



U.S. Department  
of Transportation  
**Federal Aviation  
Administration**

# Advisory Circular

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**Subject:** Bird Ingestion Certification  
Standards

**Date:** 8/7/09

**AC No:** 33.76-1A

**Initiated by:** ANE-111

**1. PURPOSE.** This advisory circular (AC) provides guidance and acceptable methods, but not the only methods, that may be used to demonstrate compliance with the bird ingestion requirements of Title 14 of the Code of Federal Regulations (14 CFR) § 33.76. Although this AC does refer to regulatory requirements that are mandatory, this AC is not, in itself, mandatory. This AC neither changes any regulatory requirements, nor authorizes changes in, or deviations from, the regulatory requirements.

## **2. APPLICABILITY.**

a. The guidance provided in this document is directed to the applicant engine manufacturer or modifier.

b. This material is neither mandatory nor regulatory in nature and does not constitute a regulation. It describes acceptable means, but not the only means, for demonstrating compliance with the applicable regulations. The FAA will consider other methods of demonstrating compliance that an applicant may elect to present. Terms such as “should,” “shall,” “may,” and “must” are used only in the sense of ensuring applicability of this particular method of compliance when the acceptable method of compliance in this document is used. While these guidelines are not mandatory, they are derived from extensive FAA and industry experience in determining compliance with the relevant regulations. On the other hand, if we become aware of circumstances that convince us that following this AC would not result in compliance with the applicable regulations, we will not be bound by the terms of this AC, and we may require additional substantiation as the basis for finding compliance.

c. This material does not change, create any additional, authorize changes in, or permit deviations from existing regulatory requirements.

**3. BACKGROUND.** This AC provides information and guidance that addresses Federal Aviation Administration (FAA) type certification standards for aircraft turbine engines with regard to bird ingestion. The requirements under § 33.76 reflect recent analysis of the bird threat encountered in service by turbine engine powered aircraft.

**4. DEFINITIONS.** For the purpose of this AC, the following definitions apply:

a. Ingestion. Ingestion is defined as either the passage of a bird into the engine inlet or impact with engine structure.

b. Front of the Engine. The front of the engine is characterized as any part of the engine which can be struck by a bird. This includes, but is not limited to, the following:

- (1) Inlet mounted components (for example, inlet sensors).
- (2) Nose cone.
- (3) Spinner (centerbody) on the fan or compressor rotor.
- (4) Engine inlet guide vane assemblies.
- (5) Any engine protection device (for example, screen or inlet barrier filter).
- (6) Fan or compressor blades (including front and aft fan designs).

c. Minimum Engine. A minimum engine is defined as a new engine that exhibits the type design's most limiting operating parameter(s) with respect to the bird ingestion conditions prescribed in this AC. These operating parameters include, but are not limited to, power or thrust, turbine temperature, and rotor speed.

d. First Stage Rotating Blades. The term "first stage rotating blades" includes the first of the exposed stages of any fan or compressor rotor which are susceptible to a bird strike or bird ingestion. These first stage rotating blades are considered to be part of the front of the engine, as defined in paragraph 4.b. of this AC. This definition encompasses ducted, unducted and aft fan engine designs. In these latter cases, blading on multiple rotors (that is, primary and secondary airflow paths) should be considered separately when complying with § 33.76.

e. Critical Impact Parameter (CIP). A parameter used to characterize the state of stress, strain, deflection, twist, or other condition which will result in the maximum impact damage to the engine for the prescribed bird ingestion condition.

f. Inlet Throat Area. The inlet throat area is an installation limitation equal to the projected capture area of the aircraft engine inlet nacelle at its minimum inside diameter.

g. Airspeed for Normal Flight Operations. Normal flight operations with respect to airspeed refers to the range of airspeed values that is allowed under normal circumstances by existing air traffic control regulations.

