U.S. Department
of Transportation
Federal Aviation
Administration

Advisory Circular

Subject: Turbine and Compressor Rotors Type Certification Substantiation Procedures

Date: 9/9/68

AC No. 33-3

Initiated by: FS-140

Change:

1. PURPOSE. This circular sets forth guidance and acceptable means, not the sole means, by which compliance may be shown with the turbine and compressor rotor substantiation requirements in Federal Aviation Regulations, Part 33.

2. CANCELLATION. Advisory Circular 20-26 effective July 22, 1964, and Changes 1 and 2 effective September 18, 1964, and July 8, 1965, respectively, are cancelled.

3. CHANGES. Principal changes issued in this revision are as follows:

   a. The acceptable means of compliance is expanded to supply more details on the establishment of rotor component life limits as a means of achieving more meaningful rotor safe life values. Life limit substantiation is covered in terms of predicted maximum safe cycle life, initial service life limits, and increases in service life limits.

   b. Criteria for acceptable rotor condition following demonstration of overstrength is more explicit and stipulates as the basis "evidence of incipient failure or critical distortions which could cause hazards to an aircraft."

4. REFERENCE REGULATIONS.

   Federal Aviation Regulations, Part 33, Sections 33.27 and 33.5.

5. SCOPE. To provide reliability and safety of turbine and compressor rotors of turbine engines, turbosuperchargers, and

power recovery turbines used with reciprocating type engines, their design and construction must provide structural integrity of sufficient strength to withstand specified overspeeds and overtemperatures without failure unless rotor bursts are demonstrated to be contained within their respective housings. To cope with the possibility of critical deterioration of rotor assemblies from service use, inspection and life limit criteria are established and are set forth in the engine instruction manual. The substantiation procedures herein are those which have been used and found to be acceptable.

6. ACCEPTABLE MEANS OF COMPLIANCE FOR SUBSTANTIATING TURBINE AND COMPRESSOR ROTORS.

a. Design and Construction. The engine manufacturer should design turbine and compressor rotors to have sufficient strength margin to allow safe operation with likely variations in materials and operating environment. The effects of damage-inducing factors, which may effectively reduce the strength of rotor discs, should be minimized by design features, taking into account the reduction of strength that may be caused by surface damage and corrosion, occasional overheating, material flaws or other substandard metallurgical properties difficult to detect, likely dimensional and quality variations, vibration, and fatigue. Vibratory stresses should be determined and allowable stress limits established. Consideration should be given to the loads and stresses, occasioned from airplane inlet distortion, bleed air, and exhaust system effects, start-stop cyclic stresses (low-cycle fatigue), and vibratory stresses (high-cycle fatigue).

b. Service Life Limits.

(1) Life limits are to be specified in the manufacturer's instruction manuals for all rotor components (except blades) believed to have a finite life and should not exceed the lowest safe life. Both an acceptable initial service life limit and an acceptable plan for life limit increase substantiation should be submitted at the time of engine certification. Such a plan may differ from the following, but the objective of providing safe life limits should be assured. Life limits should cover, when applicable, all rotor spool components including shafts, discs, drums, spacers but not

blades. All rotor life limits, whether for an initial service life or for subsequent increases, should be substantiated by the best known current techniques in terms of flight operating cycles and hours as applicable.

(2) The 150-hour engine endurance testing is helpful in substantiating high-cycle fatigue life properties, but establishing the low-cycle fatigue life requires more extensive use of engine and component testing, including testing of numerous samples. Hence, a major consideration in the establishment of life limits is the low-cycle fatigue capability of rotor components to withstand the cyclic loading conditions imposed in operation. Experience has indicated it is essential to safety to establish conservative life limits for rotor spool components as accurate assessment of all likely critical low-cycle fatigue influences is difficult in view of engine, component, and operational variables which can induce or adversely influence failures.

(3) An acceptable procedure is as follows:

(a) Predicted Maximum Safe Cyclic Life.

This value should be established with the use of basic materials data including variability for minimum acceptable material combined with stress analyses to establish stresses for typical severe operating cycles. Consider effects of any anticipated stress raisers and substantiate with confirming representative component tests and any other pertinent experience of the applicant. Analyses employed should include sound engine stress and temperature determinations and component test evaluation techniques. Substantiated increases of the predicted maximum safe cyclic life may be introduced at any life extension step.

(b) Initial Service Life Limit.

The initial service life limit should be established at a figure well below the predicted life limit. A suggested value is one-third of the predicted life. Engine or component life testing significantly in excess of the initial service life value should be employed. The tests conducted should simulate the maximum severity anticipated in mission cycles.

