U.S. Department of Transportation
Federal Aviation Administration

Advisory Circular

Subject: EVALUATING TURBINE ENGINE OPERATING CHARACTERISTICS
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1. PURPOSE. This advisory circular (AC) provides guidelines for the evaluation of turbine engine (turbojet, turboprop, and turboshaft) operating characteristics for subsonic transport category airplanes. These guidelines describe a method of demonstrating compliance with the applicable airworthiness requirements. Like all advisory circular material, these guidelines are not mandatory and do not constitute a regulation. They are derived from FAA experience in establishing compliance with the airworthiness requirements and represent the means and methods found to be acceptable by that experience. These guidelines may not be entirely applicable to all airplane designs. Each design should be examined to determine whether the suggested methods of evaluation are adequate or if other methods in addition to these may be appropriate.

2. RELATED FEDERAL AVIATION REGULATIONS (FAR). The related FAR is § 25.939(a) of Part 25. Compliance with § 25.939(c) is beyond the scope of this AC and should be established by the applicant to the satisfaction of the appropriate Aircraft Certification Office (ACO) prior to initiating the detailed engine operating characteristics tests.

3. BACKGROUND. The turbine engines of a transport category airplane must continue to operate safely during normal and emergency operation within the range of operating limitations of the airplane. Generally, compliance with § 25.939(a) can be determined to some extent while ascertaining compliance with other Part 25 requirements such as performance, controllability, maneuverability, and stalls. Turbine engines should be stable in their operation and run free of adverse characteristics in the normal flight regime. However, certain adverse characteristics are allowed in specific flight regimes if they do not present a hazardous condition.

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

Engine Stall: Flow breakdown at one or more compressor airfoils.

b. Engine Surge: The response of the entire engine which is characterized by a significant flow stoppage or reversal in the compression system.

c. Deterrent Level of Buffet: A severe level of buffet that constitutes a clear deterrent to further decrease in airspeed or increase in angle of attack.

d. Engine Damage: Damage that is in excess of the engine manufacturer's approved limits.

e. Normal Operating Envelope: Altitudes between sea level and the maximum approved operating altitude, airspeeds between stall warning and V_{MO}/M_{MO}, and sideslip angles appropriate for the type of airplane.

f. Abnormal Flight Conditions: Flight conditions outside the normal operating envelope.

5. ENGINE OPERATING CHARACTERISTICS. Adverse engine operating characteristics range from mild to severe and are classified into three levels of severity for the purpose of defining acceptable operation. These characteristics are summarized in Appendix 1.

a. Mild adverse operating characteristics include: minor compressor stalls; light, audible surges; no perceived power loss; no engine damage (see DEFINITIONS); and immediate return to normal operation. Engine operating instability is brief and of minor intensity, and crew action is not required for recovery.

b. Moderate adverse operating characteristics include audible surges and compressor stalls, a momentary loss of thrust, an exceedance of continuous engine operating limits up to the approved transient limits, a temporary rotor speed decrease from IDLE to sub-IDLE, or slow engine acceleration. Power lever movements are not normally required to restore stable engine operation; however, minor power lever movements may be allowed provided the FAA and the engine manufacturer concur, the required crew actions are simple and instinctive, and the procedures are included as part of flightcrew training. Engines are not damaged and are capable of recovering to full thrust without subsequently exceeding any engine limits.

c. Severe adverse operating characteristics usually are characterized by loud, audible surges resulting in detrimental effects on airplane performance and controllability. One or more of the following characteristics are present:

(1) Engine stall or surge which requires large or rapid power lever movements or adjustment of other engine controls for recovery or attempted recovery.

(2) A substantial, sustained thrust loss.

(3) Engine flameout or required engine shutdown.

(4) Engine damage (see DEFINITIONS).

(5) Engine vibration requiring power reduction or engine shutdown.

(6) Engine conditions that result in a hazardous cabin pressure loss.

(7) Failure of the engine rotor(s) to accelerate.