**5. GENERAL.** Section 33.76 requires that an applicant demonstrate that their engine is designed and constructed to be structurally and operationally tolerant, to the degree specified, following the defined bird ingestion events. Each of the following factors, as applicable, impacts that demonstration:

a. Front of the Engine. You should assess the bird impact to the critical parameters of the components at the front of the engine. For example, the ability of the spinner to withstand a bird impact should be assessed for the most critical parameters of the spinner. This assessment should include bird size, bird velocity, target location, and rotor speed.

b. Artificial Birds. Artificial birds or devices which simulate the mass, shape, density, and impact effects of birds, and which are acceptable to the Administrator, may be used for the ingestion tests.

c. Critical Impact Parameter (CIP). The CIP is generally a function of bird mass, bird velocity, fan or rotor speed, bird impact or aiming location, and fan or rotor blade geometry. The CIP is used to characterize the maximum impact damage to the engine at the bird ingestion conditions of § 33.76. The CIP for most modern turbofan engines is fan blade leading edge stress. However, other design features or parameters may be the CIP for any given engine model. For turboprop, turboshaft and turbojet engines, a core feature will most likely be the critical consideration (for example, compressor airfoil). Regardless of engine design, we recommend that you identify the most limiting parameter prior to any demonstration, as we will evaluate any unplanned variations in controlling test parameters for their effect on the CIP and § 33.76 requirements.

(1) Examples of CIP identification. For turbofan first stage fan blades, increasing the bird velocity or bird mass increases the slice mass, and could shift the CIP from leading edge stress to blade root stress. For fan blades with part span shrouds, blade deflection that produces shroud shingling and either thrust loss or a blade fracture may be the CIP. For unshrouded wide chord fan blades, the CIP may be the twist of the blade in the dovetail that allows it to impact the trailing blade resulting in trailing blade damage.

(2) CIP Tolerance. For certification tests, the CIP variation should not be significant. Historically, CIP variation has not been greater than 10% due to deviations in controlling test parameters.

d. Critical Test Parameters. Determine your critical test parameters using analysis or component tests. Consider your experience with similar type and size engines, and pay particular attention to the types and causes of failures in those similar engines.

e. Engine Tests. Engine tests should be conducted with a fully operational engine representative of the type design. The normal functioning of any automatic protective or recovery systems not requiring pilot intervention is acceptable (including automatic power lever movement). However, any such automatic systems will be required for dispatch (for example, Master Minimum Equipment List) if such functions are necessary to meet the requirements of § 33.76. You may also conduct the test(s) with any automatic systems in a functionally degraded state, if doing so does not constitute a less severe test.

f. Test Facilities Calibration. Calibrate the test facility to ensure that the controlling test parameters (for example, bird speed, aiming locations) remain within an acceptable tolerance band. The tolerance band should take into account how sensitive the critical impact parameter CIP is variations in the controlling test parameters. We recommend setting the tolerance band so that the CIP varies no more than 10% from any combination of controlling test parameter variation (see paragraph 5.c. of this AC). Also, certain test facilities and installations may affect or reduce engine stability margin, due to airflow distortion attributed to the close proximity of bird gun(s) to the engine inlet. These effects must be identified prior to the test. Power or thrust should be measured by a means that has an accuracy of +/- 3%.

g. Turboprop and Turboshaft Engine Tests. A turboprop or turboshaft engine may be tested using an alternative load device, which could produce different engine response characteristics compared to an engine installed in an aircraft. Under this circumstance, the response differences should be documented. Pertinent engine or facility interface data should be recorded during the test, to assure that an installed engine complies with the requirements in § 33.76.

h. Aircraft and Engine Interface. The Installation Manual should describe engine and aircraft interfaces which could be affected by bird ingestion. Dynamic interactions, such as automatic surge recovery, auto relight, or propeller auto feather, are of particular interest if the functioning of those systems is needed to comply the requirements in § 33.76.

i. **Inlet Throat Area.** Identify in the Installation Manual the inlet throat area which you used to determine the quantity and weight of birds for the overall showing of compliance to § 33.76. Ensure that you record it as an installation limitation. Section 33.76(a)(2) contains the specific requirement for this limitation. Take care in determining this value, as future models or installations may require a larger number or size of birds. Also, the tables of bird quantities and weights within § 33.76 are based on inlet throat area ( $D_t$ ) not the inlet highlight ( $D_s$ ) or engine front face ( $D_e$ ) projected areas. For variable geometry inlet designs, further evaluation may be necessary to determine an effective inlet throat area. See Figure 1 below for standard inlet dimension definitions.