(c) Increases in Service Life Limits

Evaluate service experience of rotor components to determine that experience indicates rotor acceptability at current life limits and there is a potential for increased life. Identify from service experience a representative severe operating cycle. If the current life limit is acceptable, select and demonstrate the proposed service life increase using high-time service discs in engine or component tests, assisted by further analytical and experimental stress determinations of components. The tests conducted should substantiate safe life values significantly in excess of the proposed step increase. Successive service life increases of approximately one-fourth of the predicted maximum life are suggested with the objective of intercepting possible critical effects on safe life when progressing to higher life limits. Maximum life should not exceed the predicted safe life.

c. Maintenance Criteria. Maintenance criteria provided by the engine manufacturer should include appropriate dimensional creep limits for all critical portions of rotor components and other basic inspection criteria, together with the established service life limits. Inspection criteria for highly stressed rotor components should be specified in the manufacturer's instructions and should permit reliable detection and removal of discrepant components at overhauls.

d. Overstrength Margin Testing. Representative design turbine and compressor rotors should be subjected to operation for a stabilized period of at least five minutes' duration at the maximum rated temperature conditions and accompanied by an overspeed r.p.m. as determined in the following paragraphs. In demonstrating adequate overstrength margins, evaluation of the effects of actual overload stresses at the specified maximum test conditions is desired. Knowledge of the stresses in all rotor components is needed, but the most critically stressed discs and the most critical stresses in these discs are of paramount interest. For multistage compressors and turbines, demonstration of only the most critical stages is acceptable. The condition of critical rotor components following this demonstration should be such that there is no evidence of incipient failure or critical distortions which could cause hazards to an aircraft. A five-minute stabilized test period is acceptable for the purpose of this test, which is made to evaluate short-term creep and elongation that could lead to rupture.

(1) Testing at Overspend Stresses. Overstrength margins relative to overspeeds may be demonstrated by any of the following test techniques:

(a) Rig testing a rotor disc, equipped with dummy blade weights, at maximum overspeed while heated to its usual maximum operating temperature conditions.

(b) Testing rotor assemblies in a complete engine to maximum overspeed while developing the maximum permissible gas temperature for the highest rated speed.

(c) Testing a rotor in a complete engine, but with the disc(s) having appropriately thinned sections at critical areas to produce maximum critical disc stresses, while developing maximum rated gas temperatures and maximum operating r.p.m.

(d) Turbosupercharger units tested as complete units and driven by a hot gas supply from a special burner rig.

(e) Testing rotors or units separately (complete with blades or dummy weights) by cold spinning, plus acceptable calculated data to ascertain the effects of temperature on critical stresses. For this method to be successful, accurate and extensive data are required including disc temperature survey data from operating engines and data on hot strength properties of the disc material.

(2) Determination of overspeed r.p.m. for test. The overspeed r.p.m. of all turbine engines, turbosuperchargers and power recovery turbines to which rotor discs are to be tested should be established through failure analyses criteria in determining the effects of reasonably probable and likely remote failures causing engine overspeeds. The failure of structural elements of the engine and its installation need not be considered if the probability of such failures is considered to be extremely remote. The highest r.p.m. of the following should be established as the overspeed r.p.m.:

(a) One hundred and fifteen percent of the maximum rated r.p.m. if the demonstration is made on a complete engine incorporating standard compressor and turbine assemblies.

(b) One hundred and twenty percent of the maximum rated r.p.m., if the demonstration is made under simulated conditions acceptable to the Administrator, such as in rotor component test rigs.

(c) An r.p.m. equal to 105 percent of the highest speed that would result from failure of the most critical component or system in a representative installation of the engine.

(d) An r.p.m. equal to the highest speed, which would result from the combination of two failures of components and/or systems in a representative installation of the engine. For each combination considered, one of the failures causing overspeeding should include a component or system whose failure would not normally be detected during a routine preflight check nor during normal flight operations.

(3) Testing at Overtemperatures. Turbine engine rotor assemblies should be operated at least five minutes at the maximum rated r.p.m., with the measured turbine gas temperature (as normally measured in the engine) at least 75 degrees F. in excess of the highest maximum permissible rated temperature value. This test should be accomplished by operating sufficiently long to heat-soak the turbine elements. The strength margin is sufficient only when the condition of the turbine assembly following this test is satisfactory and still within serviceable limits. The purpose of this test is to insure that excess strength is provided to preclude rapid deterioration or failure of turbine rotors in the event of 75 degree F. overtemperatures, which may result from sudden control or other system failures in a time interval in which a flight crew can be expected to be alerted and take corrective action.

e. Turbosuperchargers and power recovery turbines used with reciprocating engines should be tested at exhaust gas temperatures at least as high as the applicable type of reciprocating engine will produce under extreme conditions.

Such temperatures are normally close to that produced when operating at the stoichiometric fuel/air mixtures. The stoichiometric exhaust gas temperature is usually at or above the value at which the unit will used in service. This testing may be accomplished during endurance testing of the unit. Turbosuperchargers may be tested conveniently on gas producer rigs instead of in conjunction with a reciprocating engine. When a gas producer rig is used, a 75 degree F. overtemperature margin may be conveniently maintained for the test to provide this desired temperature margin.

/s/ R. S. Sliff
Acting Director