6. FACTORS AFFECTING ENGINE OPERATING CHARACTERISTICS. Factors that may cause the engine to operate adversely are numerous, varied, and complex. Recognition of these factors and their impact on turbine engine operating characteristics is

essential to defining a suitable airworthiness compliance test program. Some of the more dominant factors are:

a. Engine installation effects such as the design of the inlet and exhaust systems, inlet suck-in doors, anti-ice system, fuel system, type of fuel, etc.

b. Location of the engine on the airplane and its proximity to airflow disturbance caused by the fuselage, wing, landing gear, flaps, etc.

c. Configuration of the airplane (flap position, speed brakes, gear position, etc.) that can cause airflow disturbance to the engine.

d. Atmospheric conditions such as altitude, ambient temperature, icing, windshear, etc.

e. Engine control characteristics (including the effects of trim tolerance) of variable inlet guide vanes, surge bleed valves, auto-throttle, fuel controls, temperature/speed controls, etc.

f. Engine gas generator design (stall margins, compressor operating line, compressor pressure ratio, acceleration stall bucket (W_f/P_b vs. N), etc.).

g. Wind direction and intensity during takeoff, landing, and taxiing.

h. Flight condition (airplane attitude, configuration, flight regime, engine power setting, airplane "G" loading, flight transients, and flight handling techniques).

i. Engine accessories and equipment (bleed air and power extraction).

j. Pilot technique used in manipulating engine controls.

7. FLIGHT TEST EVALUATION OF ENGINE OPERATING CHARACTERISTICS.

a. Test conditions for demonstrating compliance with § 25.939(a) should be based upon an assessment of all factors affecting engine operating characteristics. Details of the engine design (and its control system as defined in the engine installation and operating manuals) and the effects of the engine installation on the airplane should be considered. The location of the engine and inlet on the airplane can make the engine more susceptible to operating instability under certain regimes of flight. The possibility of engine operating problems existing in some flight regimes should always be explored where experience and reasoning warrant. The specific flight and ambient conditions that produce engine operating instability are not always evident on the basis of engineering knowledge and evaluation.

b. The operating characteristics tests should be conducted utilizing any engine control system, including supervisory electronic engine controls and auto-throttles, for which certification is requested. The engine operating characteristics evaluation should also consider transient and stable operation of engine accessories and equipment, such as air conditioning packs, anti-ice systems, and electrical generator loads and their effects on engine operating characteristics.

c. Flight test evaluation of engine operating characteristics should consider all airplane configurations except those precluded by Airplane Flight Manual limitations or procedures. Certain airplane configurations may be limited as a function of altitude and/or airspeed. However, a minimum airspeed limit by itself is not considered an adequate warning means to preclude the low airspeed evaluation of inflight engine operating characteristics. If a stick shaker is used for airplane stall warning, its actuation may be rescheduled to operate at a higher airspeed to warn of impending adverse engine operating characteristics.

d. Specific ground and flight test procedures and criteria are suggested in paragraph 8 of this AC. The complete set of test procedures pertain to the initial approval of an airplane engine installation. For follow-on engine installation changes such as engine thrust (power) rating changes, inlet modifications, engine systems modification, etc., portions of the recommended tests that are deemed necessary should be conducted. When conducting the tests described in paragraph 8, an isolated occurrence of an apparent hazardous adverse engine operating characteristic may not necessarily constitute failure in satisfying the requirements imposed by § 25.939(a). Additional successful testing and/or engineering analysis may prove that the suspected adverse engine operating characteristic is not prevalent and does not constitute an unsafe condition. For safety, most or all of the "transient power" and "engine/inlet compatibility" testing described below should be confined to checking one engine at a time or to that engine which is most critical because of its location on the airplane.

8. GROUND AND FLIGHT TEST PROCEDURES. To achieve the level of safety required by § 25.939(a), the following tests and criteria have generally been found by experience to be an acceptable method of demonstrating engine operating characteristics. However, certain engine installations may require tests at other flight conditions, if those conditions are deemed critical. These tests are usually qualitative and require no special instrumentation. A summary of the test criteria is shown in Appendix 2.

a. Engine Operating Characteristics During Taxi, Takeoff, and Landing. Except as noted below, adverse engine operating characteristics should not exist during the following taxi, takeoff, and landing segments. Compliance with this section should be established at the maximum demonstrated crosswind component and 150 percent of the limiting tailwind component for those components greater than 10 knots.