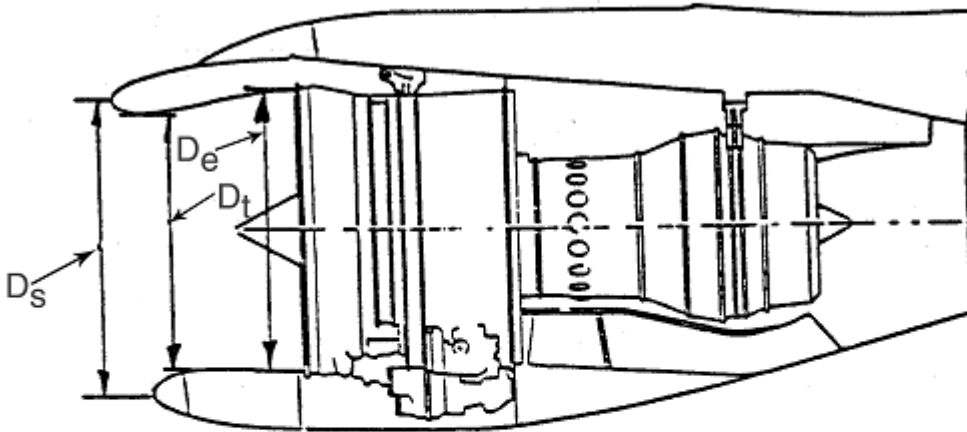


FIGURE 1. GENERIC TURBOFAN AND NACELLE CONFIGURATION

$D_s$  = nacelle inlet lip stagnation point diameter, (i.e., highlight diameter).

$D_t$  = nacelle inlet throat diameter

$D_e$  = engine front face inlet diameter, (i.e., bare-engine inlet diameter).

j. **Derivative Engines and Major Design Changes.** You must conduct the required engine tests under the conditions of § 33.76 for type certification of derivative engine models or major design changes to existing models. However, we may conclude that representative demonstration evidence meets this requirement if you provide sufficient detailed analysis to substantiate that conclusion. Substantiation evidence may come from your experience on engines of comparable size, design, construction, performance, and handling characteristics, if you obtained it during previous certification testing. Substantiation evidence may also come

from development tests or in-service operational data. Any analysis results used for type certification or major design change approval should fall within 10% of the most critical impact parameter(s) identified in the engine baseline certification. The critical impact parameter(s) is often associated with impact load at the point of bird and rotor blade contact. This is generally a function of bird mass, bird velocity, rotor speed, aiming and impact location and fan/rotor blade geometry (for example, blade twist angle). This 10% variation on the critical impact parameter should not be assumed to be a tolerance on the applicant's proposed changes to takeoff power or thrust ratings themselves.

k. Hot Day Corner Point Operation. The intent of § 33.76(a)(1) is to show that the engine is structurally and operationally tolerant to the small, medium and single large bird ingestion conditions of §§ 33.76(b) and 33.76(c) when operated at the hot day corner point condition. Compliance to § 33.76(a)(1) may include an actual engine test at hot day corner point conditions, or it may be based on other representative engine or component tests, validated analysis, representative service events, or any combination we find acceptable. The tests may be conducted at reasonable levels of power/thrust over boost (for example, operation at P3 limit) to minimize the use of less direct methods of showing compliance. This is especially true if the proposed engine test ambient conditions are less severe than sea-level standard day conditions. If you use analysis to show compliance, the analysis must be validated by showing your ability to predict bird ingestion event outcomes relative to the requirements and criteria of § 33.76.

l. Fan Frame Struts and Bifurcation Strut Fairings. Main frame struts or bifurcation strut fairings may be exposed to bird debris impact from bird debris exiting the upstream fan rotor. Additionally, these frame struts or strut fairings may house fuel, oil, hydraulic, or high pressure bleed air lines, or wiring associated with the engine control system. You should assess the potential for bird debris impact damage to these ducts, and ensure that sufficient strength exists in your design to minimize damage to critical internal components if impact to such structures occurs.

m. Protected Inlets. Section 33.76(a)(6) allows the applicant to specify an installation requirement (§ 33.5, Installation Instructions) for a protected inlet, in place of conducting certification engine test demonstrations. Therefore, engine level protection from the specified bird threats would be provided at the installation level by the inlet design. The detailed inlet design itself can be specified by the engine manufacturer in the Installation Manual, or a more general requirement could leave the detailed method of protection up to the installer. When using Section 33.76(a)(6), the installer will be complying with the applicable aircraft level requirement that requires compliance with the engine installation instructions. For example, §§ 23.901(e)(1), 25.901(b)(1)(i), 27.901(c)(1), or 29.901(b)(1)(i).

