	1.4	No	Yes
757-200	22.0.0	RB211-535E4	270.5	292.1	21.6	282.1	11.6	No	Yes
757-200	255.0	RB211-535E4	275.0	293.4	18.4	283.4	8.4	No	Yes
767-200	400.0	PW4056	287.8	298.6	10.8	288.6	0.8	No	Yes
767-200ER	395.0	PW4060	281.5	298.9	17.3	288.8	7.3	No	Yes
767-300	407.0	PW4060	290.4	299.2	8.8	289.2	-1.2	No	No
777-200	632.5	GE90-90B	282.9	304.3	21.4	294.3	11.4	No	Yes
777-200	632.5	Trent 892	290.1	304.3	14.2	294.3	4.2	No	Yes
MD-11	630.5	PW4462	295.9	307.6	11.7	297.6	1.7	No	Yes
MD-90-30	166.0	V2528-D5	265.5	287.6	22.1	277.6	12.1	No	Yes

2EPNdB at two of the measuring points. Generally, higher gross variants of the A300-600R are non-Stage 4 compliant, although this will not legally affect its continued production.

Most members of the A320 family are fully compliant, although a few variants are not. The highest gross weight A320-200 powered by the CFM56-5A1 has a noise emission 9.1EPNdB lower than Stage 3 levels. Most A320 family variants are Stage 4 compliant, however. Moreover, the latest addition to the A320 family, the A318, will be certified in January 2002. Despite not needing to be Stage 4 compliant from a legal point of view, Airbus says it has a Stage 4 margin in the region of 10EPNdB.

Several members of the 737-300/-400/-500 family have an approach noise level higher than allowed by Stage 3 noise rules. These aircraft thus used trade-off rules to comply with Stage 3. For this reason, however, they do not meet Stage 4 noise levels. These aircraft are, however, no longer manufactured, so do not actually need to meet Stage 4 compliance.

High gross weight 757-200s have high Stage 4 margins. The high Stage 4 margins of many aircraft currently in production suggests the Stage 4 ruling will bring little reduction in aircraft noise.

Many variants of the 747-400 are Stage 4 compliant, most having Stage 4 margins of up to 8EPNdB. A few variants are not Stage 4 compliant.

All current 757-200 and most 767-200/-300 models are fully Stage 4 compliant. One exception of the 767-300ER is the PW4056/60-powered aircraft with MTOWs of 407,000lbs *(see table, page 14)*, and two models powered by the PW4062.

Besides these types which have been in production for several years, all younger Boeing and Airbus types that have come into production since the early 1990s have wide Stage 4 margins. In addition to the A318, Airbus claims the A330 and A340-500/-600 all have wide Stage 4 margins.

The A380 will be certified in early 2006, and so will have to meet Stage 4 noise rules. Despite its gross weight being about 470,000lbs higher than the 747-400, Airbus says it expects the A380 to be quieter than the 747-400. Noise rules do of course allow the 747-400 and A380 to have the same noise emissions at each of the three measuring points *(see charts, page 11)*. Airbus says the A380's noise emissions should give it a margin of 20 EPNdB compared to Stage 3 rules, and thus about a 10EPNdB margin over Stage 4.

The A340-500/-600 are also expected to have a margin of 22-24 EPNdB compared to Stage 3, and thus a margin of 12-14EPNdB over Stage 4.

The A318 is also expected to have a margin of 20EPNdB over Stage 3 emission rules.

Other issues

Besides noise emissions of aircraft, ICAO also made other decisions with respect to Stage 4. It first ruled that the issue of Stage 4 should be a reduction of noise at source. These are the levels of noise for Stage 4 as described.

Second, ICAO decided aircraft should use noise abatement procedures to achieve some noise reduction, since technology alone should not have to achieve the required reduction.

Third, land planning around airports should be considered on a cost benefit basis. As aircraft noise has reduced, residential areas have grown closer to airports. New problems have arisen as traffic has grown, resulting in more aircraft movements. The cost benefit analysis of the land use around airports should consider the cost of relocating residents further away from airports and allow the land to be used for industrial purposes, compared to the cost of using technology to achieve aircraft noise reduction.

The fourth decision was that there should be operational restrictions on aircraft.

Modification programmes

All engine manufacturers will have to seek ways of reducing noise to varying degrees for their products for new aircraft certified from 2006.

Rolls-Royce has set a target to reduce noise levels of its new engines by 10EPNdB by 2010 compared to engines certified in 1998. The Trent 800 was certified in 1998, and although the 777-200 it powers is Stage 4 compliant, Rolls-Royce's target reduction will further lower noise levels. The Trent 500 is expected to have emissions about three EPNdB lower than the Trent 800, and the Trent 900 emissions five EPNdB lower than the Trent 800. The Trent 900 powers the A380, and is one of the first engines that has to meet Stage 4 emission levels.

Pratt & Whitney has advanced technology programmes used in noise reduction techniques, and these could be applied to older engines. This would either be for legal requirements to meet Stage 4, or for customers that want noise reduced on their aircraft.

General Electric (GE) has a programme in place to develop modifications to bring some aircraft powered by GE and CFM56 engines that do not comply with Stage 4 to full compliance. Like Pratt & Whitney, GE is also developing noise reduction packages for certain out of production but in service aircraft so that airlines can continue to be Stage 4 compliant, even though they are not legally required to do so.

The highest gross weight A321 powered by the CFM56-5B rated at 33,000lbs is not fully Stage 4 compliant, since emissions at two of its measuring points do not generate a large enough reduction. CFMI is working on a modification programme to make this engine Stage 4 compliant. The modification consists of an improved acoustic treatment on the internal part of the nacelle, a core chevron nozzle, and a new 3-dimensional designed outlet guide vanes in the secondary outflow path behind the fan.

Despite these various noise reduction programmes being investigated by engine manufacturers, there are few or no hushkit or other noise reduction programmes to make aircraft Stage 4 compliant. Since aircraft will not legally be required to be Stage 4 compliant if certified before 2006, and there is no phase-out timetable for Stage 3 aircraft, it will be hard for most airlines to generate a cost benefit from modifying their aircraft. Stage 4 will thus not affect the market values of aircraft in operation.