(1) Taxiing: No adverse engine operating characteristics (mild, moderate, or severe) should exist during taxiing except for operation in crosswinds and tailwinds where mild adverse operating characteristics are acceptable.

(2) Takeoff: No adverse engine operating characteristics (mild, moderate, or severe) should exist after the power setting phase (normally completed by 60 to 80 knots) of the takeoff procedure through attainment of the enroute configuration and climb to 1,500 ft. above the airport. During the power setting phase of the takeoff roll, mild adverse characteristics are acceptable for operation in crosswinds and tailwinds. The tests may be

conducted using the applicant's recommended power setting procedures, provided they are acceptable for operation and are considered in establishing the Airplane Flight Manual takeoff performance.

Note: Satisfactory engine operating characteristics should be demonstrated during all takeoff performance tests. Tests should also be conducted to determine if any engine operating problems exist for takeoffs conducted throughout the altitude range approved for takeoff.

(3) Approach and Landing: No adverse engine operating characteristics (mild, moderate, or severe) should exist during the approach to landing from 1,500 ft. above the airport elevation, and during landing and rollout, including the use of thrust reversers at speeds down to the recommended "cutoff" speed, if applicable. At speeds less than the recommended "cutoff" speed, mild or moderate adverse operating characteristics for ground thrust reverser operation may be acceptable when using the applicant's recommended procedure (including power lever movements), provided the FAA and engine manufacturer concur that a hazardous condition does not exist. During landing rollout, mild adverse engine operating characteristics are acceptable while operating in crosswinds and tailwinds.

Note: Satisfactory engine operating characteristics should be demonstrated during all landing performance tests conducted within the normal engine operating range. Tests should also be conducted to determine if any engine operating problems exist for approaches and landings conducted throughout the altitude range approved for landing.

(4) Reverse Thrust (Power) Backing: If approval for reverse thrust backing is desired by the applicant, acceptable engine operating characteristics should be demonstrated. Using the applicant's recommended procedures (including power lever movements), mild or moderate adverse operating characteristics may be acceptable for reverse thrust backing provided the FAA and engine manufacturer concur that a hazardous condition does not exist.

b. Transient Power Operating Characteristics. For normal airplane and engine configurations, no adverse engine operating characteristics of any kind should exist within the normal airplane operating envelope during engine transient power conditions unless it is determined that they do not contribute to a hazardous situation, require immediate crew action, or damage the engine(s). For abnormal airplane and engine configurations addressed by Airplane Flight Manual procedures, no moderate or severe adverse engine operating characteristics should exist within the normal airplane operating envelope. After an engine shutdown, the remaining engine(s) is considered to be in a normal state, including any required bleed air and accessory power extraction changes. Mild adverse engine operating characteristics are allowed during abnormal flight conditions (e.g., airspeeds below initial low speed buffet). When using the above criteria, the following engine acceleration/deceleration and engine operating tests are the recommended procedures to be used to demonstrate satisfactory transient operating characteristics. The tests should be conducted using the most critical engine control system configuration approved for dispatch.

(1) Engine accel-decel (jam accelerations) tests should be conducted by rapidly moving (one second or less) the power lever from stabilized IDLE to the specified thrust setting, allowing the engine to stabilize, and then rapidly moving the power lever back to IDLE.

(2) Interrupted engine deceleration tests (Bodies) should be conducted by a rapid deceleration (power lever to IDLE stop) followed by a rapid acceleration back to the initial power lever position when the engine rotor speed passes through a specified turnaround speed. Several different turnaround speeds, including IDLE, are required unless the critical speed (minimum surge margin) has been identified by the engine manufacturer.

Note: The tests described in paragraphs (1) and (2) above should be conducted using the maximum thrust (power) approved for the test altitude at the following speed/altitude points and any others deemed critical:

- As near as practical to V_{MO}/M_{MO} (maximum operating) and V_{IB} (initial buffet) + 10 knots and initiated at the maximum approved operating altitude, and

- V_{FE} (flaps extended), and V_{IB} + 10 knots at an altitude 1,500 ft. above the maximum approved takeoff altitude.