The threat level that the installer will need to address is normally that level associated with the certification basis for the engine. This means that the required size and number of birds that the protected inlet will have to accommodate will be same as would have been required for an engine test. However, the aircraft manufacturer could show compliance to later (part 33 amendment) threat levels, or aircraft certification basis threat levels, as approved by the Aircraft Certification Office managing that specific aircraft certification program.

## 6. GUIDANCE FOR LARGE SINGLE BIRD INGESTION.

a. For the purpose of the § 33.76 test, we will accept the complete loss of engine power or thrust after ingestion.

b. The most critical location on the first stage rotating blades may be determined from analysis or component tests, or both. You should include evidence, where necessary, on:

- (1) The effect of the bird strike on rotating components;
- (2) The compressor casing strength;
- (3) The possibility of multiple blade failures; and

(4) The strength of the engine structure (for example, fan frame struts and fairings) and main shafts relative to the unbalance and excessive torque likely to occur.

c. Compliance with the requirements of § 33.94(a) can be used in place of the large bird ingestion engine test. In this case we recommend that you show that the § 33.94(a) test constitutes a more severe demonstration of rotor blade containment, rotor unbalance, fire protection consideration and mount load capability than a single large bird test. The evaluation should consider the engine dynamic response to a large bird ingestion event, and include, but not be limited to:

- (1) The effects of engine unbalance loads;
- (2) Engine torque loads;
- (3) Surge related loads; and

(4) Axial loads resulting from the bird impact which are transmitted to the engine structure.

d. The 200 knot ingestion speed for the large bird requirement was selected as the optimum speed to accommodate the various CIP associated with typical turbofan engine designs currently in service. However, for a specific engine design, an ingestion speed other than 200 knots may be a more critical demonstration when considering the overall criteria of § 33.76(b). Therefore, if you show that a different bird speed is more conservative, or more completely evaluates your proposed design, then you may conduct your tests and analyses at that ingestion speed. You must note in the certification basis your different speed as an equivalent level of safety under § 21.21(b)(1).

e. All components considered to be part of the front of the engine must be evaluated under §§ 33.76(a)(3) and 33.76(b)(3).

## **7. GUIDANCE FOR SMALL AND MEDIUM FLOCKING BIRD INGESTION.**

a. You must identify the critical target locations for the small and medium bird ingestion tests required by § 33.76(c). You must also consider the potential effects of assumed installations in the aircraft. The first bird is targeted for the core primary flowpath. The second bird (if two or more are required) is targeted for the most critical exposed location. Target any remaining birds over the fan face area (including the centerbody if applicable) in a manner to achieve an even distribution of birds over the front face of the engine. The distribution of remaining birds should be such that any additional critical locations are tested. Any critical locations not targeted may be evaluated separately by analysis or component testing, or both.

b. In the tests performed under § 33.76(c), the engine is required to produce at least 75% of takeoff power or thrust after ingestion of small and medium birds. A momentary power or thrust drop (for example, surge recovery) below this value is acceptable as long as the duration does not exceed 3 seconds.

c. Rig tests may be used to determine if a particular bird size will pass through the inlet and into the rotor blades.

d. Measure thrust or power by a means that is accurate throughout the test. You must be able to set the thrust or power without undue delay, and maintain that setting within plus or minus 3% of the specified levels. If the engine experiences a sustained high vibration condition after the first 2 minutes of operation following bird ingestion, then you may vary thrust or power as a protective measure. However, thrust or power can only be varied within plus or minus 3% of the specified levels. Alternate load devices such as waterbrakes, may be unable to control power within the plus or minus 3% tolerance. Therefore, if you intend to use an alternate load device, we recommend that you obtain approval to do so before commencing your test.

e. Exceeding engine operating limits is not expected to occur. However, it is permitted to occur only during the first 2 minutes following the ingestion of the birds in the 20 minute run-on test (see § 33.76(c)(7)(ii)). Any excursions over a limit should be recorded and shown by evidence acceptable to us, that the excursion will not result in an unsafe condition (see § 33.76(c)(10)). This evidence may come from previous test or service experience, or analysis thereof. Under such circumstances, the Operating Instructions, Installation Manual, and Maintenance Manual (see §§ 33.4 and 33.5) should be evaluated to determine the need for instructions on dealing with this type of over limit condition.

f. All components considered to be part of the front of the engine must be evaluated under §§ 33.76(a)(3) and 33.76(c)(6).



## **8. GUIDANCE FOR LARGE FLOCKING BIRD INGESTION.**

a. In accordance with § 33.76(d)(2), engine power or thrust will be stabilized at a specific first stage rotor speed value (for example, fan speed, N1, etc.) independent of test day ambient conditions or actual power or thrust produced at the time of the test. This physical N1 fan rotor speed value corresponds to that which would produce 90% of maximum rated takeoff power or thrust when the engine is operated on an ISA standard day at sea level.

b. Select a target on the first exposed rotating stage or stages of the engine (for example, the fan), at not less than 50% of airfoil height, as measured at the blade leading edge (see Figure 2 of this AC). The test target location is selected at your discretion, and you should specify it in the test plan. The term 'stage or stages' addresses designs for which multiple stages are exposed, such as rear mounted fan configurations. For such designs, each exposed stage must be evaluated independently.

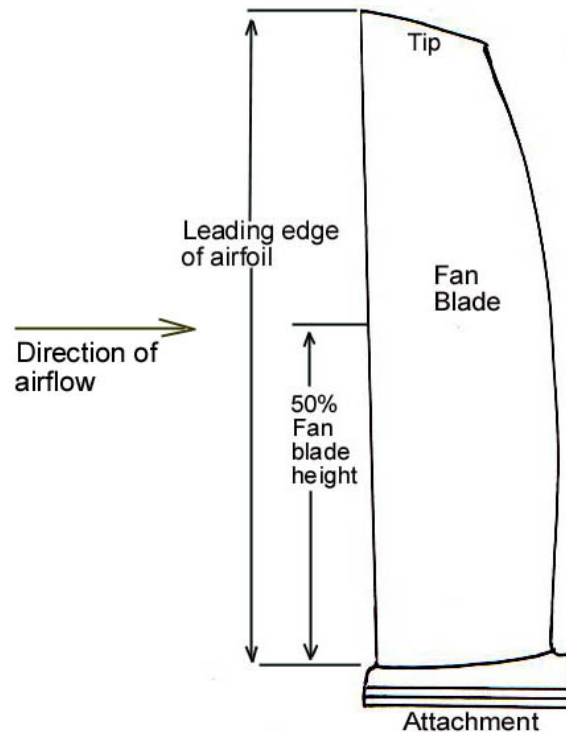


FIGURE 2. LOCATION OF TARGET POINT ON THE LEADING EDGE OF A TYPICAL FAN BLADE

c. In the test performed under § 33.76(d), the engine must operate for a minimum of 20 minutes per the required run-on schedule, after ingesting a large flocking bird (see Figure 3). A momentary drop (less than 3 seconds) in power or thrust below the required value of each segment, or when setting power between segments, is acceptable. A power or thrust loss greater than 3 seconds duration is considered a sustained power loss.

d. With respect to the run-on sequence specified in § 33.76(d)(5):

(1) Segment (5)(i) is 1 minute in duration. You are not permitted to move the power lever. Any power or thrust greater than or equal to 50% of maximum rated takeoff is acceptable.

(2) Segment (5)(ii) is 13 minutes in duration. In this segment, moving the thrust lever is at your discretion. During this portion of the test, you may set power or thrust where the engine can continue to operate (for example to minimize over limit conditions and/or vibration), provided that the engine maintains no less than 50% power or thrust. You may also vary the power control lever at any time and to any extent, and at any rate, within this period of time; provided that the engine maintains no less than 50% power or thrust.