These tests specify rapid power lever movements to evaluate the engine control system response to a rapidly changing demand for thrust (power). In most cases, rapid power lever movements have provided the least stall margin during engine acceleration and deceleration tests. However, some engines have been found to be more sensitive to slow power lever movements because of control system features that depend on the rate of engine acceleration or deceleration. An example is a normally modulating bleed valve that goes to the full open position during rapid thrust (power) changes. In this case, the engine control system should be analyzed and the appropriate accel-decel tests performed using the most critical power lever manipulation rates.

(3) Engine acceleration tests should be conducted by rapidly advancing the power levers from IDLE to maximum thrust (power) as the airplane stalls and a normal recovery is initiated (see § 25.201(d) of the FAR for stall definition). These tests should be conducted using the critical flap configuration and at altitudes sufficient to verify acceptable engine operating characteristics for the altitude range approved for landing. (Mild adverse engine operating characteristics are acceptable for these tests.)

(4) Low rate descents at IDLE thrust (power) should be conducted from within 3,000 ft. of the maximum approved operating altitude to 10,000 ft. altitude. At the bottom of descent, the engines should accelerate normally to maximum continuous thrust (power).

c. Engine/Inlet Compatibility Tests. The purpose of this flight test is to investigate the effects of distorted engine-inlet airflow that may result from unusual airplane attitudes in the normal and emergency operating range of the airplane. Inlet airflow distortion may cause adverse engine operating characteristics. Qualitative flight tests, such as sideslips, windup turns or symmetrical pull-ups, and approaches to power-on stalls, may be used to demonstrate satisfactory engine operating characteristics at high thrust (power) settings and angles of attack.

(1) The following thrust (power) settings are recommended:

(i) Use thrust (power) settings up to the maximum approved thrust (power) limit at altitudes up to 1,500 ft. above the maximum approved takeoff altitude.

(ii) From the maximum altitude considered in paragraph (i) up to the maximum altitude approved for operation, the engines should be operated at thrust (power) settings up to the maximum continuous thrust (power) limit for the tests.

(2) The degree of adversity allowed for engine operating characteristics depends on the airplane speed range being considered:

(i) No adverse engine operating characteristics should exist within the normal airplane operating envelope from V_{MO}/M_{MO} down to natural or artificial (stick shaker) stall warning cues used to show compliance with § 25.207. However, at altitudes greater than 3,000 ft. above the highest altitude approved for takeoff and landing, mild adverse operating characteristics may be permitted if it is determined that they do not contribute to a hazardous situation.

(ii) At altitudes up to 3,000 ft. above the maximum approved takeoff altitude, between the angle of attack for stall warning and an angle that exceeds the stall warning angle by an amount that might occur during recovery from a dynamic penetration past stall warning, the engines should be free of moderate or severe adverse engine operating characteristics. However, at altitudes greater than 3,000 ft. above the highest altitude approved for takeoff and landing, mild and moderate adverse operating characteristics may be permitted if it is determined that they do not contribute to a hazardous situation.

Note: Flight maneuvers to an angle of attack that exceeds the stall warning angle by approximately 10 percent will fulfill the intent of this requirement although other proposals offered by the applicant will be considered if they are based on sound reasoning that relates to the applicant's specific design. During the windup turn and approach to stall, the airplane angle of attack should be increased to that point before recovery is initiated, unless one of the following conditions is reached first:

- An FAA approved structural limit, or
- A controllability limit, or
- A deterrent level of buffet or an artificial barrier (stall prevention device).

(3) If stall characteristics and/or static directional and lateral stability testing is required for airframe approval, the engines should not

exhibit any severe adverse operating characteristics during these tests while outside of the normal operating envelope. Thrust (power) settings appropriate for the type of test being conducted should be used.