(3) The total duration of the test may exceed 20 minutes due to the time used for accelerations and decelerations.

(4) Wherever a percentage of maximum rated takeoff power or thrust is specified in this section, the rotor speed to attain the specified power setting will vary with test day conditions. Also, these power settings are a percentage of maximum rated takeoff power or thrust, and not a percentage of the actual test day pre-ingestion power or thrust specified in § 33.76(d)(2).

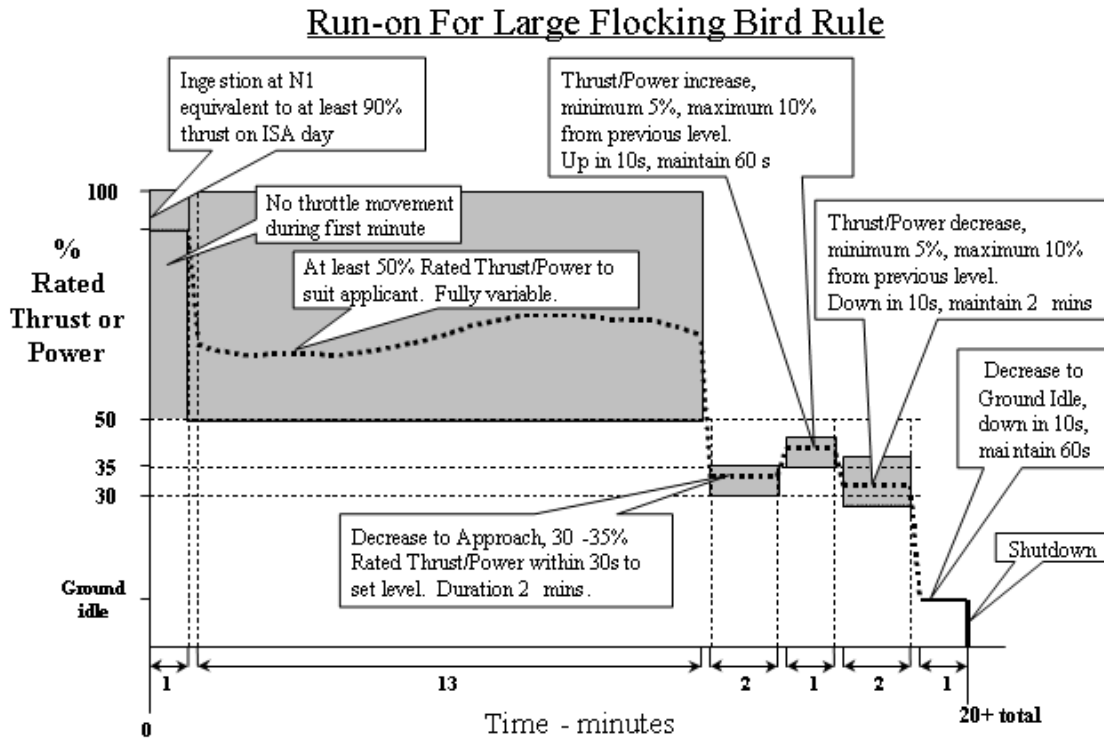



FIGURE 3. RUN-ON PROFILE FOR LARGE FLOCKING BIRD TEST

e. A subassembly test under the § 33.76(d)(6)(ii) method should include all type design hardware which you consider significant to the outcome of the test. Potential examples include, but are not limited to, fan blades and their retention/spacer components, fan inlet and outlet (exit) guide vanes; spinners, fan disks and shafts; fan cases; frames; main bearings and bearing supports including frangible bearing assemblies or devices; and other critical parts. Your subassembly test must adequately represent the mechanical aspects of your engine during large flocking bird ingestion. The dynamic effects (and related operability concerns) noted in this section include, but are not limited to, surge and stall, flameout, limit exceedance, and any other considerations relative to the engine's ability to comply with the requirements of §§ 33.76(d)(4) and 33.76(d)(5).

f. Engine operating limit excursions are permitted during the 20 minute run-on. Record any excursions that occur, and show that they do not produce an unsafe condition. This evidence may come from previous test or service experience, or analysis. You should also include appropriate instructions in the engine Operating Instructions, Installation, and Maintenance Manuals.



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