9. IN-FLIGHT OPERATED AUXILIARY POWER UNITS. The operating characteristics of inflight operated auxiliary power units (APU) may be evaluated concurrently with the engine/inlet compatibility tests. The APU should not exhibit any hazardous adverse operating characteristics. The APU operating characteristics should be checked within the APU operating envelope while operating in the most critical mode with respect to power extraction and pneumatic air supply as appropriate for the flight condition. A nonessential APU may be shut down, using adequate annunciation and normal procedures, as a means to prevent a hazardous situation. However, if an APU is to perform essential tasks, then it must continue to perform those functions.

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APPENDIX 1. SUMMARY OF DEFINITIONS

Level of severity is determined by the occurrence of one or more of the most severe characteristics.

ADVERSE ENGINE OPERATING CHARACTERISTICS	MILD	MODERATE	SEVERE
AUDIBLE SURGES	YES	YES	YES
OPERATING INSTABILITY	MINOR/ BRIEF	YES	YES
ENGINE ROTOR ACCELERATION	NORMAL	SLOW	NONE
ENGINE LIMITS EXCEEDANCE	NONE	BRIEF	SUBSTANTIAL
POWER LOSS/ROTOR SPEED DECREASE	NONE	TEMPORARY	SUBSTANTIAL
ENGINE VIBRATION	NONE	MINOR	REQUIRES SHUTDOWN
CREW ACTION REQUIRED FOR RECOVERY	NO	MAYBE	YES
ENGINE FLAMEOUT	NO	NO	YES
ENGINE DAMAGE	NO	NO	YES
HAZARDOUS CABIN PRESSURE LOSS	NO	NO	YES

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ADVERSE ENGINE OPERATING CHARACTERISTICS	MILD	MODERATE	SEVERE
AUDIBLE SURGES	YES	YES	YES
OPERATING INSTABILITY	MINOR/ BRIEF	YES	YES
ENGINE ROTOR ACCELERATION	NORMAL	SLOW	NONE
ENGINE LIMITS EXCEEDANCE	NONE	BRIEF	SUBSTANTIAL
POWER LOSS/ROTOR SPEED DECREASE	NONE	TEMPORARY	SUBSTANTIAL
ENGINE VIBRATION	NONE	MINOR	REQUIRES SHUTDOWN
CREW ACTION REQUIRED FOR RECOVERY	NO	MAYBE	YES
ENGINE FLAMEOUT	NO	NO	YES
ENGINE DAMAGE	NO	NO	YES
HAZARDOUS CABIN PRESSURE LOSS	NO	NO	YES

APPENDIX 2. RECOMMENDED TEST CRITERIA

ENGINE OPERATING CHARACTERISTICS TESTS	ADVERSE ENGINE OPERATING CHARACTERISTICS ALLOWED			
	NONE	MILD	MODERATE	SEVERE
TAKEOFF & LANDING OPERATIONS				
• Taxiing (Calm Air)	X			
In Crosswinds or Tailwinds	X	X		
• Takeoff (Calm Air)	X			
In Crosswinds or Tailwinds	X	X		
• Approach & Landing (Calm Air)	X			
In Crosswinds or Tailwinds	X	X		
At Speeds Below Reverser "Cutoff" Speed	X	X	⊗	
• Reverse Thrust (Power) Backing	X	X	⊗	
TRANSIENT POWER CONDITIONS				
• Jam Accels & Decels	X			
• Bodies (Interrupted Deceleration)	X			
• Airplane Stall Recovery ("Idle" to "Max. Power")	X	X		
For the Above Transient Tests:				
At Abnormal Airplane & Eng. Conf.	X	X		
• Cold Soak Descent & Recovery	X			
ENGINE AIRFLOW DISTORTION TESTS				
• Sideslips, Windup turns, or Symmetrical pull-ups, Approaches to Power-On Stalls:				
1. V_{MO} to stall warning	X			
@ Alt. well above T.O. & Land.	X	X		
2. Speeds below stall warning	X	X		
@ Alt. well above T.O. & Land.	X	X	⊗	
• Airframe Stalls & Sideslips @ conditions outside normal operating envelope (if required).	X	X	⊗	

X = ALLOWED
⊗ = MAY BE ALLOWED (FAA & ENGINE MFG. MUST CONCUR)